CALOR 2018

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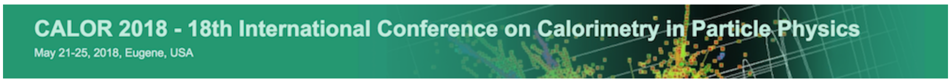

Book of Abstracts

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Session 2 / 1

Performance of the CMS Zero Degree Calorimeters in the 2016 pPb run

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Two neutral particle detectors, Zero Degree Calorimeters (ZDCs) at the LHC-CMS experiment, cover the $|\eta| > 8.5$ region. The ZDCs are Cherenkov calorimeters that use tungsten as the absorber and quartz clad quartz fibers as the active medium. They have a five element electromagnetic section followed by a hadronic section divided into four depth segments. For the 2016 pPb run, the ZDCs were calibrated using test beam data and the single spectator neutron peak at 2.56 TeV. Peaks corresponding to 1, 2 and 3 neutrons are visible in the ZDC total signal distribution. Then the effect of pileup is corrected by a Fourier deconvolution method. Using this, the spectator neutron number distribution can be unfolded by a linear regularization method. This information serves as a strong constraint to models of pPb collisions and has the potential to produce an unbiased measure of centrality in pPb collisions.

Secondary topics:

Algorithms, data processing methods

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Cherenkov

Session 14 / 2

CaloCube: a new concept calorimeter for the detection of high energy cosmic rays in space

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The direct measurement of cosmic rays spectrum up to the knee region is a crucial point for the improvement of our knowledge on the mechanisms responsible for production, acceleration and propagation of cosmic rays. At present, calorimeters are the best suited detectors to reach this instrumental challenge because they offer good performances in terms of geometrical acceptance and energy resolution. In order to exploit this potential, the design of calorimeters must be carefully optimized to take into account all limitations related to space missions, due mainly to the mass of the experimental apparatus.

CaloCube is a three-years R&D project, approved and financed by INFN in 2014 aiming to optimize the design of a space-borne calorimeter. The basic idea is to develop a cubic calorimeter whose geometry is designed as homogeneous and isotropic as possible, so as to detect particles arriving from every direction in space, thus maximizing the acceptance. Another important feature of the detector is the high granularity, because having a fine 3D sampling capability is necessary to achieve a high discrimination power for hadrons and nuclei with respect to electrons.

In order to optimize detector performances with respect to the total mass of the apparatus, comparative studies on different scintillating materials, different sizes of crystals and different spacings among them have been performed making use of MonteCarlo simulations. In parallel to simulations studies, several prototypes instrumented with CsI(Tl) cubic crystals has been constructed and tested with particle beams (electrons, protons and ions). An overview of the results obtained so far will be shown and the perspectives for future space experiments will be discussed.

In addition, we will present the TIC (Tracker-In-Calorimeter) project, thought as the natural development of CaloCube and financed by the INFN for 2018. The basic idea is to study the feasibility of including several silicon layers at different depths in the calorimeter in order to reconstruct the particle direction. Respect to the traditional approach of using a tracker with passive material in front of the calorimeter, the TIC solution can save a significant amount of mass budget in a space satellite experiment, that can be therefore exploited to improve the acceptance and the resolution of the calorimeter. While the upgrade of the prototype for the beam tests scheduled for this year is currently in progress, we will present the studies realized so far making use of MonteCarlo simulations.

Secondary topics:

Applications:

Design concepts for future calorimeter at the cosmic frontier

Primary topic:

Crystals

Session 3 / 3

CaloGAN: Simulating 3D High Energy Particle Showers in Multi-Layer Electromagnetic Calorimeters with Generative Adversarial Neural Networks

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The precise modeling of subatomic particle interactions and propagation through matter is paramount for the advancement of nuclear and particle physics searches and precision measurements. The most computationally expensive step in the simulation pipeline of a typical experiment at the Large Hadron Collider (LHC) is the detailed modeling of the full complexity of physics processes that govern the motion and evolution of particle showers inside calorimeters. We introduce CaloGAN, a new fast simulation technique based on generative adversarial neural networks (GANs). We apply these neural networks to the modeling of electromagnetic showers in a longitudinally segmented calorimeter, and achieve speedup factors comparable to or better than existing full simulation techniques on CPU (100x-1000x) and even faster on GPU (up to $\sim 10^5$x). There are still challenges for achieving precision across the entire phase space, but our solution can reproduce a variety of geometric shower shape properties of photons, positrons and charged pions. This represents a significant stepping stone toward a full neural network-based detector simulation that could save significant computing time and enable many analyses now and in the future. Using the same techniques, we also show how to use deep neural networks for classification and regression.

Secondary topics:

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Simulation and algorithms

Session 12 / **4**

The Electromganetic Calorimeter of the BelleII experiment at SuperKEKB and its upgrade.

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The upgrade of the KEKB e+e− collider to SuperKEKB and of the Belle detector to BelleII has just been completed at KEK (Tsukuba, Japan) and the accelerator is starting the Phase2 operations on March 2018 for a new experiment with high luminosity up to 8×1035cm−2s−1.
We report on the upgrade of the electromagnetic calorimeter (ECL) which will provide good energy and time resolution in a high background environment. The Belle calorimeter is based on 8736 CsI(Tl) crystals with PIN diodes used as photodetectors. The electronics has been modified to shorten the shaping time from 1µs to 500 ns in order to reduce the signal from pile-up events and provide pipeline readout of ECL information with further waveform analysis and readout data in FPGA. An algorithm of wave shape analysis reconstructs the amplitude and time of the signal. The calorimeter is also exploiting a new method based on Pulse Shape Discrimination (PSD) to distinguish between the signal produced in CsI(Tl) crystals by heavily-ionising particles and photons.
The second stage of the ECL upgrade includes a replacement of the forward endcap CsI(Tl) crystals

with pure CsI with Photopentodes or Avalanche Photodiodes readout. Measurements with new electronics and results obtained with a prototype are presented.

Secondary topics:

Applications:

Primary topic:

Crystals

Session 7 / 5

On the limits of the hadronic energy resolution of calorimeters

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In the calorimetric particle detection, the hadronic energy resolution is considerably worse than the electromagnetic energy resolution. We understood the hadron shower physics and investigated the fundamental reasons to cause the poor performance in the measurement of hadron energy. Dual readout and compensation are two methods to remedy this problem. We evaluated these two methods and show the theoretical limits of the hadronic energy resolution of calorimeters in CALOR 2018.

Secondary topics:

Compensation

Applications:

Primary topic:

Dual-readout

Session 4 / 6

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

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The physics reach and feasibility of the Future Circular Collider (FCC) with centre of mass energies up to 100 TeV and unprecedented luminosity is entering its final phase before releasing a Conceptual Design Report. 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 $\langle\mu\rangle = 1000$).
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 $|\eta| > 1.3$ (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.

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Simulation and algorithms

Session 1 / 7

ATLAS LAr Calorimeter Performance in LHC Run-2

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The ATLAS detector was designed and built to study proton-proton collisions produced at the LHC at centre-of-mass energies up to 14 TeV and instantaneous luminosities above 1034 cm−2 s−1. Liquid argon (LAr) sampling calorimeters are employed for all electromagnetic calorimetry in the pseudo-rapidity region |η| < 3.2, and for hadronic and forward calorimetry in the region from |η| = 1.5 to |η| = 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 between year of 2010 to 2012. After a period of detector consolidation during a long shutdown, Run-2 started in 2015 and 3.9 fb-1, 35.6 fb-1 and 46.9 fb-1 of data at a center-of-mass energy of 13 TeV have been recorded up to now per year.
In order to realize the level-1 acceptance rate of 100 kHz in Run-2 data taking, the number of read-out 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 Liquid Argon Calorimeter reached its design values both in energy measurement as well as in direction resolution, which was a main ingredient for the successful discovery of a Higgs boson in the di-photon decay channel.
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.

Secondary topics:

Applications:

Primary topic:

Ionization

Session 12 / 8

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

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The expected increase of the particle flux at the high luminosity phase of the LHC (HL-LHC) with instantaneous luminosities up to L ⊠ 7.5 × 1034 cm−2 s-1 will have a severe impact on the ATLAS detector performance. The pile-up is expected to increase on average to 200 interactions per bunch crossing. The reconstruction and trigger performance for electrons, photons as well as jets and transverse missing energy will be severely degraded in the end-cap and forward region, where the liquid Argon based electromagnetic calorimeter has coarser granularity and the inner tracker has poorer momentum resolution compared to the central region. A High Granularity Timing Detector (HGTD) is proposed in front of the liquid Argon end-cap calorimeters for pile-up mitigation and for bunch per bunch luminosity measurements.

This device should cover the pseudo-rapidity range of 2.4 to about 4.0. Two Silicon sensors double sided layers are foreseen to provide a precision timing information for minimum ionizing particle with a time resolution better than 50 pico-seconds per hit (i.e 30 pico-seconds per track) in order to assign the particle to the correct vertex. Each readout cell has a transverse size of 1.3 mm × 1.3 mm leading to a highly granular detector with about 3 millions of readout electronics channels. Low Gain Avalanche Detectors (LGAD) technology has been chosen as it provides an internal gain good enough to reach large signal over noise ratio needed for excellent time resolution.

The requirements and overall specifications of the High Granular Timing Detector at the HL-LHC will be presented as well as the conceptual design. Most recent results on the main R&D will be discussed, with emphasis on the LGAD sensors (sensor optimisation as thickness, dead zone⋯., and radiation hardness) and ASIC. Beam test results of gain, timing resolution and efficiency will be also shown.

Secondary topics:

Applications:

Primary topic:

Fast timing

Session 9 / 9

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

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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. The LAr Trigger Digitizer system will digitize 34000 channels at a 40 MHz sampling with 12 bit precision after the bipolar shaper at the front-end system, and transmit to the LAr Digital Processing system in the back-end to extract the transverse energies. Results of ASIC developments including QA and radiation hardness evaluations, performances of the final prototypes and results of the system integration tests will presented along with the overall system design.

Secondary topics:

Ionization, Noble liquids

Applications:

Primary topic:

Front-end readout and trigger

Session 14 / 11

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

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The high-luminosity LHC will provide 5-7 times higher luminosites than the orignal design. An improved readout system of the ATLAS Liquid Argon Calorimeter is needed to readout the 182,500 calorimeter cells at 40 MHz with 16 bit dynamic range in these conditions. Low-noise, low-power, radiation-tolerant and high-bandwidth electronics components are being developed in 65 and 130 nm CMOS technologies. First prototypes of the front-end electronics components show good promise to match the stringent specifications. The off-detector electronics will make use of FPGAs connected through high-speed links to perform energy reconstruction, data reduction and buffering. 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.

Secondary topics:

Ionization, Noble liquids

Applications:

Primary topic:

Front-end readout and trigger

Session 13 / 12

A new approach to use LYSO scintillators for polarimetry in the storage ring EDM measurements

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One of the fundamental questions of modern particle physics is the existence of finite electric dipole moments (EDM) of the hadrons. In case of charged particles, like protons and deuterons, the proposed method is the precise determination of the precession of the beam polarization vector in a storage ring. For that purpose, the JEDI (Jülich Electric Dipole moment Investigations) collaboration is developing a precise polarimeter detector based on LYSO scintillator coupled to SiPM modules. They are capable of stopping almost 300 MeV elastically scattered deuterons and protons. Measuring the kinetic energy of the scattered projectiles ensures the accurate reaction identification leading to a precise polarization determination.
To create the long-term reliable detector system, we have performed four iterations of the detector development (three of them since last CALOR 2016). Currently, we are operating 52 LYSO modules with a dedicated dead-time less sampling ADC readout system. The modules are very compact, due to modern high pixel density SiPM readout. A summary of all test beam times and the accumulated experience will be presented and discussed.

Secondary topics:

Polarimetry

Applications:

Other

Primary topic:

Scintillators

Session 2 / 13

Overview of the calorimetry performance of ALICE at the LHC

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The ALICE experiment at the LHC is dedicated to the study of the quark-gluon plasma formed in high-energy nuclear collisions. The ALICE electromagnetic calorimeter system, which includes the EMCAL/DCAL lead-scintillator sampling calorimeters and the PHOS high-granularity lead-tungstate crystal calorimeter, provides measurements and triggering on hard probes of the quark-gluon plasma such as high-momentum electrons, photons and jets. In this talk, I will present a summary of the performance of the EMCAL, DCAL and PHOS subsystems during the LHC Run-2, and plans for future upgrades.

Secondary topics:

Experience with current calorimetric systems at accelerators

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Other

Session 6 / 15

Gain stabilization of Silicon Photomultipliers and Afterpulsing

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The gain of silicon photomultipliers (SiPMs) increases with bias voltage and decreases with temperature. To operate SiPMs at stable gain, the bias voltage can be adjusted to compensate temperature changes. We have tested this concept with 30 SiPMs from three manufacturers (Hamamatsu, KETEK, CPTA) in a climate chamber at CERN varying the temperature from 1℃ to 50℃. We built an adaptive power supply that used a linear temperature dependence of the bias voltage readjustment. With one selected bias voltage readjustment, we stabilized four SiPMs simultaneously. We fulfilled our goal of limiting the deviation from gain stability in the 20℃-30℃ temperature range to less than ±0.5% for most of the tested SiPMs. We have studied afterpulsing of SiPMs for different temperatures and bias voltages.

Secondary topics:

Photodetectors (SiPM)

Applications:

Primary topic:

Other

Session 7 / 16

Dual-readout fibre-sampling calorimetry with SiPM light sensors

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Hadronic showers develop an electromagnetic (from neutral mesons such as π 0 and η 0) and a non-electromagnetic component that are sampled with very different sensitivities ("non compensation") in traditional calorimeters. The large fluctuations among the relative weight of the two components largely dominate the detector response resolution. Dual-readout calorimetry is a technique able to overcome this problem through the detection of two, independent, scintillation and Cherenkov light signals. The former is correlated with the whole energy deposition in the calorimeter while the latter provides a signal almost exclusively related to the electromagnetic component. The combination of the two allows to estimate, event by event, the electromagnetic fraction and correctly reconstruct the primary-hadron energy. The expected energy resolution for single hadron detection, estimated to be better than ˜40%/√E, together with the excellent particle identification capability, makes a dual-readout fibre-sampling calorimeter one of the most promising options for future leptonic colliders.
A first module, with Silicon PhotoMultipliers (SiPM) single-fibre readout, was designed, constructed and tested with beams. Thanks to their high photon-detection efficiency, high granularity and compactness, SiPMs represent the most promising solution to exploit this technique for future collider experiments. On the other hand, much attention is needed in order to minimize the optical crosstalk between the two types of fibers, which are located very close to each other and carry light signals that differ in intensity by about 2 orders of magnitude.
In this talk, the most significant testbeam results (about crosstalk, linearity response and particle separation capability) will be presented. We will discuss as well the R&D program that is planned in order to move towards a successful exploitation of a dual-readout fibre-sampling calorimeter at future e+e- colliders.

Secondary topics:

Silicon PhotoMultipliers application for dual-readout fibre calorimetry light detection

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Dual-readout

Session 7 / 17

Research of Neutral Pion Reconstruction with Forward Meson Spectrometer at STAR/RHIC

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The forward meson spectrometer, FMS, is the most forward electromagnetic calorimeter at the STAR detector at RHIC, covering rapidity from 2.5 to 4.1. It is an electromagnetic calorimeter comprised of 1254 lead-glass cells of two different types in content and size. The FMS was built primarily to unravel the novel spin effects seen in transversely polarized proton collisions. These effects relate to the spin-orbit correlation of the partons in the proton to the spin of the proton, which is a consequence of the confined motion of partons in nucleons. The reconstruction of neutral pion in the FMS is essential to such purpose. The gain calibration of the FMS is solely based on the reconstruction of the mass of neutral pions at a fixed energy since there is no tracker or hadronic calorimeter around, which poses the complication that the calibration gets intertwined with the reconstruction algorithm. Also, in order to cover the kinematic region of interest, the FMS needs to measure pions energies as high as 80 GeV at center-of-mass enegies of 200 and 500 GeV. It was found that there was a strong correlation between the reconstructed neutral pion mass and its energy. It is due to the

combination of biases in the photon finding, namely the energy and the opening angle of the decayed photons. The bias of the energy scale due to non-linear response of the lead glass was verified in detailed simulations of the light attenuation and a correction function could be established. The fitting of the electromagnetic shower shape was modified to include non-zero incident angles and non-zero vertex position. The reconstruction algorithm was optimized for clusters with two showers, especially when the separation of the two photons nears the physical limit in terms of the cell sizes. This talk will present details of all these improvements and their impact on the reconstruction of neutral pion with the FMS.

Secondary topics:

Applications:

Primary topic:

Simulation and algorithms

Session 11 / 18

Performance of DSB - a new glass and glass ceramic as scintillation material for future calorimetry

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In the past crystalline inorganic scintillation material has played a dominant role in calorimetry in medium and high energy physics experiments. Future detector developments will have to focus on cheap, fast, and radiation hard materials in particular with respect to damage caused by hadrons. Developments have been directed towards scintillation materials with a lower effective nuclear charge. The present study is focusing on the glass material BaO*2SiO2 (DSB) using different activators such as Ce or Gd ions, respectively. The production of samples in different geometries has optimized the sintering processes using the established technology of glass production. We will report on the achieved performance of various DSB samples up to large blocks of 20x20x120mm3 or thin fibers with respect to the light output, scintillation kinetics, optical transmission and homogeneity and radiation hardness after irradiation with high doses of gamma-rays or 150 MeV protons. For the first time, a 3x3 matrix read out with photomultiplier tubes has been used to measure the response to energy marked photons between 20 MeV and 380 MeV provided by the A2-tagging facility of MAMI at Mainz. The paper will discuss the achieved energy resolutions compared to GEANT4 simulations.

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Secondary topics:

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Novel Materials

Session 5 / 19

Design and test of the Mu2e undoped CsI crystal calorimeter

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The Mu2e experiment at Fermilab will search for the charged-lepton flavour violating
neutrino-less conversion of a negative muon into an electron in the field of an aluminum nucleus.
The Mu2e detector is composed of a tracker and an electromagnetic
calorimeter and an external veto for cosmic rays.
The calorimeter plays an important role in providing excellent particle identification capabilities,
a fast online trigger filter while aiding the track reconstruction capabilities.
The calorimeter requirements are to provide a large acceptance for ˜100 MeV electrons and reach:
1) a time resolution better than 0.5 ns @ 100 MeV;
2) an energy resolution O(10\%) @ 100 MeV;
3) a position resolution of 1 cm.

The calorimeter consists of two disks, each one made of 674 undoped CsI
crystals readout by two large area 2×3 array of UV-extended
SiPMs of 6x6 mm^2 dimensions.
A large scale prototype has also been constructed and tested at the beam test facility in Frascati.
It consists of 51 pre-production crystals readout by two Mu2e SiPM.
We present the progresses done to complete the calorimeter design as well as
a summary of results obtained in the production of components and on the test beam
of the prototype.

Secondary topics:

Silicon photosensors, radiation hardness, calorimeter systems

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Crystals

Session 5 / 20

Production and quality assurance of Mu2e CsI crystals

Authors: MIscetti Stefano[1]; Ren-Yuan Zhu[2]

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The Mu2e calorimeter is composed by two disks of 1348 pure CsI crystals of 34 x 34 x 200 mm^3 dimension,
each one readout and coupled in air by two large area SiPMs.
The calorimeter requirements translate in a series of technical specifications
for the crystals that are summarized by the following list when the crystal
is readout by a PMT and illuminated with a ^{22}Na source:
(1) dimension tolerance: ± 100 um;
(2) high Light Yield, $>$100 photoelectrons/MeV;
(3) Longitudinal response uniformity < 5\%;
(4) energy resolution less than 19\%;
(5) ratio between the scintillation light fast component over the total one better than 75\%.
In order to not affect calorimeter performance, the crystals have also to withstands the following requirements:
(6)A radiation induced noise below 0.6 MeV for a dose rate of 1.8 rad/hour.
(7) A normalized LY after 10 (100) krad $>$ 85\% (60\%).

A detailed quality assurance will be performed on each production crystals. Automatized station have
been designed and constructed at the National Lab of Frascati.
The measurement of the radiation hardness for a small random sample
of the production group will be performed at Caltech/HZDR.
A summary of the techniques used will be presented.

Secondary topics:

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Crystals

Posters / 21

Production and quality assurance of Mu2e calorimeter SiPMs

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The Mu2e calorimeter is composed by two disks of 1348 un-doped parallelepiped CsI crystals of $34 \times 34 \times 200$ mm^3
dimension, each one readout by two large area SiPM arrays. We translated the calorimeter requirements in a series of technical specifications for the SiPMs that are summarized by the following list:
(1) a high gain, above 10ˆ6, for each monolithic (6× 6) mm^2 SiPM cell;
(2) a good photon detection efficiency, PDE, of above 20\% at 310 nm to match the light from undoped CsI crystals;
(3) a large active area that, in combination with the PDE, could provide a light yield of above 20 p.e./MeV;
(4) a fast rise time and a narrow signal width to improve time resolution and pileup rejection;
(5) a Mean to Time Failure (MTTF) of O(10^6) hours;
(6) and a good resilience to neutrons for a total fluency up to 10^{1}2 n(1 MeVeq)/cm^2.

A modular and custom SiPM layout has been chosen to satisfy these requirements. The configuration readout of 2 series of three

6×6 mm^2 monolithic SiPMs has been selected to overcome the issues related to the parallel connection that, due to the large capacitance, could spoil the pileup rejection and the energy and time measurements.
After pre-production we have selected Hamamatsu as vendor and the production of 4000 pieces is ongoing.
A detailed quality assurance, QA, will be carried out on each SiPM, with an automatized station built by INFN Pisa, for the determination of the operation voltage, gain, quenching time and dark current. For small samples of each production batch, the measurement of the MTTF and the increase of the dark current increase as a function of the neutron fluency will be carried out.

Secondary topics:

photosensors

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Silicon

Posters / 22

Test results of the Mu2e Module-0 at an electron beam

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The baseline calorimeter configuration consists of 1348 undoped CsI crystals coupled to 2 large area UV-extended Silicon Photomultipliers (SiPMs) and divided in two annular disks.
An intense R\&D program has been pursued in order to control if this configuration satisfies the Mu2e requirements.
In May 2017, a dedicated test has been performed at the Beam Test Facility (BTF) in Frascati (Italy) where
a large calorimeter prototype, dubbed Module-0, has been exposed to an electron beam in the energy range between 60 and 120 MeV.

The prototype consisted of 51 crystals, each one readout by 2 Mu2e SiPMs.
The analog signals were acquired with a CAEN waveform digitiser.
Here we present results for calibration methods and timing and energy resolution performance.
With the beam at normal incidence, a time resolution of ˜97 ps (˜130 ps) was measured at
100 MeV beam energy when using 1 GHz (250 MHz) sampling rate.
In the same configuration, an energy resolution of about 5\% was achieved, in good agreement with Monte Carlo expectations.
Dependence of time and energy resolutions response as a function of the beam impinging angle and energy will be also presented.

Secondary topics:

Data reconstruction and test beam

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Other

Session 13 / 23

Upgrade of a Cesium Iodide calorimeter for the KOTO experiment

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The KOTO experiment, conducted at J-PARC (Ibaraki Japan), is set to observe the rare decay $K_L \to \pi^0\nu\bar{\nu}$.
Since the amplitude of $K_L \to \pi^0\nu\bar{\nu}$ violates the charge conjugation and parity symmetries, the branching ratio is heavily suppressed in the Standard model (SM) and calculated to be $\mathcal{B}(K_L \to \pi^0\nu\bar{\nu}) = (3.0 \pm 0.3) \times 10^{-11}$.
The experimental observation may reveal hints of physics beyond the SM.
The observed signature of $K_L \to \pi^0\nu\bar{\nu}$ is two γ's produced from a π^0 and no other signal. Thus the KOTO detector consists of an electromagnetic calorimeter and hermetic veto counters.

The calorimeter, made of 50-cm-long Cesium Iodide (CsI) crystals, plays a crucial role in both the detection of photons, and the rejection of neutron-induced background.
%It is a key to reject accidental hits of neutron produced by beam to maintain the sensitivity.
Comparing the difference of waveforms and shower shapes between photon and neutrons, we have developed dedicated discriminators to achieve rejection of neutron contamination by a factor of ~ 100.
To reach the SM sensitivity, however, we need to reject neutron by another factor of ten.
In the summer of 2018, we are planning to instrument the front surface of CsI calorimeter with Multi Pixel Photon Counters (MPPC) to measure the timing difference between the arrival of signals at MPPCs and at photo multiplier tubes connected to the rear surface of the calorimeter.
The depth of energy deposition is measured through the timing difference, which in turn aids to discriminate neutron and photon.
In this presentation, we explain the performance of the developed system and the status of the calorimeter upgrade.

Secondary topics:

neutron gamma separation

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Crystals

Session 10 / 24

Predicting hadron-specific damage from fast hadrons in crystals for calorimetry

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Fast hadrons have been observed to cause a cumulative damage in Lead Tungstate and LYSO crystals. The underlying mechanism has been proven to be the creation of fission tracks, which act as scattering centers, thus reducing the light collection efficiency. For calorimetry applications in an environment where large, fast hadron fluences are anticipated, predictions about damage in crystals are of great importance for making an informed choice of technology.
In the study presented here, simulations using the FLUKA package have been performed in Lead Tungstate, LYSO and Cerium Fluoride, and their results have been compared with measurements. The agreement that is found between simulation results and experimental measurements allows to conclude that the damage amplitude in a given material can be predicted with a precision that is sufficient to anticipate the damage expected during detector operation.

Secondary topics:

Hadron damage, Simulation

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Crystals

Session 10 / 25

Multifunctional scintillation materials of the garnet structure for nonhomogeneous detecting cells of electromagnetic calorimeters to operate in a harsh irradiation environment

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Irradiation environment of experiments to be considered at novel colliders will be harsh enough to limit the long term maintenance of homogeneous detector calorimeters. This will occur due to accumulation of the damage caused by various effects, particularly due to hadron component of irradiation environment. Non-homogeneous calorimetric detecting cells, consisting of absorber and low-volume scintillation elements in a form of plates or fibers become very promising in this view. Here we just mention the two most popular designs: "spaghetti"and "shaslik"type detecting cells, combining heavy metal absorber and plastic scintillator. However, plastic scintillation materials are heavily damaged under irradiation, as follows from observations at LHC experiments and, preferably, should be replaced by more radiation hard materials. Among them, scintillation materials of the garnet structure have few preferences. They can be produced in a single crystalline or ceramic

form; their atomic composition can be varied to meet requirements of the application. Gadolinium-aluminum gallium garnet Gd3Al2Ga3O12, (GAGG), activated by cerium ions, can be used to detect γ-quanta and to absorb neutrons in a wide energy range. The capture of neutrons is accompanied by the emission of relatively soft γ-quanta which can be virtually ignored. On the contrary, yttrium-aluminum gallium garnet Y3Al2Ga3O12, (YAGG), activated by cerium ions, is sensitive to γ-quanta only. Here we compare scintillation properties and radiation hardness as well, of GAGG and YAGG scintillators in the single crystalline and ceramic form. Both single- and polycrystalline forms are founded to be prospective for detecting cells construction. The results for perspective new materials will be contrasted to the ongoing investigation of PWO (PbWO4) as today's choice of detector material for modern detector systems such as PANDA, for which a long-term study with the EMC barrel crystals is being performed.

Supported by BMBF

Secondary topics:

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Scintillators

Session 9 / 26

The ATLAS High-Level Calorimeter Trigger in Run-2

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The ATLAS Experiment uses a two-level triggering system to identify and record collision events containing a wide variety of physics signatures. It reduces the event rate from the bunch-crossing rate of 40 MHz to an average recording rate of 1 kHz, whilst maintaining high efficiency for interesting collision events. It is composed of an initial hardware-based level-1 trigger followed by a software-based high-level trigger. A central component of the high-level trigger is the calorimeter trigger. This is responsible for processing data from the electromagnetic and hadronic calorimeters in order to identify electrons, photons, taus, jets and missing transverse energy. In this talk I will present the performance of the high-level calorimeter trigger in Run-2, noting the improvements that have been made in response to the challenges of operating at high luminosity.

Secondary topics:

Applications:

Primary topic:

Front-end readout and trigger

Session 9 / 27

The ATLAS Electron and Photon Trigger

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ATLAS electron and photon triggers covering transverse energies from 5 GeV to several TeV are essential to record signals for a wide variety of physics: from Standard Model processes to searches for new phenomena. To cope with ever-increasing luminosity and more challenging pile-up conditions at a centre-of-mass energy of 13 TeV, the trigger selections need to be optimized to control the rates and keep efficiencies high. The ATLAS electron and photon trigger performance in Run 2 will be presented, including both the role of the ATLAS calorimeter in electron and photon identification and details of new techniques developed to maintain high performance even in high pile-up conditions.

Secondary topics:

Applications:

Primary topic:

Front-end readout and trigger

Session 9 / 28

An Ensemble of Neural Networks for Online Electron Filtering at the ATLAS Experiment.

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In 2017 the ATLAS experiment implemented an ensemble of neural networks (NeuralRinger algorithm) dedicated to improving the performance of filtering events containing electrons in the high-input rate online environment of the Large Hadron Collider at CERN, Geneva. The ensemble employs a concept of calorimetry rings. The training procedure and final structure of the ensemble are used to minimize fluctuations from detector response, according to the particle energy and position of incidence. A detailed study was carried out to assess profile distortions in crucial offline quantities through the usage of statistical tests and residual analysis. These details and the online performance of this algorithm during the 2017 data-taking will be presented.

Secondary topics:

Applications:

Primary topic:

Front-end readout and trigger

Session 4 / 29

Physics object performance of the FCC-hh calorimeter system

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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=30e34), 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.

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Simulation and algorithms

Session 12 / 30

Precision Timing Calorimetry with the upgraded CMS Crystal ECAL

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Particle detectors with a timing resolution of order 10 ps can improve event reconstruction at high luminosity hadron colliders tremendously. The upgrade of the Compact Muon Solenoid (CMS) crystal electromagnetic calorimeter (ECAL), which will operate at the High Luminosity Large Hadron Collider (HL-LHC), will achieve a timing resolution of around 30 ps for high energy photons and electrons. The benefits of precision timing for the ECAL event reconstruction at HL-LHC will be discussed in this presentation. Simulation and test beam studies carried out for the timing upgrade of the CMS ECAL will be presented and the prospects for a full implementation of this option will be discussed.

Secondary topics:

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Crystals

Session 14 / 31

The CMS ECAL Upgrade for Precision Crystal Calorimetry at the HL-LHC

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The electromagnetic calorimeter (ECAL) of the Compact Muon Solenoid Experiment (CMS) has been operating at the Large Hadron Collider (LHC) with proton-proton collisions at 13 TeV center-of-mass energy and a bunch spacing of 25 ns since 2015. Challenging running conditions for CMS are expected after the High-Luminosity upgrade of the LHC (HL-LHC). We review the design and R&D studies for the CMS ECAL barrel crystal calorimeter upgrade and present first test beam studies. Particular challenges at the HL-LHC are the harsh radiation environment, the increasing data rates and the extreme level of pile-up events, with up to 200 simultaneous proton-proton collisions. We present test beam results of hadron irradiated PbWO crystals up to fluences expected at the HL-LHC. The R&D for the new readout and trigger electronics, which must be upgraded due to the increased trigger and latency requirements at the HL-LHC, will also be reported.

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Crystals

Session 1 / 32

Performance of the CMS electromagnetic calorimeter during the LHC Run II

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Many physics analyses using the Compact Muon Solenoid (CMS) detector at the LHC require accurate, high resolution electron and photon energy measurements. In particular, 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. Following the excellent performance achieved in Run I at center-of-mass energies of 7 and 8 TeV, the CMS electromagnetic calorimeter (ECAL) is operating at the LHC with proton-proton collisions at 13 TeV center-of-mass energy. The instantaneous luminosity delivered by the LHC during Run II has achieved unprecedented values, using 25 ns bunch spacing. High pileup levels necessitate a retuning of the ECAL readout and trigger thresholds and reconstruction algorithms, to maintain the best possible performance in these more challenging conditions. The energy response of the detector must be precisely calibrated and monitored to achieve and maintain the excellent performance obtained in Run I in terms of energy scale and resolution. A dedicated calibration of each detector channel is 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 new reconstruction algorithm and calibration strategies that were implemented to maintain the excellent performance of the CMS ECAL throughout Run II. Performance results from the Run II data taking period will be reported.

Secondary topics:

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Crystals

Session 1 / 33

CMS ECAL monitoring and calibration in LHC Run 2

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Precise calibration and monitoring of the CMS electromagnetic calorimeter (ECAL) is a key ingredient in achieving the excellent ECAL performance required by many physics analyses employing electrons and photons. This presentation describes the methods used to monitor and inter-calibrate the ECAL response, using physics channels such as W/Z boson decays to electrons and pi0/eta decays to photon pairs, and also exploiting the azimuthal symmetry of the minimum bias events. Results of the calibrations obtained with Run 2 data are reported.

Secondary topics:

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Crystals

Session 3 / 34

Simulation of the CMS electromagnetic calorimeter response at the energy and intensity frontier

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The electromagnetic calorimeter (ECAL) of the CMS experiment at the LHC is a homogeneous calorimeter made of 75848 lead tungstate (PbWO_4) scintillating crystals, designed for high precision electron and photon energy measurements in hadron collisions at the TeV scale. The detailed simulation of the calorimeter response is crucial for physics analyses involving electrons, photons, jets or missing energy. The detector simulation has been tuned during the first LHC run, including a detailed description of the upstream material. The increase of center-of-mass energy, bunch crossing rate and instantaneous luminosity in the second run has resulted in updated and improved data readout settings and reconstruction techniques. Furthermore, aging effects due to radiation, in particular increases in noise in the photodetectors and crystal transparency losses, have caused a change of the calorimeter response. All of these effects have been taken into account in order to improve the simulation of the calorimeter response and to ensure that it describes the data well over time, notwithstanding the evolving conditions. In 2024 the ECAL will undergo an upgrade to cope with the high luminosity phase of the LHC (HL-LHC). The temperature of the calorimeter will be lowered to mitigate the aging effects, the front-end electronics will be replaced with a faster version and the data will be read out in streaming mode towards the off-detector electronics. The fast PbWO_4 response time will be exploited to measure the timing of high-energy showers with high precision. A detailed simulation description of the crystal response is fundamental for the design of the detector electronics and to predict the performance for the energy and timing measurements. The techniques employed in tuning the simulation of the detector response for the present running conditions and for the upgrade will be presented.

Secondary topics:

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Crystals

Session 3 / 35

Mitigation of Direct APD signals in the CMS Barrel Electromagnetic Calorimeter

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Anomalous large signals are observed in the barrel region of the CMS Electromagnetic Calorimeter (ECAL) during proton-proton collisions at the LHC. They are ascribed to direct energy deposition by particles in the Avalanche Photodiodes (APDs) used for the light readout. They must be suppressed in order to prevent the spurious triggering of CMS, and to maintain the lowest possible trigger thresholds for electrons and photons, jets, and calorimeter energy sums.

The algorithm that has been employed to reject these signals in the Level-1 trigger of CMS is described. The signals occur at a rate that is proportional to the intensity of the LHC proton beams. As a consequence, the algorithm must be retuned to preserve its efficiency for the more challenging conditions of LHC Run II. The details of this optimisation are presented, and the performance of the algorithm on CMS Run II data is shown.

Secondary topics:

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Crystals

Session 8 / 36

Fine-grained calorimeters for experiments at CLIC and FCC-ee

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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 Si-W layers and a lateral segmentation of 5x5 mm2. Beyond the ECAL, a steel-scintillator HCAL is placed, with 60 layers (for CLIC) or 44 layers (for FCC-ee) and scintillator tiles, coupled to SiPMs, with lateral dimensions of 30x30 mm2. The newly developed software chain based on the DD4Hep detector description toolkit is used for the studies, together with the PANDORA particle flow algorithms. Results obtained for photon and jet energy resolution as well as particle identification efficiencies for the two detector models at CLIC and FCC-ee are presented in this talk.

Secondary topics:

Simulation and algorithms

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Particle Flow

Session 5 / 37

Construction of the Forward Endcap Calorimeter of the PANDA Experiment at FAIR

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PANDA is the main hadron physics addressing experiment of the future FAIR (Facility for Antiproton and Ion Research) center at Darmstadt, Germany. Located at the HESR antiproton storage ring the PANDA detector is optimized for physics of the weak and strong interactions in the charm sector: Search for new and exotic states of matter, precise determination of quantum numbers, masses and widths of hadronic resonances and deeper insights in the structure of hadrons.
The detector consists of a target spectrometer build around the interaction region of antiprotons carrying momenta of 1.5-15 GeV/c with a fixed hydrogen target and a forward spectrometer. Its design is based on compactness and cost saving while achieving high resolution, rate capability and physics selectivity.
In the PANDA target spectrometer the electromagnetic calorimeter is composed of three subdetectors based on at -25 degrees C operated lead tungstate crystals. A barrel structure build from 11360 crystals will be closed in up- and downstream direction by two endcaps containing 524 and 3856 crystals, respectively. After intense beam test phases with a 200 crystal forward endcap prototype the required performance was shown to be met and the design finished. The upstream located forward endcap is currently under construction. Besides the overall mechanical design and cooling concept the 16-crystal submodules series manufacturing and quality assurance measures will be presented.

Secondary topics:

Applications:

Primary topic:

Other

Session 9 / 38

Design of the CMS upgraded calorimeter trigger from Phase I to Phase II of the LHC

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The CMS experiment implements a sophisticated two-level triggering system composed of the Level-1, instrumented by custom-design hardware boards, and software High Level Trigger. In 2017, the LHC delivered proton-proton collisions at a centre-of-mass energy of 13 TeV with a peak instantaneous luminosity larger than $2 \cdot 10^{34} cm^{-2} s^{-1}$, more than twice the peak luminosity reached during Run 1 and far larger than the design value. The CMS Level-1 calorimeter trigger was upgraded during the end-of-the year technical stop between 2015 and 2016, to improve its performance at high luminosity and large number of simultaneous inelastic collisions per crossing (pile-up). All the electronic boards have been replaced and the upgraded electronics tested and commissioned with data. Smarter, more sophisticated, and innovative algorithms are now the core of the first decision layer of CMS: the upgraded trigger system implements dynamic clustering techniques in the trigger boards,

pile-up subtraction, and isolation requirements for electrons and tau leptons. In addition, the new global trigger is capable of evaluating complex selection algorithms such as those involving the invariant mass of trigger objects. The trigger selections used for a wide variety of physics signal during Run 2 will be presented, ranging from simpler single-object selections to more sophisticated algorithms combining different objects and applying analysis-level reconstruction and selection. This presentation will cover the design and performance of the Phase I calorimeter trigger and how it influences the path towards the Phase II upgrade system necessary for the LHC run at a center-of mass energy of 14 TeV with luminosity of $5 - 7 \cdot 10^{34} cm^{-2} s^{-1}$, corresponding to 140-200 pile-up events. The addition of the tracker information at Level-1 and the enhanced calorimeter granularity will be used to maintain the trigger efficiency at a similar level as the present system.

Secondary topics:

Trigger for Future calorimetry

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Front-end readout and trigger

Session 1 / 42

Calibration and Performance of the ATLAS Tile Calorimeter During the LHC Run 2

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The Tile Calorimeter (TileCal) is the central section of the hadronic calorimeter of the ATLAS experiment and provides important information for reconstruction of hadrons, jets, hadronic decays of tau leptons and missing transverse energy. It also assists in muon identification. This sampling calorimeter uses steel plates as absorber and scintillating tiles as active medium. The light produced by the passage of charged particles is transmitted by wavelength shifting fibres to photomultiplier tubes (PMTs). The readout is segmented into about 5000 cells (longitudinally and transversally), each of them being read out by two PMTs in parallel.
TileCal exploits several calibration systems: a Cs radioactive source that illuminates the scintillating tiles directly, a laser light system to directly test the PMT response, and a charge injection system (CIS) for the front-end electronics. These systems together with data collected during proton-proton collisions provide extensive monitoring of the instrument and a means for equalizing the calorimeter response at each stage of the signal propagation. The performance of the calorimeter has been established with cosmic ray muons and the large sample of the proton-proton collisions. The response of high momentum isolated muons is used to study the energy response at the electromagnetic scale, isolated hadrons are used as a probe of the hadronic response. The calorimeter time resolution is studied with multijet events.
A description of the different TileCal calibration systems and the results on the calorimeter performance during the LHC Run 2 will be presented. The results on the pile-up noise and response uniformity studies with MC will also be discussed.

Secondary topics:

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Scintillators

Session 14 / 43

Upgrade of the ATLAS Tile Calorimeter for the High luminosity LHC

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The Tile Calorimeter (TileCal) is the hadronic calorimeter covering the central region of the ATLAS experiment. TileCal is a sampling calorimeter with steel as absorber and scintillators as active medium. The scintillators are read-out by wavelength shifting fibers coupled to photomultiplier tubes (PMTs). The analogue signals from the PMTs are amplified, shaped, digitized by sampling the signal every 25 ns and stored on detector until a trigger decision is received.
The High-Luminosity phase of LHC (HL-LHC) expected to begin in year 2026 requires new electronics to meet the requirements of a 1 MHz trigger, higher ambient radiation, and for better performance under high pileup. Both the on- and off-detector TileCal electronics will be replaced during the shutdown of 2024-2025. PMT signals from every TileCal cell will be digitized and sent directly to the back-end electronics, where the signals are reconstructed, stored, and sent to the first level of trigger at a rate of 40 MHz. This will provide better precision of the calorimeter signals used by the trigger system and will allow the development of more complex trigger algorithms. Changes to the electronics will also contribute to the data integrity and reliability of the system.
Three different front-end options were built and investigated both in laboratory as well as in several beam test campaigns. The final version has been chosen after evaluating the results. A hybrid demonstrator compatible with the present system has been developed, adopting the new chosen front-end option. The demonstrator is undergoing extensive testing and is planned for future insertion in ATLAS.

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Front-end readout and trigger

Session 2 / 44

Optics robustness of the ATLAS Tile Calorimeter

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TileCal, the central hadronic calorimeter of the ATLAS detector is composed of plastic scintillators interleaved by iron plates, and wavelength shifting optical fibres. The optical properties of these components are known to suffer from natural ageing and degrade due to exposure to radiation. The

calorimeter was designed for 10 years of LHC operating at the design luminosity of $10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$. Irradiation tests of scintillators and fibres have shown that their light yield decrease by about 10% for the maximum dose expected after 10 years of LHC operation.
The robustness of the TileCal optics components is evaluated using the calibration systems of the calorimeter: Cs-137 gamma source, laser light, and integrated photomultiplier signals of particles from proton-proton collisions. It is observed that the loss of light yield increases with exposure to radiation as expected. The decrease in the light yield during the years 2015-2017 corresponding to the LHC Run 2 will be reported.
The current LHC operation plan foresees a second high luminosity LHC (HL-LHC) phase extending the experiment lifetime for 10 years more. The results obtained in Run 2 indicate that following the light yield evolution in TileCal is an essential step for drawing a prediction of the calorimeter performance in future runs. Preliminary studies attempt to extrapolate these measurements to the HL-LHC running conditions.

Secondary topics:

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Scintillators

Session 14 / **45**

Test Beam Studies for the ATLAS Tile Calorimeter Upgrade Readout Electronics

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The Large Hadron Collider (LHC) Phase II upgrade aims to increase the accelerator luminosity by a factor of 5-10. Due to the expected higher radiation levels and the aging of the current electronics, a new readout system for the Tile hadronic calorimeter (TileCal) of the ATLAS experiment is needed. A prototype of the upgrade TileCal electronics has been tested using the beam from the Super Proton Synchrotron (SPS) accelerator at CERN. Data were collected with beams of muons, electrons and hadrons at various incident energies and impact angles. The muon data allow to study the response dependence on the incident point and angle in a cell and inter-calibration of the response between cells. The electron data are used to determine the linearity of the electron energy measurement. The hadron data allow to determined the calorimeter response to pions, kaons and protons and tune the calorimeter simulation to that data. The results of the ongoing data analyses are discussed in the presentation.

Secondary topics:

Scintillators

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Front-end readout and trigger

Session 12 / 46

Precision Timing with the CMS MIP Timing Detector

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The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive Phase II upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). A new timing layer is designed to measure minimum ionizing particles (MIPs) with a time resolution of ˜30ps and hermetic coverage up to a pseudo-rapidity of |eta|=3. This MIP Timing Detector (MTD) will consist of a central barrel region based on LYSO:Ce crystals read out with SiPMs and two end-caps instrumented with radiation-tolerant Low Gain Avalanche Detectors (LGADs). The precision time information from the MTD will reduce the effects of the high levels of pile-up expected at the HL-LHC and will bring new and unique capabilities to the CMS detector. The time information assigned to each track will enable the use of 4D-vertexing which will render a 5-fold pile-up reduction thus recovering the current conditions. Precision timing will also enable new time-based isolations and improved b-tagging algorithms. All of this translates into a ˜20% gain in effective luminosity when looking at di-Higgs boson events decaying to a pair of b-quarks and two photons. We present the current status and ongoing R&D of the MTD, including implications on the physics reach at the HL-LHC and test beam results.

Secondary topics:

Applications:

Primary topic:

Crystals

Session 12 / 47

Low Gain Avalanche Diodes for Precision Timing in the CMS Endcap

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The Compact Muon Solenoid (CMS) detector at the CERN Large Hadron Collider (LHC) is undergoing an extensive Phase II upgrade program to prepare for the challenging conditions of the High-Luminosity LHC (HL-LHC). In particular, precision timing can offset the performance degradation due to event pileup at the HL-LHC, recovering the purity of vertices of current LHC conditions. As such, a new timing layer will be introduced to measure minimum ionizing particles (MIPs) with a time resolution of ˜30ps. The endcap region of this MIP Timing Detector (MTD) will be instrumented with a hermetic, single layer of silicon low gain avalanche detectors (LGADs), covering the high radiation pseudo-rapidity region between $|\eta|$=1.6 to 3.0. Radiation tolerance studies of the LGADs indicate promising performances of 30 and 50 ps at fluences corresponding to $|\eta|$=2.5 and 3.0, respectively. In addition, the LGADs have intrinsic gain, which enhances the MIP signal and provides adequate signal-to-noise for good timing precision. We present the status of the R&D for the LGADs for the endcap region of the MTD and report on recent test beam results.

Secondary topics:

Applications:

Primary topic:

Crystals

Session 13 / 48

The ECAL Status of CEPC

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Circular Electron Position Collider (CEPC) is proposed as a Higgs or Z factory. One option of CEPC-ECAL(Electromagnetic calorimeter), designed based on the Particles Flow Algorithm(PFA), consists of tungsten and scintillator coupling with SiPM as active sensor. A advanced study of the gain with single photon and the responding curve of SiPM will be presented. Scintillator module also had been studied, different degrees of polishing and different ways of coupling with SiPM, to make light yield meet the dynamic range requirements and improve the uniformity of output light. The electronics board desiged and tested which based on the SPIROC chip also will be presented.

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Scintillators

Session 2 / 49

Performance of the ALICE Zero Degree Calorimeters and upgrade strategy

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The Zero Degree Calorimeters of the ALICE experiment were designed with the twofold purpose of both estimating the centrality in heavy ion collisions by measuring the energy carried away by the spectator nucleons and of measuring the luminosity delivered to the experiment exploiting the high cross sections for neutron emission from electromagnetic dissociation process. The measurement of centrality has been succesfully extended to p-A collisions with the detection of nucleons ejected from the nucleus by the collisions with the projectile proton (”gray” nucleons) and those resulting from de-excitation processes (”black” nucleons). The applications of the detector in triggering and analysis

have been expanded during the years of operation in RUN1 and RUN2. These now include both the reaction plane and the longitudinal asymmetry measurements in heavy ion collisions. Moreover the ZDC is used to reject the parasitic interactions of main bunches with satellite bunches in A-A and p-A and to tag diffractive events in p p collisions.
The foreseen operation in RUN3 with the tenfold increase in the luminosity delivered by LHC in heavy ion collisions, together with the continuous acquisition strategy that is being adopted by ALICE, will be challenging for the ZDC readout system. The readout upgrade will be based on FMC digitizers with trigger, timing and charge integration functionality performed through FPGA.
The performance of the ZDC with respect to the different measurements and the upgrade strategy will be presented.

Secondary topics:

Front-end readout and trigger, experience with current calorimeters at the energy frontier

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Cherenkov

Session 5 / 50

The Electromagnetic Calorimeter for the PANDA Target Spectrometer

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The future PANDA experiment features a next generation detector. Measurements will focus on hadron spectroscopy. PANDA will use cooled anti-proton beams with momenta between 1.5 GeV/c and 15 GeV/c interacting with various targets. This allows to populate directly states of all quantum numbers and to measure their widths with accuracies of a few tens of keV. The experiment will be located at the Facility for Anti-proton and Ion Research in Germany, which is currently under construction.
The electromagnetic target calorimeter of the PANDA experiment has the challenging aim to detect high energy photons with excellent energy resolution over the full dynamic range from 15 GeV down to a few tens of MeV within a 2T solenoid. To reach this goal, improved $PbWO_4$ scintillator crystals, cooled down to −25℃ have been chosen. They provide a fast decay time for highest count rates, short radiation length for compactness, improved light yield for lowest thresholds and sufficient radiation hardness.
The target calorimeter itself is divided into a barrel and two endcaps. The individual crystal will be read out with two precisely matched large area avalanche photo diodes. In the most inner part of the forward endcap vacuum photo-tetrodes will be used.
The talk will give an overview of the PANDA experiment and focuses on its target calorimeter including the scintillator material and the production status. Furthermore, the design, construction and assembly procedure of the barrel part will be discussed in detail.

Secondary topics:

Instrumentation, Front-end readout

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Scintillators

Session 11 / **51**

A visualization of the damage in Lead Tungstate calorimeter crystals after exposure to high-energy hadrons

Authors: Guenther Dissertori[1]; David Luckey[2]; Francesca Nessi-Tedaldi[2]; Felicitas Pauss[3]; Rainer Wallny[3]; Richard Spikings[4]; Roelant Van der Lelij[4]; Gonzalo Arnau Izquierdo[5]

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The damage caused in scintillating crystals by fast hadrons has been observed to present specific contributions, that are absent in a purely ionising radiation field. All the observed features point towards the creation of so-called "fission-tracks" in materials whose elements lie above the fission-threshold. In this paper we present visual evidence for the creation of fission tracks in Lead Tungstate, using techniques that have been developed in geochronology and are commonly used for rock dating.

Secondary topics:

Damage mechanisms

Applications:

Experience with current calorimeter at the intensity frontier

Primary topic:

Crystals

Session 3 / **52**

New Fast Calorimeter Simulation in ATLAS

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The ATLAS physics program relies on very large samples of simulated events. Most of these samples are produced with GEANT4 which provides a detailed simulation of the ATLAS detector. However, this simulation is very time consuming. To solve this problem, fast simulation tools are used when detailed detector simulation is not needed. Until now, a fast calorimeter simulation (FastCaloSim) was used in ATLAS to replace the slowest part of the simulation. The detailed particle shower shapes and the correlations between the energy depositions in the various calorimeter layers are used to provide a parametrisation of the calorimeter response. FastCaloSim was tuned to data to improve its performance but had limitations in reproducing boosted objects and very forward regions of the detector. ATLAS is currently developing an improved version of FastCaloSim to overcome these problems by using machine learning techniques, such as principal component analysis and neural networks. A prototype is being tested and validated which shows significant improvements in the description of cluster level variables in electromagnetic and hadronic showers. To complement the new FastCaloSim, ATLAS is developing Fast Chain which provides fast tools for the digitisation and reconstruction of the events. By combining these tools ATLAS will have the capabilities to simulate the required numbers of events to achieve its physics goals. In this talk, we will describe the new FastCaloSim parametrisation and the performance as well as the status of the ATLAS Fast Chain.

Secondary topics:

Applications:

Primary topic:

Simulation and algorithms

Session 3 / 53

CMS electron and photon performance at 13 TeV

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The Compact Muon Solenoid (CMS) detector is one of the two multi-purpose experiments at the Large Hadron Collider (LHC) and has a broad physics program. Many aspects of this program depend on our ability to trigger, reconstruction and identify events with final state electrons, positrons, and photons with the CMS detector with excellent efficiency and high resolution.

In this talk we present the full process of electron and photon reconstruction in CMS, starting from tracker hits and energy deposits in the electromagnetic calorimeter, the method to achieve the ultimate precision in Run II energy measurements, the trigger and identification strategies (based both on cut based approach and on multivariate analysis) to discriminate prompt electrons and photons from background, and the methods to estimate the associated systematic uncertainties. Finally the performance on benchmark channels (such as H->gamma gamma and Z->ee) will be shown.

Secondary topics:

Electron and Photon Trigger/Reconstruction/Identification/Energy Resolution

Applications:

Primary topic:

Simulation and algorithms

Session 10 / **54**

Fast Neutron Induced Radiation Damage in Fast Inorganic Scintillators

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One crucial issue for applications of scintillation crystals in HEP calorimeters is radiation damage in severe radiation environment, such as the HL-LHC. While radiation damage induced by ionization dose is well understood, investigations are still on going to understand radiation damage caused by hadrons, including both charged hadrons and neutrons. In this paper, we report investigations on radiation damage in fast inorganic scintillators, including BaF_2, LYSO:Ce and PWO crystals, by mixed particles, including neutrons, γ-rays and protons, at the East Port of the Weapons Neutron Research facility of Los Alamos Neutron Science Center (WNR of LANSCE). In 2015, three groups of LFS (a type of LYSO) plates (6/each) of 14×14×1.5 mm^3 were irradiated for 13.4, 54.5 and 118 days with fast neutron (>1 MeV) fluences of 0.22, 1.0 and 2.1 $\times 10^{15}$ n/cm^2 plus ionization dose of 0.45, 2.0 and 4.3 Mrad, respectively. To evaluate the contribution from accompanying γ-rays quantitatively, we applied 5 mm Pb shielding to half samples for a comparison in 2016. Three groups of BaF_2, LYSO and PWO plates of 10/15×10/15×5 mm^3 were irradiated for 21.2, 46 and 120 days with fast neutron (>1 MeV) fluences of 0.39, 0.86 and 1.9 $\times 10^{15}$ n/cm2 plus ionization dose of 0.80, 1.7 and 3.9 Mrad, respectively. The results of this investigation show that LYSO and BaF_2 are radiation hard against fast neutrons up to 2 $\times 10^{15}$ n/cm^2 plus 4 Mrad ionization dose, and the ionization dose dominates the observed damages in these samples.

Secondary topics:

radiation damage

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Scintillators

Session 11 / **55**

A New ATLAS ZDC for the High Radiation Environment at the LHC

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Increases in luminosity at the LHC will lead to higher radiation exposure of detectors located along the beamline. This problem is especially acute for the Zero Degree Calorimeters (ZDCs) in ATLAS, which are exposed to dosages on the order of 10 Grad/yr during p+p running. We have systematically studied the damage this radiation has caused in our current detector, while at the same time explored potential upgrade options. One particularly promising option would be based around recent, experimental results suggesting transmission loss saturation in ultra-pure, amorphous quartz rods at very high radiation exposure. If this effect can be harnessed, it may be possible to construct a highly radiation-tolerant quartz-tungsten sampling calorimeter. Our R&D aims to understand the physical defects created in quartz and methods by which these defects can be annealed or controlled. Spectrometric analysis of irradiated quartz rods will be presented and implications will be discussed for calorimetry design in extreme radiation environments.

Secondary topics:

Applications:

Primary topic:

Cherenkov

Session 4 / 57

A Highly Granular Calorimeter Concept for Long Baseline Near Detectors

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Future long baseline neutrino experiments such as the DUNE experiment under construction at Fermilab will perform precision measurements of neutrino oscillations, including the potential for the discovery of CP violation in the lepton sector. These measurements require an understanding of the unoscillated neutrino beam with unprecedented accuracy. This will be provided by complex near detectors which consist of different subsystems including tracking elements and electromagnetic calorimetry. A high granularity in the calorimeter, provided by scintillator tiles with SiPM readout as used in the CALICE analog hadron calorimeter, provides the capabillity for direction reconstruction of photon showers, which can be used to determine the decay positions of neutral pions. This can enable the association of neutral pions to neutrino interactions in the tracker volume, improving the event reconstruction of the near detector. Beyond photon and electron reconstruction, the calorimeter also provides sensitivity to neutrons. In this presentation, we will discuss a simulation study exploring the potential of high granularity for the electromagnetic calorimeter of the DUNE near detector. Particular emphasis will be placed on the combination with a high pressure TPC as tracking detector, which puts particularly stringent requirements on the calorimeter. The dependence of the projected detector performance on granularity, absorber material and absorber thickness as well as geometric arrangement satisfying the constrants of the TPC are explored.

Secondary topics:

Highly granular calorimeters, simulation studies of a new detector concept

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Other

Session 11 / 58

Ultrafast and Radiation Hard Inorganic Scintillators for Future HEP Experiments

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Future HEP experiments at the energy and intensity frontiers require fast and ultrafast inorganic crystal scintillators with excellent radiation hardness to face the challenges of unprecedented event rate and severe radiation environment. This paper reports recent progress in fast and ultrafast inorganic scintillators, such as LYSO:Ce crystals and LuAG:Ce ceramics for a shashlik sampling calorimeter and yttrium doped BaF2 crystals for the proposed Mu2e-II experiment. Applications of ultrafast inorganic scintillators for Gigahertz hard X-ray imaging will also be discussed.

Secondary topics:

Scintillators

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Crystals

Session 6 / 59

Construction and Commissioning of a highly granular hadron calorimeter with SiPM-on-tile read-out

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The CALICE collaboration has constructed a hadron calorimeter prototype based on the SiPM-on-tile read-out technology. The scintillator-steel sandwich structure has 38 active layers consisting of 30x30x3mm3 tiles and has 22'000 channels in total. The read-out electronics - including zero-suppression, front-end memory buffering and digitisation of energy and time measurements - and the LED calibration system are fully embedded in the active layers, and the SiPMs are surface-mounted on the electronics boards. The detector is operated with cycled power supply and SiPM bias voltage adapted to temperature variations. The design and the production and quality assurance procedures are scalable to a full collider detector system. We report on the construction, commissioning and first test beam exposure of the prototype.

Secondary topics:

Scintillators

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Particle Flow

Session 7 / 60

Research on the performance of light reflecting materials for shashlik electromagnetic calorimeter

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Electromagnetic calorimeter (Ecal) is an important part of the Multi Purpose Detector (MPD) at the NICA collider. A shashlik-type electromagnetic calorimeter is selected as MPD ECal. The particular goals of the MPD ECal are to measure of spatial positions and energy of photons and electrons. Therefore, the energy resolution of the detector is the most important performance. The light yield is an important factor that affecting the energy resolution of ECal. The reflective materials play the role of reflecting the light emitted by the scintillator and transmitted to the end of the WLS fibers. Therefore, research on the performance of light reflecting materials is crucial to increase the light yield and improve the energy resolution. A variety of fiber-end reflective materials and scintillator surface reflective materials were selected and tested. The best performance materials will be used for the production of shashlik ECal. In addition, Since MPD requires high position resolution of the calorimeter, the size of a single module is only 4x4cm2, so more than 40,000 modules need to be produced. Not only that, to reduce the dead zones effect, all modules will be cut from two sides at an angle 1.5 degree. These pose a huge challenge to mass production. This article also gives a detailed description of the mass production process.

Secondary topics:

Applications:

Primary topic:

Novel Materials

Session 6 / 61

Suppression of a slow component of the BaF2 crystal luminescence with a thin multilayer filter

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Fast component of the BaF2 crystal luminescence with emission peak at 220 nm allows to employ those crystals to construct fast calorimeters to operate at high radiation rate. However, a slow component with emission peak at 330 nm and about 85% of total emission light could create big problems when working at high radiation environment.
In this work we report results of tests of multilayer filters that can suppress luminescence in the range about from 250 nm to 400 nm what covers most of the BaF2 slow component luminescence. The filters are made by spraying layers of rare earth oxides on the quartz glass substrate. Typically filters comprise 200-220 layers.
A few samples of filters were prepared by spraying of thin layers on quartz glass. The filters have a peak transmittance of about 70-80% in the range 200-250 nm. Measurements of light output of the BaF2 crystal with and with no filter between the crystal readout end and PMT demonstrate essential suppression of the slow component. Thin filter applied directly on the crystal readout end demonstrated suppression of the slow component as well.

Secondary topics:

Applications:

Experience with current calorimeter at the intensity frontier

Primary topic:

Crystals

Session 15 / **62**

Design and object performance of the CMS High Granularity Calorimeter Level 1 trigger

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The high luminosity (HL) LHC will pose significant detector challenges for radiation tolerance and event pileup, especially for forward calorimetry, and this will provide a benchmark for future hadron colliders. The CMS experiment has chosen a novel high granularity calorimeter (HGCAL) for the forward region as part of its planned Phase 2 upgrade for the HL-LHC. Based largely on silicon sensors, the HGCAL features unprecedented transverse and longitudinal readout segmentation which will be exploited in the upgraded Level 1 (L1) trigger system. Together with the tracking information, which will also be available at L1, this will open the possibility of pioneering particle flow-based techniques in the L1 trigger. The high channel granularity results in around one million trigger channels in total and so presents a significant challenge in terms of data manipulation and processing for the trigger, to be compared with the 2000 channels in the endcaps of the current detector. In addition, the high luminosity will result in an average of 140 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, 3-dimensional reconstruction of the HGCAL clusters, which will be used for particle flow, in events with high hit rates is also a complex computational problem for the trigger, unprecedented with the 2-dimensional reconstruction in the current CMS calorimeter 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 and their impact on trigger object performance, will be presented.

Secondary topics:

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Front-end readout and trigger

Session 15 / 63

Reconstruction and clustering for the CMS High Granularity Calorimeter

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The existing CMS endcap calorimeters - electromagnetic and hadronic - will be replaced by a sampling calorimeter - the High Granularity Calorimeter (HGCAL) - featuring unprecedented transverse and longitudinal readout and triggering granularity. This will facilitate particle-flow reconstruction in the harsh radiation and pileup environment of HL-LHC collisions. Exploiting the high granularity in this environment requires advances in reconstruction techniques beyond those that have been used in present experiments and particle-flow detectors being designed for future linear colliders. This work will continue throughout the design/construction phase, but many studies have already made excellent progress. We report on the reconstruction and clustering algorithms, and the simulated performance for particle identification and energy/position resolution.

Secondary topics:

Simulation and algorithms

Applications:

Primary topic:

Particle Flow

Session 13 / 64

The study on the Calorimeter for CEPC

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Circular Electron Position Collider (CEPC) is proposed as a Higgs or Z factory and the concept design of the CEPC detectors is on the way. The design and optimization of the CEPC calorimetry system include ECAL and HCAL with several options will be presented. This report will focus on the study of HCAL based on the Particles Flow Algorithm with different technologies including gas detector and scintillator-SiPM. The plan to build the physics prototypes for both the ECAL and HCAL will also be introduced.

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Particle Flow

Session 12 / 65

New method of out-of-time energy subtraction for the CMS hadronic calorimeter

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The CMS hadronic calorimeter employs plastic-scintillator-based sampling calorimeters in the barrel and endcap (HBHE). In Run 2, the LHC operates at 13 TeV center of mass energy with up to 50 simultaneous collisions per bunch crossing (pileup) and a 25 ns bunch spacing. The HBHE scintillator light pulse is only 60% contained in a 25 ns window, resulting in significant pulse overlap for consecutive events (referred to as 'out-of-time pileup').

This talk presents a novel algorithm that will be used in 2018 for subtracting out-of-time pileup in HBHE both online in the software trigger and offline. The algorithm includes methods for both the barrel with hybrid photodiode photosensors and QIE8 digitizers, and the endcap with silicon photomultipliers and QIE11 digitizers, including the challenging charge-dependent pulse shaping effects of the QIEs. The on-detector pulse shape measurement method and results are also shown.

The new algorithm is 5-10 times faster than the previous one, and for the first time CMS will use the offline method at the trigger level. This and other changes improve missing transverse energy (MET) resolution by 50% at 25 pileup. The impact of out-of-time pileup subtraction on jet and MET reconstruction are also presented.

Secondary topics:

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Simulation and algorithms

Session 10 / 66

Studies of radiation effects on the hadronic calorimeters at CMS

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In this talk, we present studies on the longevity of both the current and potential alternative active materials to be used in the backing hadronic calorimeters of the CMS detector for the High Luminosity LHC upgrades. We will also present a proof of concept data-driven method to systematically extrapolate dose rate dependent model parameters from high dose rate regime (0.3 to 500 krad/h in which several controlled irradiations are discussed in this talk) into more realistic HL-LHC regime (0.1 to 20 rad/h in which a controlled irradiation is impractical). The method serves as a guidance to implement relevant inputs into GEANT4 simulation in order to provide a more realistic prediction of light yield reduction due to radiation damage, and additionally allows one to compare light output performance between different geometry designs of active material.

Secondary topics:

Radiation tolerance, simulation

Applications:

Other

Primary topic:

Scintillators

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First results from CMS SiPM-based hadronic endcap calorimeter

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The CMS hadronic calorimeter employs a plastic-scintillator-based endcap detector. In early 2017, a 20° wedge of the endcap was upgraded with silicon photomultipliers (SiPMs) and readout electronics based on the QIE11 digitizer. Based on the excellent experience with this 20° pilot system in 2017, the entire endcap detector was upgraded with SiPMs in early 2018. We report on the first ever operation of SiPMs in a high-rate collider detector. We show results for both the 20° pilot system and the fully upgraded detector (with first 2018 collisions).

We compare SiPM performance to that of the previous hybrid photodiode / QIE8-based readout and describe how the factor three improvement in photon-detection efficiency, increased longitudinal segmentation, and improved response stability allow for mitigation of scintillator radiation damage and simplified calibration. We report in situ measurements of radiation-induced SiPM dark current. Overall, we show that the upgraded SiPM-based system allows more than 50% improvement in radiation-induced response degradation.

Secondary topics:

Front-end readout - Silicon photomultipliers

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Scintillators

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Evolution and Performance of Highly Granular Calorimeters

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Highly granular "imaging"calorimeters, developed by the CALICE collaboration, have evolved from a conceptual idea to a well-proven technology over the last decade. Initially proposed for the detector concepts of future linear electron-positron colliders, such devices are now finding an increasing number of applications in other areas of particle physics as well. This presentation will review key aspects of the technology for highly granular electromagnetic and hadronic calorimeters, sketch the evolution from the first physics prototypes demonstrating the concepts to technological prototypes addressing the constraints of realistic experiments and issues of scalability and mass production and discuss performance highlights of the CALICE detectors.

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Particle Flow

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Shashlik calorimeters for the ENUBET tagged neutrino beam

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The uncertainty in the initial neutrino flux is the main limitation for the measurements of the absolute neutrino cross sections. The ENUBET project (Enhanced NeUtrino BEams from kaon Tagging, Horizon-2020 ERC-CoG grant, 2016-2021) is developing an innovative technique to produce intense sources of electron neutrinos with a ten-fold improvement in accuracy.

A key element of the project is the instrumentation of a decay tunnel with detectors being able to monitor large-angle positrons arising from Ke3 decays and to discriminate them from the background of charged and neutral pions.

An e+/pi separation capability of about 2% as well as a high e+ efficiency is required for a diffuse particle source over a length of several tens of meters. Additional constraints, due to the harsh beam environment, involve radiation hardness and fast response.

For this purpose we have developed a specialized shashlik calorimeter (steel-scintillator) with a compact readout based on small-area Silicon Photo Multipliers coupled to WLS fibers. The Ultra-Compact modules are composed of 1.5 cm thick steel absorbers coupled to 5 mm thick plastic scintillators tiles with TiO reflective painting. A matrix of 3 x 3 fibers run transversely with a density of one fiber/cm2 and an overall surface of about 10cmˆ2. Fibers are coupled individually to HD SiPM with 20x20 um cells mounted on a custom PCB allowing reduce the dead zones between adjacent

modules to an extremely small level compared to "fiber bundling" configurations. This setup allows a very effective longitudinal segmentation or electron/hadron separation.

In this talk we will present the results of the experimental campaign performed in 2016-2017 at the CERN-PS East Area (T9 beam line) and the future tests planned in May and November 2018. The prototype tagger fulfills the project requirements in terms of energy resolution, linearity and electron/pion identification.

We will also discuss the characterization of SiPM of different cell size (12μm and 15 μm) before and after being exposed to neutron fluxes up to 10^{12}/cm^2 at the INFN-LNL CN accelerator facility in June 2017.

Alternative options for the active material have also been investigated. In particular we have successfully characterized with CERN beams a (12 X0) shashlik calorimeter based on polysiloxane scintillators. These are scintillators which come in liquid form, are poured around the fiber arrays and finally made solid with a thermal treatment. This scheme is very appealing for practical reasons related to the construction of such a large calorimeter. Energy resolution, linearity, spacial uniformity and light yields have been assessed and are very promising.

References

- G. Ballerini et al, Testbeam performance of a shashlik calorimeter with fine-grained longitudinal segmentation, arXiv:1801.06167 (pdf), JINST 13 (2018) P01028.
- A. Berra et al., Shashlik Calorimeters With Embedded SiPMs for Longitudinal Segmentation, IEEE Trans. Nucl. Sci. 64 (2017) no.4, 1056-1061
- A. Berra et al., Longitudinally segmented shashlik calorimeters with SiPM readout, Nucl. Instrum. Meth. A845 (2017) 511-514, pdf
- M. Pozzato et al. High precision flux measurements with ENUBET, J. Phys. Conf. Ser. 888 (2017) no.1, 012119
- F. Pupilli et al., The ERC ENUBET Project: high precision neutrino flux measurements in conventional neutrino beams Proceedings of NuPhys 2016, arXiv:1705.00150 (pdf)
- A. Longhin et al., High precision flux measurements in conventional neutrino beams: the ENUBET project, PoS NOW2016 (2017) 035
- F. Terranova et al., The ENUBET project: high precision neutrino flux measurements in conventional neutrino beams, PoS (EPS-HEP2017) 138
- A. Meregaglia et al., ENUBET: Enhanced NeUtrino BEams from kaon Tagging, JINST 11 (2016) no.12, C12040
- A. Berra et al. Enabling precise measurements of flux in accelerator neutrino beams: the ENUBET project CERN-SPSC-2016-036 / SPSC-EOI-014, 05/10/2016

Secondary topics:

fast timing, novel materials, simulation

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Scintillators

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Overall Status of the CMS High Granularity Calorimeter

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The endcap calorimeters of CMS will be replaced, during LHC long shutdown 3 (~2024-2025), with the High Granularity Calorimeter (HGCAL). Hexagonal silicon sensors will be used in the high radiation regions, complemented by scintillator tiles with on-tile SiPMs in the less harsh regions. Through an extensive R&D campaign in the past two years, the design of the HGCAL has converged, with many choices on structure and technology having been made, leading to the submission of the HGCAL TDR in November 2017. An overall status of the HGCAL is presented, summarising the main design choices that have been made, the expected performance and the work still to be done.

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

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Status and Performance of the Calorimeter Systems for the sPHENIX Experiment at RHIC

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The sPHENIX experiment at RHIC will make high statistics measurements of jets, jet correlations, and upsilon states in heavy ion collisions in the early 2020's. High resolution tracking coupled with uniform electromagnetic and hadronic calorimetry will be used to characterize the temperature dependence of transport coefficients of the quark-gluon plasma.
In this talk we will present a brief introduction to the sPHENIX detector design with emphasis on calorimetry. The latter includes a compact tungsten/scintillating fiber electromagnetic calorimeter and a steel/scintillating tile hadronic calorimeter. The outer calorimeter steel also serves as a magnetic flux return for the central magnet. The design is optimized for jet energy measurements above the underlying event background in Au-Au collisions at RHIC energies, electron and photon identification and measurement over whole range of secondary particle momenta including those from W/Z-decays and photon/p0 separation at transverse momenta critical for precision measurements of the thermal photon emission from early stages in heavy ion collisions. Built around the preexisting BaBar superconducting magnet, we have chosen for sPHENIX a calorimetry system segmented with towers in each longitudinal section overlapping in azimuth and rapidity.
Prototypes of the sPHENIX calorimeter systems have been extensively simulated within the GEANT4 simulation framework. and repeatedly tested in particle beams in the T1044 test beam experiment at the FTBF at FNAL. Both simulation data and test beam data will be reported in this talk.

Secondary topics:

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Scintillators

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Triggering on electrons, photons, tau leptons, Jets and energy sums with the CMS Level-1 Trigger

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The Compact Muon Solenoid (CMS) experiment implements a sophisticated two-level triggering system composed of the Level-1, instrumented by custom-design hardware boards, and a software High Level Trigger. A new Level-1 trigger architecture with improved performance is now being used to maintain high physics efficiency for the more challenging conditions experienced during Run II. In this presentation, we present the upgraded CMS calorimeter trigger algorithms. The calorimeter trigger system plays a central role in achieving the ambitious physics program of Run II. The upgraded electronics architecture benefits from an enhanced granularity of the calorimeters to optimally reconstruct the trigger objects. Dedicated pile-up mitigation techniques are implemented for the lepton isolation, the jets and the missing transverse energy to keep the rate under control in the intense running conditions of the LHC. The performance of the new calorimeter trigger will be presented, based on proton-proton collision data collected in Run II. The selection techniques used to trigger efficiently on benchmark analyses will be presented, along with the strategies employed to guarantee efficient triggering for new resonances and other new physics signals.

Secondary topics:

Applications:

Experience with current calorimeter at the energy frontier

Primary topic:

Front-end readout and trigger

Session 15 / 75

Detector performance studies for the CMS High Granularity Calorimeter

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The CMS High Granularity Calorimeter will replace the existing endcap calorimeters for the High-Luminosity phase of LHC. It will be based on hexagonal silicon pad sensors (in the highest radiation regions) and scintillator tiles with on-tile SiPM readout (in the lower radiation regions). Prototypes of both detector types have been made and tested extensively in laboratories and beams, with many devices also undergoing irradiations to study before/after performance. We present a summary of the results of these tests, focusing on the measured performance in terms of signal production, calibration, resolution (position, energy and time) and stability. We compare with the expected performance using detailed GEANT4-based simulations.

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Silicon

Session 15 / **76**

Engineering Challenges of the CMS High Granularity Calorimeter

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At the High Luminosity LHC, the CMS detector will be exposed to large pile-up conditions and large radiation dose. To cope with the challenges, the whole endcap calorimeter system will be replaced with the High Granularity Calorimeter containing 52 longitudinal sampling layers made of silicon sensors in the high radiation area and scintillators read out by SiPMs in the low radiation area. A fine lateral segmentation of 0.5-1cm2 silicon pads and 4-10cm2 scintillator tiles amounts to a total of 6M channels in a very compact and necessarily dense structure, a major engineering challenge. The on-detector electronics is expected to dissipate ˜200kW and to reduce radiation damage the whole detector will operate at a temperature of -30C, achieved with a two-phase CO2 cooling system. Additional engineering challenges arise from the large difference in the coefficient of thermal expansion of Si and the mechanical structure. In order to study the thermal and mechanical properties of the detector the first mockup cassette with silicon modules has been built and CO2 cooling tests have been performed. We present an overview of the engineering design of the detector with an emphasis on the thermal tests of the mockup cassette and compare results to FEA calculations.

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Silicon

Session 8 / **77**

SiD silicon tungsten ECAL for ILC

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We present an update on the status of the SiD silicon-tungsten ECAL development effort. The calorimeter design consists of thirty layers of silicon sampling embedded in a stack of tungsten plates. The first twenty tungsten plates are 2.5 mm thick followed by ten 5.0 mm thick plates. The six-inch silicon sensors contain 1,024 channels, with nominal pixel cross sections of 13 mmˆ2, and are read out by the 1,024 channel CMOS ASIC "System on a Chip"KPiX.[1] A nine-layer prototype was assembled and tested in a SLAC electron test beam. The beam test revealed crosstalk from capacitive coupling among pixels. A novel improved design of the sensor was developed with two metal layers, aimed at significantly reducing the capacitive coupling. A new set of prototypes sensors was fabricated, with an additional improvement of a gold surface stack under bump metallization for KPiX bonding. A new cable with wire bond connections to the sensor has also been developed to simplify the cable bump bonding procedure. Studies of the test beam data have demonstrated excellent isolation of electromagnetic showers, and separation of neighboring showers.[2]

[1] J. Brau, M. Breidenbach et al., "KPiX - A 1,024 Channel Readout ASIC for the ILC," SLAC-PUB-15285 (2013), 2012 IEEE Nuclear Science Symposium, http://slac.stanford.edu/pubs/slacpubs/15250/slac-pub-15285.pdf

[2] A. Steinhebel and J. Brau, "Studies of the Response of the SiD Silicon-Tungsten ECal," Proceedings of the 2016 Linear Collider Workshop (LCWS), Morioka, Japan, arXiv:1703.08605 [physics.ins-det].

Secondary topics:

Applications:

Design concepts for future calorimeter at the energy frontier

Primary topic:

Silicon

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PADME electromagnetic calorimeter

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The PADME experiment, hosted at Laboratori Nazionali di Frascati in Italy, is going to start its data taking in a short time. It is designed to search for the Dark Photon (A'), an hypothetical particle that can explain the Dark Matter elusiveness, possibly produced in the reaction $e^+ e^- \to A' \gamma$.
Together with the target, the segmented electromagnetic calorimeter is the most important component of the experiment, since it is needed to detect the recoil photon energy and position, in such a way to measure the A' mass. It will consist of 616 $2.1 \times 2.1 \times 23.0\,\text{cm}^3$ BGO crystals arranged in a cylindrical shape and read by HZC photomultipliers with a diameter of 1.9 cm.
Here we present the results obtained during the measurements performed on the scintillating units with a radioactive source and test beams, together with an overall description of the entire experiment.

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Secondary topics:

Applications:

Design concepts for future calorimeter at the intensity frontier

Primary topic:

Crystals

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CALOR2018 Introduction

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Closing Remarks

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