RPC2020

Report of Contributions

https://agenda.infn.it/e/19942

Contribution ID: **4** Type: **Oral Contribution**

mTOF performance during mCBM beam time at GSI

Wednesday, February 12, 2020 9:30 AM (20 minutes)

The future Facility for Anti-proton and Ion Research (FAIR), currently in construction in Darmstadt, Germany, is one of the largest research projects world wide. The Compressed Baryonic Matter (CBM) experiment is one of the main pillars at FAIR, studying the quantum chromodynamics (QCD) phase diagram at high baryon densities with unprecedented interaction rate in heavy ion collisions up to 10 MHz. This requires new free-streaming data acquisition methods, new data analysis concepts and high-rate capable detector systems. The task of the CBM Time of Flight wall (CBM-TOF) is the charged particle identification. Muitl-gap Resistive Plate Chambers (MRPCs) with different rate capabilities will be used at their corresponding regions. To reduce the commissioning time for CBM, a CBM full systetest-setup called mini-CBM (mCBM) has been installed and tested by beams at GSI SIS18 facility in 2019. The high-rate MRPC prototypes developed at Tsinghua University, called MRPC3a, were selected to be implemented in mTOF modules for mCBM. Additional thin float glass MRPCs from USTC, foreseen for the CBM low rate region, were also tested in mCBM experiment. Performance results from these prototypes analyzed by the so called tracking method will be the scope of the talk.

Primary authors: Ms ZHANG, QIUNAN (Tsinghua University, Heidelberg University); Dr DEPPER, Ingo (Heidelberg University); Prof. HERRMANN, Norbert (Heidelberg University); Prof. WANG, YI (Tsinghua University)

Presenter: Ms ZHANG, QIUNAN (Tsinghua University, Heidelberg University)

Session Classification: Large systems and Upgrades

Contribution ID: **5** Type: **Oral Contribution**

Precision time measurements of single-gap trigger RPCs for large-scale accelerator-based high-energy physics experiments

Tuesday, February 11, 2020 9:10 AM (20 minutes)

The goal of the present research is to achieve functionally improved trigger RPCs with a two-dimensional strip readout method whose intrinsic time resolution is better than 500 ps. In the present research, we constructed single-gap RPCs with gap thicknesses of 1.0, 1.6, and 2.0 mm using phenolic high pressurized laminate (HPL). The detector performances was examined for cosmic muons using a 64-channel multi-hit TDC with a time resolution of 17 ps. The test results of the prototype RPCs using cosmic rays show x-y matching coincident efficiency of about 94%, and the images of the two-dimensionally tagged cosmic muons are well reconstructed from the data with a spatial resolution better than 10 mm. The intrinsic time resolution achieved with the 1.0 mm single-gap RPC was estimated to be about 400 ps.

Primary authors: LEE, Kyong Sei (Korea University); Mr KANG, Minho (University of Seoul); Mr JO, Youngmin (University of Seoul)

Presenter: LEE, Kyong Sei (Korea University)

Session Classification: New Ideas

Contribution ID: **6** Type: **Oral Contribution**

Use of the MRPC telescopes of the EEE Project to investigate possible instabilities of civil structures on a long-time scale

Friday, February 14, 2020 11:20 AM (20 minutes)

Cosmic ray muons are created by high energy primary cosmic radiations, mostly made of protons when striking the Earth's atmosphere. Besides the common use of secondary cosmic rays in nuclear and elementary particle physics for detector testing and calibration and for the alignment of detectors in the very complex apparata used in this field, cosmic muons have also been considered since several decades as a powerful probe to many applications in physics and engineering fields. Muons are highly penetrating in matter and their average energy is sufficient to penetrate even hundreds meters of rock. Thanks to this peculiarity, cosmic muons are used for muography of volcanoes and for absorption radiography of possible hidden rooms inside large structures, such as Pyramids. Muon scattering is also used for the detection of high-Z illicit nuclear materials inside containers.
This contribution discusses the possibility to employ the Multigap Resistive Plate Chambers (MRPC) of the Extreme Energy Events (EEE) Project as muon tracking detectors to monitor the long-term stability of civil buildings and structures when used in conjunction with additional detectors. The high detection efficiency and the excellent tracking capabilities of the EEE MRPC chambers make them an optimal choice for such application. The performance of such setup is discussed and experimental results from first coincidence measurements obtained with one of the EEE telescopes operated in the same building with an additional scintillator detector, at about 15 m vertical distance from it, are presented. Simple Monte Carlo and GEANT simulations were also carried out to evaluate typical acceptance values for the operating conditions employed so far, to extrapolate to other geometrical configurations, and to evaluate multiple scattering effects.

Primary author: PINTO, Chiara (CT)

Presenter: PINTO, Chiara (CT)

Session Classification: Outside Particle and Astroparticle Physics

Contribution ID: **7** Type: **Oral Contribution**

MRPC technology used in muon tomography

Friday, February 14, 2020 10:30 AM (20 minutes)

ABSTRACT: Since 2008, Tsinghua University has been developing Multi-gap Resistive Plate Chamber (MRPC) for the muon tomography. In 2012, we setup TUMUTY (Tsinghua University cosmic ray Muon tomography facility) based on MRPC and got some reconstruction imaging results. The RPC-type detector developed for position resolution started in 2003. T. Francke built the first position resolution RPC with a strip width between 30-50 μm, and got a position resolution about 50 μm. Then M. Petris also carried out the position resolution MRPC study using a detector of two-chamber structure with 14 gaps and 2.54 mm strip pitch. Their position resolution reached to 500 μm. Li Qite, A. Blanco, Ye Jin also studied the position resolution RPC-type detector in a detailed way. Their results proved that the RPC-type detector is a perfect choice for muon tomography.
The first generation muon tomography MRPC, the track detector in the TUMUTY, was built by Fan Xingming in Tsinghua University. The TUMUTY MRPC has a sensitive area of 736 mm *736 mm. Two MRPCs were used respectively for the X-Y dimension. Each MRPC has six gaps whose width is 0.25 mm. The readout strip's width is 2 mm and the pitch is 3 mm. Two readout boards are needed to cover an electrode because of the large sensitive area. The reason why it is called the first generation of muon tomography MRPC is that many technology has been taken into consideration, such as the efficiency at the two readout PCBs' connection area, the uniformity of the sensitive area of the detector and so on.*
*Our research is focused on developing a muon NDT (Non Destructive Testing) system that will be used in homeland security operations such as custom inspections, airport security and so on. Based on a car detection project, we developed the second generation position resolution MRPC with the same 6 gaps structure whose gap width is 0.25 mm. But the second generation detectors have a smarter structure and larger sensitive area of 1060 mm*1060 mm. Moreover, we can get X-Y two dimension readout within one detector. We move the encoding readout device into the gas box to improve the data transmission stability. Considering industrial production, studies on temperature effect and pure Freon working mode were also carried out for the second generation position resolution MRPC detectors.
Most RPC-type detectors are operating with gas mixtures containing R134a (C2F4H2) and SF6, both possess a high GWP value. The alternative eco-gas is expensive and will greatly increase the detector system's running cost. Fortunately the flux of muons from cosmic ray at sea level is low, so a kind of position resolution SMRPC (sealed MRPC) prototype working in extremely low gas flow has been developed in our team, which is called as the third generation of muon tomography MRPC. The prototype has a sensitive area of 500 mm*500 mm. It can work very well at an extremely low gas flow of 0.5 ml/min. Moreover, the performance of the detector in a mode without gas exchange is also studied. The result shows that the detector can work for more than 60 hours without any gas exchange. The calculated average gas flow of the detector reduces to 0.05 ml/min in no-gas-exchange mode. Carbon film glass and sealing bar are used in SMRPC to provide a working space instead of an aluminum gas box that the last two generations of position MRPCs needed. SMRPC makes RPC-type detector more lightweight and convenient for the industrial application.
In addition, a complete simulation framework for position resolution MRPC is built by ANSYS Maxwell+Geant4. The factors which affect the position resolution in the MRPC can be studied in detail. Machine learning method is also used for our position resolution MRPC's data processing to obtain the best performance of the detector, by training the algorithm parameters through the comparison of experimental data and the simulation data.

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Presenter: Dr CHEN, Xiaolong (Tsinghua University)

Session Classification: Outside Particle and Astroparticle Physics

Contribution ID: **8** Type: **Poster Session**

RPCs and readout system for the neutrino detector of the SHiP experiment

Thursday, February 13, 2020 4:30 PM (8 minutes)

SHiP (Search for Hidden Particles) is a proposed experiment to be installed at CERN, exploring the high intensity beam frontier, in order to study both hidden particles and tau neutrino and antineutrino physics.
The SPS proton beam interacting with the SHiP high density target is expected to produce a large neutrino flux, with about 10^15 $\nu\tau$ and $\bar{\nu}\tau$ in five years (integral p.o.t. 2·10^20). A dedicated Scattering Neutrino Detector (SND) is being designed. It consists of an emulsion target and a tracking fibres detector in magnetic field followed by a Muon identification system.
The Muon system is composed of iron filters interleaved with tracking planes (dimension ~2x4m^2), instrumented with Resistive Plate Chambers (RPCs), operated in avalanche mode. Each plane consists of three large gaps (~2x1m^2 each) read-out by two planes of perpendicular strips (pitch~1cm, length~2m).
The RPC readout electronics is being developed in Bari. It is based on the use of front-end FPGAs connected to a concentration system, transmitting data serially at high speed via optical link to the data acquisition & control system.
A small-scale prototype of the SHiP Muon identification system, with 5 RPC planes consisting of one large gap each, has been produced and exposed at CERN H4 in a test beam.

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Session Classification: Poster Session

Contribution ID: **9** Type: **Oral Contribution**

The CEE-eTOF wall constructed with new sealed MRPC

Tuesday, February 11, 2020 10:10 AM (20 minutes)

The CSR (Cooler Storage Ring) External-target Experiment (CEE), located at the Heavy Ion Research Facility in Lanzhou (HIRFL), is designed for the physical purpose of approaching the critical point from the hadronic phase side in Quantum Chromo Dynamics (QCD) phase diagram. In addition, it is also expected to offer a probe for study on the density dependence of symmetry energy, and for hyper-nucleus measurement. Two identical TOF walls will be placed symmetrically at 6-meter downstream of the target as part of the dipole detector array, with zero degree vacated for collision centrality measurement. This work has given a preliminary technical design of the TOF wall, which consists of 6 modules, 24 MRPC detectors with 768 channels. The whole coverage of each wall is 2m × 2m. Reasonable width of overlap between MRPCs is considered to deal with the edge effect.

The Sealed MRPCs will be applied to form the TOF wall. With an elaborate integral sealing structure by 3D printing, the modularized assembling of this type can be achieved in the future mass production. More importantly, the gas consumption will be reduced significantly thanks to small gas volume. This improvement will help reduce the emission of gas with high Global Warming Potential (GWP) value, which is of concern at the background of "F-gas Regulation"by EU. The sealed MRPC prototype for CEE-TOF has been produced and tested. It has two stacks, each with 5 gas gaps of 0.25 mm thickness, divided by float glass plates, and has 16 readout strips with a 22 mm strip pitch (20 mm width and 2 mm gap), 52cm strip length. Differential signals are readout from both sides of the strip. Cosmic test result shows that the sealed MRPC prototype meets the performance requirement of CEE-TOF, reaching the plateau efficiency of over 96% and time resolution better than 70 ps, working stably with reasonable crosstalk and noise level. During about 1 month of the test time, the gas volume has excellent gas-tightness in a gas flow as low as 5 mL/min though 3 serial detectors, which verifies the module design for CEE-TOF operation. Thanks to the sealed design, cost and emission from gas consumption will decline, and the encapsulation and installation of TOF module can be simplified. The new sealed design of MRPC and test results will be presented in this paper.

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Presenter: WANG, Botan (Tsinghua University)

Session Classification: New Ideas

Contribution ID: **10** Type: **Poster Session**

RPC online monitor

Thursday, February 13, 2020 4:38 PM (8 minutes)

An online monitor with GUI interface has been developed for ATLAS Phase I RPC mass production in BB5, CERN. It could speed up the RPC cosmic ray tests which are the QC procedures after singlets and triplets RPC assembled.
The monitor could control VME controller and TDC e.g. start or end the DAQ. During the data taking, the monitor would read the data from TDC, reconstruct the event, calculate the preliminary results and display all plots in real time. The mapping between TDC channels and readout strips is accepted by specifying a mapping CSV file so that the monitor could reconstruct events of different singlet RPCs.
Around 20 plots are offered for preliminary results including efficiency curves, cluster size histograms, hit maps, TOT, TOF distribution and so on. Several kinds of efficiency curves and histograms show chamber / gap efficiency and Eta / Phi strips efficiency to help find the broken channels. Another singlet could be specified as reference. 2D hit heat-plot and 2D noise heat-plot give quick views of inefficiency areas and noisy areas of gas gaps. TOF with gaussian fit could give preliminary RPC time resolution.
Simple cosmic ray track reconstruction is offered for AR propose: the reconstructed tracks would be broadcasted via TCP/IP and could be received by AR program to display the tracks upon the video recorded by the camera in real time.
After DAQ finishes, a pdf-formatted quick analysis report would be generated contains all the plots and the mapping for archive.
Basing on Qt, C++ and root, the monitor could reconstruct events and refresh plots in an efficient way.
The monitor is fully open source on gitlab and has the potential to be utilized in further RPC production and cosmic ray tests.

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Presenter: XIE, Xiangyu (USTC)

Session Classification: Poster Session

Contribution ID: **11** Type: **Oral Contribution**

Study on RPC signal attenuation and dispersion

Thursday, February 13, 2020 10:30 AM (20 minutes)

RPC Signal attenuation and dispersion are interesting topics and become more concerned since thin-gap RPC got popular and new readout methods proposed. Theoretical calculation indicates that attenuation and dispersion exist while signals propagating along the readout strips and both are relating to the surface resistivity of graphite layer and the propagation distance. In simulation we found the existence of signal attenuation and dispersion and verified that they are sensitive to the two factors mentioned above. To confirm and quantify, the measurements on thin-gap RPCs are performed. The lower limit of graphite surface resistivity of a certain RPC structure could be set which relates to the uniformity of electric field especially when the counting is high.

Gas gaps with different graphite surface resistivity are prepared for this study. To perform the propagation-distance-relating measurement, we manage to get two signals which are originally identical but have different propagation distance. While the charge induced on the readout strips by the avalanche, two signals would be generated and propagate towards both ends of the strip. In the far end the strip is kept floating i.e., connecting to an infinite resistor, to make the signal reflected back to the near end keeping the strength and polarity. Both signals would be terminated on the near end connecting to the matching resistors then observed and recorded by the oscilloscope. The difference of propagation distance could be given by the orthogonal readout strips or derived from the time difference of two signals'leading edges together with pre-measured signal propagation velocity. By this way two signals with different propagation distance are not only identical after induced but also are read from one readout strip oscilloscope channel, thus the systematical errors of this study would be suppressed.

Analysis of the waveforms would be performed offline. Charge, frequency and dispersion of each two signals would be studied and compared. Lowpass filter would be used to filter the high frequency noise. Influence of signal reflection would be studied using TDR (Time Domain Reflectometry) and would be calibrated.

Preliminary results show that the existence of both signal attenuation and dispersion, and the charge attenuation is about -2 dB/m with 120 kΩ/SQ graphite layer. The relationships between attenuation, dispersion and graphite surface resistivity, propagation distance would be discussed in details and counter measurements would be proposed.

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Presenters: XIE, Xiangyu (USTC); LIU, Yanwen

Session Classification: Electronics and DAQ

Contribution ID: **12** Type: **Oral Contribution**

Time reconstruction in MRPC detector using deep-learning algorithms

Thursday, February 13, 2020 9:50 AM (20 minutes)

Multi-gap resistive chamber (MRPC) has been well-known for its extremely high time resolution, and therefore, it has been chosen by Jefferson Lab to constitute the Time-of-Flight system in the Solenoidal Large Intensity Device (SoLID). In this experiment, the requirement for the time resolution of MRPC detectors is around 20 ps, which far exceeds the typical time resolution (50~70 ps) that can be achieved in present large physics experiments. In this work, a very thin gap (104um) MRPC detector with 32 gaps which are arranged as 8 gaps in 4 chambers is implemented and tested with the cosmic rays. The signal waveforms of the MRPCs are readout by a waveform digitizer with a bandwidth of 1 GHz and sampling rate of 10 Gsample/s. The waveforms collected in the experiment are analyzed with three new algorithms based on neural networks and deep learning, and the time resolutions of the detector achieved with these three different algorithms are 16.8 ps, 19.7 ps and 23.62 ps respectively.

The first algorithm includes a detailed simulation of the MRPC detector used in the test. The deep neural networks are trained with the simulation waveforms, and the model generated from the training is then applied to evaluate the time resolution of the experiment. The similarities between the simulation and experiment play a vital role in this algorithm, and hence they are carefully compared and analyzed in this work. This algorithm takes the advantages of the knowledge in the simulation and achieves the best result ——16.8 ps. In the contrast, the other two algorithms are trained with the experiment waveforms. In the cosmic ray test, four runs are conducted, each using different spacers in order to make the distance between the two MRPC detectors to be 0, 1, 2, 4 cm. The second algorithm proposed in this work uses the time interval between the two detectors of vertical events as the network label, which means the labels of different events in the same run are the same, while in the third algorithm, the labels are time intervals obtained by the traditional slewing correction. The result of the second algorithm is 19.7 ps which is slightly worse than the first but better than the third, because the cosmic rays are not perfectly perpendicular to the MRPC, making the true time interval between 2 detectors different from events to events and thus bringing uncertainties if they are considered the same. Meanwhile, since the true time interval between the detectors are unknown, utilizing the interval obtained with the slewing correction in the third algorithm can only be an approximation which depends largely on the correction. So the resolution of the third algorithm is not as good as the other two.

In general, it has been proved that an MRPC detector with a time resolution below 17 ps can be achieved and the algorithms based on neural networks and deep learning are useful in reconstructing the time of MRPC. This should be of paramount importance to the development and applications of the MRPC detectors in the future.

Primary authors: WANG, Fuyue (Tsinghua University); WANG, Yi (Tsinghua University)

Presenter: WANG, Fuyue (Tsinghua University)

Session Classification: New software approaches to data analysis

Contribution ID: **13** Type: **Oral Contribution**

A neural network based algorithm for MRPC position reconstruction

Thursday, February 13, 2020 9:30 AM (20 minutes)

Multi-gap Resistive Plate Chamber (MRPC) is a well-preformed gasous detector with good efficiency, high position and time resolution and low cost. In the recent years, muon tomography has attracted much attention due to its possible application to detect high Z materials. Precise measurements of the incident and outgoing angles of the cosmic muons are mandatory in this application. Large size MRPC with sub-millimetre position resolution should be an ideal candidate for the detector system. Prior work on improving the position resolution of MRPC mainly focuses on adjusting read-out panel and the detector geometry, while little work has been done on improving the position reconstruction algorithm.
The traditional method of the center of gravity (COG) for position (and other) measurements is extremely widespread in scientific and practical applications, which are far too numerous to list here. However, the use of the COG introduces a systematic error (discretization error) in measurement due to its origin in the discretization of the signal collection. This paper proposes a new position reconstruction algorithm based on the deep neural networks(NN) which gives a better result than COG method. This work is based on a standalone simulation of a 5-gap MRPC detector with 2.54 mm strip pitch.
A detailed simulation based on Maxswell and Geant4 is carried out and the noise and crosstalk compared to the experiment are introduced. Thus, we can easily get the signal charge and the discrete points of each strip, which will be feed into the network as input (features). Labels in the NN are the truth position where particles impinge into the detector. Finally it is trained to find the best prediction. X-ray test based on this 5-gap MRPC detector is carried out in our lab. The position resolution of this prototype with the deep learning based algorithm and the COG method will be given.

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Presenter: YU, Yancheng (Tsinghua University)

Session Classification: New software approaches to data analysis

Contribution ID: **14** Type: **Poster Session**

Charge sharing in Gas Electron Multipliers

Thursday, February 13, 2020 5:26 PM (8 minutes)

The Gas Electron Multiplier (GEM) has become a widely used technology for high-rate particle physics experiments like COMPASS, LHCb and are being planned to use as the readout system for the upcoming upgrade version of other experiments such as ALICE TPC.
The radiation hardness, ageing resistance and stability against discharges are the main criteria for the long-term operation of such detectors in the high-rate experiments. In particular, discharge is a serious issue as it may cause irreversible damages to the detector as well as the readout electronics. The charge density inside the amplification region is the limiting factor of detector stability against discharges. By using multiple devices and thus, sharing the electron multiplication in different stages, maximum sustainable gain can be shifted upwards by several orders of magnitude. A common explanation for this is connected to the transverse electron diffusion, widening of the cloud and reducing the charge density in the last multiplier. However, this has not been verified yet. There are several ways to distribute the voltages among all electrodes in a multi-GEM set-up depending on the requirement of a particular experiment. In our work, we are using Garfield/Garfield++ simulation framework as a tool to extract the information related to the transverse size of the propagating electron cloud and thus, to estimate the charge density in the GEM holes for multiple stages. For a given gas mixture, we will present the initial results of charge sharing using single and double GEM detectors under different electric field configurations and its effect on other measurable detector parameters such as single point position resolution.

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Presenters: Ms ROY, Promita (Saha Institute Of Nuclear Physics, HBNI, INDIA); Ms BHATTACHARYA, Purba (Departimento Di Fisica, Istituto Nazionale di Fisica Nucleare, Monserrato CA, Italy.)

Session Classification: Poster Session

Contribution ID: **15** Type: **Oral Contribution**

Characterization of new RPC eco-friendly gas mixtures at GIF++

The Resistive Plate Chamber (RPC) is a parallel plate, gaseous detector with a wide range of applications in physics experiments at e.g. the CERN LHC collider and future, beyond LHC facilities.
In order to operate the detector in avalanche mode, the standard RPC gas mixture is based on C2H2F4, which is characterized by a high Global Warming Potential (GWP) and therefore considered greenhouse gas (GHG).
Recent European regulations demand the reduction of the GHG emissions and new alternatives have to be found.
The quest for a suitable eco-friendly gas is a multi-parameter problem
that has to take into account several aspects: flammability, toxicity, handling hazards and matching with the available on-board detectors electronics. An interesting eco-friendly replacement gas has been identified in the form of HFO-1234ze and several groups have already characterized it for RPCs with different layouts.
A crucial point to be evaluated is the long term behaviour with eco-friandly gas mixtures under irradiation.
For this reason, a collaboration among ALICE, ATLAS, CMS, CERN EP-DT and groups working at experiments beyond colliders was set up to investigate the performance of RPCs with eco-friendly based gas mixture under irradiation .
Several RPC detectors with different layouts have been tested at the CERN Gamma Irradiation Facility (GIF++), which provides an intense gamma source allowing to simulate the LHC experiments background radiation.
The RPC performance with eco-frienldy gas mixtures is being studied at GIF++ for different gamma rates. The detector longevity and the Hydrogen Fluoride (HF) production rate are under study as well and are evaluated as a function of the integrated RPC charge.
The long term program of the Collaboration and preliminary results on the detector performance and longevity will be reported in this talk.

Primary authors: GELMI, Andrea (BA); PICCOLO, Davide (LNF)

Presenters: GELMI, Andrea (BA); PICCOLO, Davide (LNF)

Session Classification: Ageing and Gas Studies

Contribution ID: **16** Type: **Poster Session**

Detector Control System for CBM-TOF

Thursday, February 13, 2020 4:46 PM (8 minutes)

For charged hadron identification, a high-performance time-of-flight (TOF) RPC wall is being built for the Compressed Baryonic Matter (CBM) experiment at FAIR. The Detector Control System(DCS) for CBM-TOF is designed based on the Experimental Physics and Industrial Control System(EPICS).

Instruments including high voltage power supply, low voltage power supply distributor and gas control system are controlled and monitored in the mini-CBM at GSI. For monitoring environmental parameters such as pressure and temperature, a demonstration application was also implemented in EPICS.

Among the environmental parameters, especially the temperature in the detector is a very important reference to judge whether the detector is behaving properly. Considering the radiation environment, a sensor in the detector is controlled by GBT-SCA, which is a radiation tolerant ASIC for detector control and monitoring applications developed by CERN. Slow control information is being transferred to a FPGA, and a IPbus slave for GBT-SCA in the FPGA firmware will communicate with the EPICS I/O Controller(IOC). GPIOs interface of GBT-SCA is used for switching the clock between GBTx recovered clock and an external 160MHz clock (copper distributed clock) and for monitoring low voltage power of the Front-End Electronics(FEE).

In addition, an archive system for slow control data analysis and an alarm system is built. There is an exception handling system addressing the problem when some fatal errors happen, for example, the sudden loss of gas or low voltage.

During the beam time in mCBM, March 2019, GSI, this control system has proved to be usable and stable. Part of the DCS for CBM-TOF, the low voltage distributor and the GBT-SCA controlling will be adopted in the eTOF of the STAR experiment at RHIC/BNL during the beam energy scan campaign planned for 2019/2020.

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Presenter: DONG, Sheng (Central China Normal University)

Session Classification: Poster Session

Contribution ID: **17** Type: **Oral Contribution**

R&D on Double-end Readout RPC for ATLAS Phase-II Upgrade

Tuesday, February 11, 2020 9:30 AM (20 minutes)

A large number of thin gap RPCs with new type of electronics board will be installed in the ATLAS BI region during the Phase-II Upgrade. A new double-end readout method is proposed. In precondition of satisfying the upgrade performance requirement, this method will potentially reduce the detector thickness, the dead area between units and save the electronics channels. With the signals read out from both ends of each strip, the time difference is proportional to the hit position along the strips. The performance of this method is tested in USTC based on RPC prototypes with 1 mm gas gap and 140 cm length. The measured spatial resolution is around 1 cm which meets the requirement for the Phase II Upgrade.

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Presenters: LI, Quanyin (USTC); SUN, Yongjie

Session Classification: New Ideas

Contribution ID: **18** Type: **Oral Contribution**

A new way to enhance rate capability of MRPC

Tuesday, February 11, 2020 9:50 AM (20 minutes)

The multi-gap Resistive Plate Chamber (MRPC) has been used in many high energy physics and nuclear experiments in the last decade, such as ALICE and STAR. The MRPC usually works in the condition where the particle flux is under1 kHz/cm^2, so normal commercial glass (ρ≈〖10〗^12 Ω.cm) can be used. But with the increasing of beam energy and final state particles, the rate capability of MRPC has to be enhanced accordingly. One normal way is to decrease the bulk resistivity ρ of the resistive plate, as the low resistive glass developed by Tsinghua University for the CBM experiment. Alternatively, the surface of the electrode is also a possible path for the neutralization of the avalanche charges, as schematically shown in Fig.1.
Recently, we managed to carry this method out by coating a Diamond-Like-Carbon (DLC) layer on the surface of the normal glass. DLC, applied by magnetically controlled sputtering method, has very good physical and chemical stability. The surface resistivity can be changed easily. A series of DLC-coated glass with different resistivity have been tested in our lad. We have also made some MRPC prototypes and tested them with cosmic ray. Some preliminary results, including the signal shape, the efficiency and time resolution have been achieved. More research is ongoing to improve the design and performance of this new high rate MRPC with resistive surface.

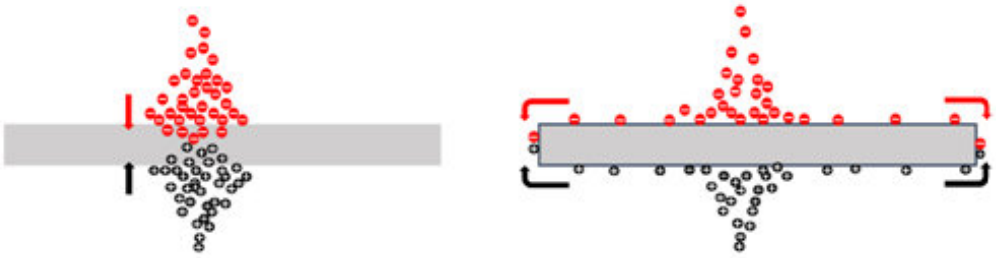

Figure 1: enter image description here

Fig.1. Two paths for the neutralization of the avalanche charges.

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Presenter: Mr WANG, Xinjian (University of Science and Technology of China)

Session Classification: New Ideas

Contribution ID: **19** Type: **Oral Contribution**

Strategies to reduce the Global Warming impact in the MRPC array of the EEE experiment

Tuesday, February 11, 2020 11:40 AM (20 minutes)

The Extreme Energy Events (EEE) Project employs Multi-gap Resistive Plate Chambers (MRPC) detectors for studying the secondary cosmic ray muons in Extensive Air Showers. The array is made up by ~60 tracking detectors, sparse on Italian territory and CERN. Each EEE telescope consists of 3 layers of MRPCs with an active area of 158 x 82 cm^2, operated in avalanche mode. The MRPCs are fluxed in daisy chain with a standard gas mixture 98%/2% of C2H2F4 and SF6 at a continuous flow of 2 l/h, at atmospheric pressure. This means the array emission in atmosphere is order of 10^6 l/year, where the Global Warming Potential (GWP) of its gas mixture is 1880. This value results far beyond the limits of the new law restrictions and regulations of the European Union.

The gases as C2H2F4, under commercial name R134a, SF6, etc, continue to be available for research purposes but their cost largely increased due to the reduced interest from industry. Thus the greenhouse gases are becoming an important issue for gas detector experiments budget, as the EEE Project.

With the aim of containing costs and decreasing environmental impact, the EEE Collaboration has started a campaign along different lines, to reduce gas emission and employ new, eco-firendly, gas mixtures.
The main goal is reducing the gas mixture flow in the MRPC, that means to measure and fix any possible gas pressure leak in the MRPC telescopes. It includes the development of new gas recirculation system of which a dedicated prototype has been installed in a EEE telescope at CERN. Jointly a parallel strategy is focused on searching for environmental-friendly gas mixtures which are able to substitute the standard mixture without an excessive impact on costs.

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Presenter: Dr PANETTA, Maria Paola (INFN Lecce - Centro Fermi)

Session Classification: Ageing and Gas Studies

Contribution ID: **20** Type: **Oral Contribution**

Performance and aging studies for the ALICE muon RPCs

Tuesday, February 11, 2020 11:20 AM (20 minutes)

The ALICE muon trigger (MTR) system consists of 72 Resistive Plate Chamber (RPC) detectors arranged in two stations, each composed of two planes with 18 RPCs per plane. The detectors are operated in maxi-avalanche mode using a mixture of 89.7% $C_2H_2F_4$, 10% $i-C_4H_{10}$, 0.3% SF_6. A number of detector performance indicators, such as efficiency, dark current and dark counting rate, have been monitored over time throughout the LHC Run2 (2015-18). While the efficiency showed very good stability, a steady increase in the absorbed dark current and counting rate was observed.

Since the end of 2018, the LHC has entered a phase of long shutdown, during which the ALICE experiment will be upgraded to cope with the next phase of data taking, expected in 2021. The MTR is undergoing a major upgrade of the Front-End and Read-Out electronics, and will change its functionalities, becoming a Muon Identifier. However, only the most irradiated RPCs will be replaced during the upgrade. It is therefore important to perform dedicated studies to gain further insights into the status of the detector. In particular, two RPCs were flushed with pure Ar for a prolonged period of time and a plasma was created by fully ionizing the gas. The output gas was analyzed using a Gas Chromatograph combined with a Mass Spectrometer and the possible presence of fluorinated compounds originating from the interaction of the plasma with the detector's inner surfaces has been assessed using an Ion-Selective Electrode station.

This contribution will include a detailed review of the ALICE muon RPC performance at the LHC; the procedure and results of the argon plasma test, described above, are also discussed.

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Presenter: Mr QUAGLIA, Luca (Università degli Studi di Torino and INFN Torino)

Session Classification: Ageing and Gas Studies

Contribution ID: **21** Type: **Oral Contribution**

The ALICE Muon IDentifier (MID)

Tuesday, February 11, 2020 2:00 PM (20 minutes)

During the LHC Run-I (2010-2013) and Run-II (2015-2018), the selection of interesting events for muon physics in ALICE was performed by a dedicated muon trigger system, based on 72 single-gap bakelite Resistive Plate Chambers (RPCs), operated in maxi-avalanche mode (ADULT front-end electronics without amplification and a threshold of 7 mV).
From Run-III (starting in 2021) on, in order to fully profit from the increased luminosity of Pb-Pb collisions, the ALICE experiment will run in continuous readout (triggerless) mode and the muon trigger system (MTR) will become a Muon Identifier (MID). The read-out electronics is being upgraded in order to support continuous readout.
Moreover, in order to increase the RPC rate capability and to mitigate possible aging effects, it was decided to operate the detectors with a lower gain, and to replace the ADULT front-end cards with new cards (FEERIC), equipped with an amplification stage. Also, an upgrade of the threshold distribution system to the front-end will allow one to tune thresholds at the single front-end card level, while this was previously only possible at the single-RPC level.
Finally, since some of the RPCs currently installed in ALICE have integrated a non-negligible charge with respect to their certified life-time, about 25% of the detectors will be replaced with new ones, built with a different type of bakelite laminates.
A detailed description of the MTR upgrade and of its current status will be presented in this contribution.

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Presenter: Ms TERLIZZI, Livia (Università degli Studi di Torino and INFN Torino)

Session Classification: Large systems and Upgrades

Contribution ID: **22** Type: **Oral Contribution**

First high rate test of a MRPC detector with novel low resistivity float-glass electrodes

Tuesday, February 11, 2020 3:00 PM (20 minutes)

Multigap Resistive Plate Chambers (MRPC) with an excellent time accuracy in the range of sub-nanoseconds are often used as time-of-flight detector. For the Compressed Baryonic Matter experiment (CBM) at GSI/FAIR, MRPCs are required to work in the CBM-TOF-wall at particle fluxes on the order of 1-10 kHz/cm2 for the outer region and 10-25 kHz/cm2 for the central region. The high bulk resistivity of normal soda-lime float glass reduce the usage of RPC with such electrodes to fluxes below 1 kHz/cm2, that's why different types of low resistive glasses and ceramics are under consideration for MRPC-electrodes , to improve the rate capability of the TOF detectors. A new type of commercially available thin low-resistivity float-glass could sufficiently reduce the costs of the central region of the TOF-wall. We report on the working and timing characteristics of a MRPC built with this new low-resistivity electrode material. The tests have been performed, using the continuous single-electron beam at ELBE/Dresden. This 10-gap MRPC with 160 µm gaps reaches 97% efficiency for mips at 19.2 kV and a time resolution of 36 ps at particle fluxes near 2 kHz/cm2. At a flux of 100 kHz/cm2, the efficiency is still above 95% and a time resolution of 50 ps is obtained, which would fulfil the requirement of CBM.

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Session Classification: New Ideas

Contribution ID: **23** Type: **Oral Contribution**

A simulation tool for MRPC telescopes of the EEE project

Friday, February 14, 2020 9:30 AM (20 minutes)

The Extreme Energy Events (EEE) Project is mainly devoted to the study of the secondary cosmic ray radiation by using muon tracker telescopes made of three Multigap Resistive Plate Chambers (MRPC). The experiment is constituted by a network of MRPC telescopes mainly distributed throughout Italy, hosted in different building structures pertaining to high schools, universities and research centers. Therefore, the possibility to take into account the effects of these structures on collected data is important to carry on the large physics program of the project.
A simulation tool, based on GEANT4 by using GEMC framework, has been implemented to take into account the muons interaction with EEE telescopes and to estimate the effects of the structures surrounding the experimental apparata on data. Dedicated events generator producing realistic muon distribution, detailed geometry and microscopic behavior of MRPCs have been included to produce experimental-like data. The comparison between simulated and experimental data, and the estimation of detector resolutions in different operation conditions will be presented and discussed.

Primary authors: Prof. MANDAGLIO, Giuseppe (Department of Physics - University of Messina and INFN Sezione di Catania); FOR EEE COLLABORATION

Presenter: Prof. MANDAGLIO, Giuseppe (Department of Physics - University of Messina and INFN Sezione di Catania)

Session Classification: Simulations

Contribution ID: **24** Type: **Oral Contribution**

Study of Streamer Development in Resistive Plate Chamber

Friday, February 14, 2020 9:50 AM (20 minutes)

India-based Neutrino Observatory (INO) is an underground facility for studying different neutrino properties. Iron Calorimeter (ICAL) is one of the experiments, which will be housed in the facility for identification of neutrino mass hierarchy and measurement of neutrino mixing parameters. It will consist of a horizontal stack of 151 layers of iron plates interleaved with Resistive Plate Chambers (RPC) for tracking the muons generated out of charged-current interaction of the passing neutrinos with the iron nuclei and the whole ICAL setup will be magnetized for distinguishing between the muon charges. The requirement of the experiment demands RPC operation in avalanche regime in order to achieve excellent position resolution and long term operation for which a gas mixture of R134a, iso-Butane and sulfur hexafluoride (95.5: 4.2: 0.3) has been chosen. These gases have high Global Warming Potential and hence better be replaced with eco-friendly ones, however, without compromising the performance of the RPC and the objectives of the experiment thereof. This study has been carried out to simulate the working modes (avalanche and streamer) in RPC and compare with the experimental data in order to build a numerical test bench for exploring proposed eco-friendly gas mixtures to fulfill the required working conditions of the RPC. The simulation of the RPC dynamics has been carried out using COMSOL Multiphysics 1. It uses finite element method to calculate the time evolution of electric field, propagation of electrons and ions in the gas gap and their multiplication. The necessary electron propagation and Townsend coefficients have been calculated using MAGBOLTZ [2], while the number of primary electrons and their initial positions have been obtained with HEED [3]. The time evolution of the electron number has been simulated to study the working modes of the RPC for a given gas mixture. As a test case the streamer probability for different voltages for a mixture of R134a and iso-Butane 95:5 ratio by volume has been calculated and compared with the experimental result to examine the efficacy of the proposed simulation framework for studying the RPC dynamics.

References:

1. https://www.comsol.co.in
2. https://magboltz.web.cern.ch/magboltz
3. http://ismirnov.web.cern.ch/ismirnov/heed

Primary authors: DATTA, Jaydeep (Homi Bhabha National Institute); TRIPATHY, SRIDHAR (SAHA INSTITUTE OF NUCLEAR PHYSICS, KOLKATA); Mrs MAJUMDAR, Nayana (Saha Institute Of Nuclear Physics, HBNI, INDIA.); Mr MUKHOPADHYAY, Supratik (Saha Institute Of Nuclear Physics, HBNI, INDIA.)

Presenters: DATTA, Jaydeep (Homi Bhabha National Institute); TRIPATHY, SRIDHAR (SAHA INSTITUTE OF NUCLEAR PHYSICS, KOLKATA)

Session Classification: Simulations

Contribution ID: **25** Type: **Oral Contribution**

Characteristics and performance of the Multigap Resistive Plate Chambers of the EEE experiment

Tuesday, February 11, 2020 12:20 PM (20 minutes)

The Extreme Energy Events (EEE) experiment, dedicated to the study of secondary cosmic rays, is arguably the largest detector system in the world implemented by Multigap Resistive Plate Chambers. The EEE network consists of 60 telescopes, each made by three MRPCs, distributed over all the Italian territory and allows to reconstruct the trajectory of cosmic muons with high efficiency and optimal angular resolution.
The experiment started to take coordinated data in a pilot run in the fall of 2014. Raw data are transmitted from all EEE telescopes to the INFN-CNAF data center, where they are immediately reconstructed and stored. Our current analyses concern more than 100 billion candidate muon tracks reconstructed.
A complete overview of the experiment will be presented, focusing on the excellent performance and specific qualities of these detectors and how we study them in depth also thanks to simulations.
A distinctive feature of the EEE network is that our telescopes are housed in High Schools and managed by groups of students and teachers, who previously took care of their construction at CERN. This peculiarity is a big plus for the experiment, which combines the scientific relevance of its objectives with effective outreach activities. The unconventional location of the detectors, mainly in common classrooms of school buildings, with heterogeneous maintenance conditions and without controlled temperature and dedicated power lines, is a unique test field to verify the robustness, the low aging characteristics and the long-lasting performance of MRPC technology for particle monitoring and timing. Since the first beam test where performed in 2006 at CERN and the last telescopes have been built till a few months ago, now we are able to understand how the spatial resolution, efficiency, tracking capability and stability of the chambers behave in time. This behavior will be also compared to a detailed Monte Carlo simulation realized with CORSIKA and GEANT to implement buildings characteristics.
In the next few years, more MRPCs will be built by students at the CERN, therefore an overview will be provided of all the challenging aspects related to the technological solutions chosen for the construction, quality controls and performance tests we intend to perform.
Finally, our ongoing studies on the use of eco-friendly gases to replace the current mixture of R-134a and SF₆ will be mentioned.

Primary authors: COCCETTI, Fabrizio (Centro Fermi - Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Rome, Italy); FOR EEE COLLABORATION

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Session Classification: Large systems and Upgrades

Contribution ID: **26** Type: **Oral Contribution**

Precise investigation of gas parameters in timing RPC with laser test facility

Tuesday, February 11, 2020 10:30 AM (20 minutes)

This work is devoted on the recent work on precise investigation of gas parameters in the realistic Resistive Plate Chamber (RPC) detectors. A laser test facility is assembled in Helmholtz-Zentrum Dresden Rossendorf. UV laser pulses of 257 nm wavelength are generated and focused into the gas gap of detector prototypes to ignite primary electrons by Multi-photon Ionization process. As the volume, position and intensity of the laser focus are well defined, the volume and position of primary electrons is controlled to micro-meter scale, and number of primary electrons is also possible to be investigated. An overall accuracy in the order of micro-meter is achieved, and be validated by experiments.

RPC prototypes that works under realistic conditions are developed, tested with the laser test facility to investigate the gas parameters. A serial of interconnected experiments are operated to investigate the performance of RPC detector and the electron avalanche process, to investigate the effective Townsend coefficient and electron drift velocity. The experimental results are in agreement with the previous experiments and simulations at the field strengths of trigger RPC (around 50 kV/cm). For the effective Townsend coefficient, as the field strength increases, the measured gas parameters begins to separate with simulation values, and the value at timing RPC fields (around 100 kV/cm) is only half compared to the simulation value. The experimental results has also supported the current understanding about the relation of rate capability and electrode resistivity.

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Presenter: Dr FAN, Xingming (Helmholtz-Zentrum Dresden-Rossendorf)

Session Classification: Ageing and Gas Studies

Contribution ID: **27** Type: **Oral Contribution**

A portable, gas-tight, and compact glass-RPCs telescope for muon imaging

Friday, February 14, 2020 11:40 AM (20 minutes)

Imaging techniques that use atmospheric muons, collectively named under the neologism "muography", have seen a tremendous growth in recent times, mainly due to their diverse range of applications. The most well-known ones include but are not limited to: volcanology, archaeology, civil engineering, nuclear reactor monitoring, nuclear waste characterization, underground mapping, etc. These methods are based on the attenuation or deviation of muons to image large and/or dense objects where conventional techniques cannot work or their use becomes challenging.

In this context, we have developed a muography telescope based on "mini-gRPC" planes using the same principles as the gRPC detectors used by TOMUVOL and by the CMS and CALICE experiments, but with smaller active area (16x16 cm2). The compact size makes it an attractive choice with respect to other detectors previously employed for imaging on similar scales. An important innovation in this design is gas-tightness. This makes the detector more portable and solves the usual safety and logistic issues for gas detectors operated underground and/or inside small rooms. In this talk, we will give an overview on the detector development along with why RPC technology has been chosen for the project, spanning the numerous advantages and the drawbacks we encountered during its operation.

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Presenter: BASNET, Samip (UCLouvain - CP3)

Session Classification: Outside Particle and Astroparticle Physics

Contribution ID: **28** Type: **Oral Contribution**

Environment-friendly gas mixtures for Resistive Plate Chambers: an experimental and simulation study

Wednesday, February 12, 2020 11:00 AM (20 minutes)

Resistive Plate Chambers (RPC) have shown stable operation at the Large Hadron Collider and satisfactory efficiency for the entire Run 1 (2010–2013) and Run 2 (2015–2018) with $C_2H_2F_4$-based gas mixtures and the addition of SF_6 and i-C_4H_{10}. However, $C_2H_2F_4$ and SF_6 are greenhouse gases with a high Global Warming Potential (GWP): in particular, $C_2H_2F_4$ is already phasing out of production, due to the recent European Union (EU) regulations, and its cost is progressively increasing. In parallel, CERN has elaborated a number of strategies to reduce as much as possible the greenhouse gas emissions or, at least, optimize their use in the LHC experiments. For these reasons, finding gas mixtures with a low GWP has become extremely important.

This study is focused on the characterization of innovative gas mixtures with tetrafluoropropene $C_3H_2F_4$ (HFO1234ze), a hydrofluoroolefin with very low GWP. The lack of knowledge on fundamental parameters of $C_3H_2F_4$, e.g. its electron collision cross sections, makes implementation of this gas in simulations rather difficult. A dedicated experimental set-up with a small-size (50×50 cm^2, 2 mm thick) RPC was built in order to carry out direct measurements with several $C_3H_2F_4$-based gas mixtures and the addition of various gases to optimize the performance in terms of efficiency, streamer probability and cluster size. In parallel, simulation studies were carried out using an iterative method to unfold the electron swarm parameters of $C_3H_2F_4$ and obtain its electron collision cross sections.

Promising gas mixtures with low environmental impact will be presented, along with a systematic study of the behaviour of $C_3H_2F_4$-based gas mixtures performed by varying separately the fraction of each gas in the mixture. Preliminary results regarding the simulation of RPC efficiency with $C_3H_2F_4$-based gas mixtures will also be discussed.

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Presenter: BIANCHI, Antonio (INFN and University of Torino)

Session Classification: Ageing and Gas Studies

Contribution ID: **29** Type: **Oral Contribution**

The FAIR Phase 0 program of the CBM Time-of-Flight project

Monday, February 10, 2020 4:30 PM (20 minutes)

In order to provide particle identification (PID) of charged hadrons at the future high-rate Compressed Baryonic Matter (CBM) experiment the TOF group has developed a large-area Time-of-Flight (ToF) wall equipped with high rate capable Multi-gap Resistive Plate Chambers (MRPC). Prior to its destined operation at the Facility for Antiproton and Ion Research (FAIR) - starting in 2025 - this high-rate timing MRPC technology will be used for physics research at two scientific pillars of the FAIR Phase-0 program: the end-cap TOF upgrade of the STAR experiment at RHIC and the mTOF wall of the mCBM experiment at SIS18. At STAR, the fixed- target program of the Beam Energy Scan II (BES-II) will rely on 108 CBM MRPC detectors for forward PID at trigger rates of up to 2 kHz. At mCBM, high-performance benchmark runs of Lambda-baryon production at top SIS18 energies and CBM design interaction rates of 10 MHz will become feasible with a PID backbone consisting of 25 CBM MRPC detectors. Apart from the physics perspective, these pre-FAIR involvements will help gathering experience in operating the final CBM TOF wall comprising about 1500 MRPC detectors and 110,000 readout channels. The status of the FAIR phase 0 program will be discussed.

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Presenter: DEPPNER, Ingo (Pysikalisches Institut der Universität Heidelberg)

Session Classification: New Experiments

Contribution ID: **30** Type: **Poster Session**

Development of RPC for muon tracking in heavy ion experiment

Thursday, February 13, 2020 5:18 PM (8 minutes)

Single gap Resistive Plate Chamber (RPC) detectors are one of the options for the 3rd and 4th stations of Muon Chamber (MUCH) of the Compressed Baryonic Matter (CBM) experiment at future FAIR facility. From simulation it has been predicted that there will be a particle rate of 15 kHz/cm2 and 5.6 kHz/cm2 respectively on the 3rd and 4th stations for central Au-Au collisions at 8 AGeV. To handle such a rate, it is necessary to use plates with low bulk resistivity. It is also necessary to operate the detector at a lower gas gain such that the dead time fraction is lower.
For this study moderately resistive and commercially available bakelite plates has been used to build RPC module. The chamber has been tested with cosmic ray using 100% Tetrafluoroethane and premixed Argon/CO2 gas in 70/30 ratio. Standard NIM electronics has been used for this study. Sharp breakdown in the I-V characteristics has been obtained with Ar/CO2 at a lower potential difference compared to that with the Tetrafluoroethane. The efficiency and count rate are also compared for these two set of gases. The detailed method of measurement and the first test results will be presented.

Primary authors: SEN, ARINDAM (BOSE INSTITUTE); CHATTERJEE, SAYAK (BOSE INSTITUTE); ROY, Shreya (Bose Institute); BISWAS, Saikat (Bose Institute); DAS, Supriya (Bose Institute)

Presenter: SEN, ARINDAM (BOSE INSTITUTE)

Session Classification: Poster Session

Contribution ID: **31** Type: **Oral Contribution**

Precise Tracking of Cosmic Muons Using Time-over-Threshold Property of NINO ASICs

Thursday, February 13, 2020 2:00 PM (20 minutes)

Muon Scattering Tomography (MST) requires tracking detectors with fairly good spatial resolution in order to identify the material contents of the target object from its reconstructed image. A prototype MST set up is being fabricated at SINP using RPC as the muon trackers. Six Bakelite RPCs have been fabricated with pick-up panels equipped with copper strips of width 1 cm to populate the setup. NINO ASIC 1 has been opted for the front-end pre-amplification and discrimination of the RPC signal. A sample detector has been placed in a vertical cosmic-ray hodoscope of three plastic scintillators with an overlap that matches the strip width of the pick-up panel. The signal waveforms from the triggered strip along with three strips from both sides have been saved for analysis using a Tektronix MSO 4104-b oscilloscope. From the waveform, the widths of signals are measured. In the avalanche mode, the mean width of the signals obtained from the central strip was found to be 25 ns, whereas in streamer mode, it was found to be 60ns. The same technique is to be used for a pick-up panel with thinner strips (width ~ 1mm) in coincidence with more precise tracking detectors like GEM (resolution ~ 200 um). To take care of increment in the number of strips an Altera MAX-10 based developer board is being used instead of the oscilloscope. Exploiting the time-over-threshold property of NINO, the charge profile of the signal on the pick-up strips is obtained. The spatial resolution of the RPC will be estimated by comparing the center of the charge profile to the estimated hit as obtained from the track reconstructed using the GEM detectors.

Reference:
F. Anghinolfi, et.al, Nuclear Instruments and Methods in Physics Research A 533 (2004) 183–187.

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Presenters: TRIPATHY, SRIDHAR (SAHA INSTITUTE OF NUCLEAR PHYSICS, KOLKATA); DATTA, Jaydeep (Homi Bhabha National Institute)

Session Classification: Electronics and DAQ

Contribution ID: **32** Type: **Poster Session**

Determination of the sensitivity of an ATLAS RPC to gamma and neutrons with Geant4

Thursday, February 13, 2020 5:02 PM (8 minutes)

Resistive Plate Chambers (RPCs) are sensitive to the passage of charged particles and represent a fast and cost-effective solution widely adopted in experiments at high-energy colliders when instrumenting large areas detectors.

In a high-radiation environment such as the ATLAS experimental area at the Large Hadron Collider (LHC) at CERN, where gammas and neutrons are copiously produced, even a small sensitivity to neutral radiation can have an impact on the detector measurements and performance.

In RPCs, the sensitivity to neutral radiation is caused by the extraction of secondary charged particles by the neutral primary radiation from the materials composing the detector, which can subsequently enter the active part of the chamber and ionize the gas. The presence of a signal is inferred in this work from the amount of ionization energy deposition in the active part of the gas gap.

The results presented are compatible with the available measurements and, compared with previous calculations, predict a smaller sensitivity to neutrons with energies below 1 MeV, which represent a large fraction of the radiation in the LHC environment.

The results of the study are published in: Nuclear Inst. and Methods in Physics Research, A (2019) 163122, https://doi.org/10.1016/j.nima.2019.163122

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Presenter: NEGRINI, Matteo (BO)

Session Classification: Poster Session

Contribution ID: **33** Type: **Oral Contribution**

Uniformity study of large size glass RPC detector using an alternate front-end electronics for INO-ICAL Experiment

Thursday, February 13, 2020 11:20 AM (20 minutes)

The proposed Iron Calorimeter (ICAL) detector will use approximately 29,000 glass-based Resistive Plate Chambers (RPCs) as sensitive detector elements. A huge 3.7 million electronic channels would be required to read out the full detector. For such a large scale experiment, an optional multichannel front-end ASIC designated as HARDROC has been tested and commissioned with a prototype RPC detector. HARDROC can amplify, shape and discriminate up to 64 signals simultaneously very efficiently. The pre-amplifier gain, DAC threshold and the window size of the data acquisition are optimized according to the RPC raw signal. RPC performance has been measured with cosmic muons with its count rate, efficiency, and cluster size. The present study involves the homogeneity response of the RPC plane by simultaneously reading all the strips at once. Finally, the number of consecutive strips fired at the same time by the passage of a charged particle as a function of electronegative SF6 gas is presented.

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Presenter: Dr NAIMUDDIN, Md. (University of Delhi)

Session Classification: Electronics and DAQ

Contribution ID: **34** Type: **Oral Contribution**

Outgassing and Leak Test Studies in INO RPC Detectors

Wednesday, February 12, 2020 11:20 AM (20 minutes)

Resistive Plate Chambers are the gaseous detectors having gas as a sensitive medium for the detection of charged particles. Glass based resistive plate chambers of size 2m X 2m operated in avalanche mode will be used as an active detector element at INO-ICAL experiment. To fulfil the physics goal, about 29,000 RPCs will be used for 20 long years. A large amount of gas mixture is to be circulated inside the RPC during active operation of the ICAL detector, so a proper leak test will help minimize leakage of gas which will reduce operating costs and atmospheric air pollution. A quantitative leak test is performed for RPC by monitoring the absolute pressures, both outside and inside of the RPC, along with the temperature to estimate the leakage rate. The quality and purity of the gas also play a vital role in the stable operation of RPC detectors over the projected lifetime of the experiment. The presence of impurities in a gas mixture contribute toward the degradation of detector performance. The various materials like glues, buttons spacers, frames, etc. used in the construction of the chamber may cause outgassing and contaminate the input gas mixture as a result. We have performed the very first study to estimate the outgassing due to various materials used in the construction of INO RPCs. The present study includes the results obtained from gas chromatography showing the generation of impurities and dangerous radicals produced due to outgassing when RPC was operated in the cosmic stand. The study also includes a test of purity and effectiveness of the gas mixing system.

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Presenter: Dr KUMAR, Ashok (University of Delhi, India)

Session Classification: Ageing and Gas Studies

Contribution ID: **35** Type: **Oral Contribution**

Numerical study of electric field due to space charge in Resistive Plate Chamber

Friday, February 14, 2020 10:10 AM (20 minutes)

Resistive plate chamber (RPC) is one of the state-of-the-art particle detection technology for the HEP experiments. The basic operating mechanism of an RPC involves ionization of gas due to the passage of charged particles, electron transport , avalanche, and subsequent electromagnetic induction on readout strips due to the movement of the electrons and ions. Especially during streamer mode of operation, the electric field applied to the RPC can get significantly modified due to the presence of large number of electrons and ions.
In this study, we have worked on dominant issues related to the estimation of electric field due to the space charge arising out of the presence of electrons, ions within an RPC. For this purpose we have considered two approaches: representation of the space charge cloud as (a) a collection of point charges, and (b) as a collection of line charges. Due to the parallel plate geometry of RPC, the number of reflections or images of these charged entities is infinite. For representation (a), the convergence of the electric field at any point due to image charges has been studied by evaluating the electric field only for several possible number of image charges. For (b), we have calculated the electric field with standard electric field formula for line charge distribution, and their images. The same has also been estimated with the help of the neBEM1 field solver. The results from these different methods have been compared with results available in the literature[2,3,4].
Reference:
1. http://nebem.web.cern.ch/nebem/
2. C. Lippmann et al., Nuclear Instruments and Methods in Physics Research A, 508 (2003) 19–22.
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4. T. Heubrandtner et al., Nuclear Instruments and Methods in Physics Research A, 489 (2002) 439–443.

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Session Classification: Simulations

Contribution ID: **36** Type: **Oral Contribution**

Towards high counting rate RPC-based neutron detectors: current state and perspectives

Tuesday, February 11, 2020 4:10 PM (20 minutes)

At LIP-Coimbra and in collaboration with the TUM-FRMII and ESS detector groups, we have been refining the concept of a novel type of position-sensitive neutron detector (PSND) based on resistive plate chambers with ¹⁰B₄C layers (¹⁰B-RPCs) as neutron converters. Our studies performed in the frame of SINE2020 (EU project 654000) have successfully proven the feasibility of this detection technology. We have demonstrated thermal neutron detection efficiency above 50% by using ¹⁰B-RPCs in a multilayer architecture and a spatial resolution better than 250 μm FWHM. The RPCs fast timing should also allow measurements of the neutron time-of-flight (TOF) with nanosecond resolution. RPCs also may offer very attractive practical properties such as low price per unit area, high modularity of the design and robustness. These manifold advantages render RPC-based neutron detectors a promising technology.
However, there are challenges which still have to be addressed such as, e.g. the counting rate capability limitation of these devices and which is narrowing the widespread use of this technology. Further decreasing the sensitivity of ¹⁰B-RPCs to gamma rays is also beneficial for applications requiring high signal-to-noise ratio.
Here, we present experimental results on the ¹⁰B-RPCs counting rate measurements when exposed to a thermal neutron beam. Several ¹⁰B-RPCs prototypes with anode plates made from float glass, low resistivity glass and low resistivity ceramics were built. The prototypes have been tested at V17 monochromatic neutron beamline at HZB-Berlin. For the RPC with the anode plate made from low resistivity glass, the counting rate did not show any non-linearity at the maximum flux available at this neutron beamline, reaching a value > 30 kHz/cm².
We also report results on the sensitivity of ¹⁰B-RPCs to gamma rays, measured using the angular correlations between the two annihilation photons of a ²²Na radioactive source, as well as a simulation study targeting the gamma sensitivity minimization, performed with GEANT4. The experimental results demonstrate that gamma sensitivity should be less than 10⁻⁶ and 10⁻⁵ for 0.511 and 1.27 MeV, respectively, for polarization voltages within the plateau for thermal neutrons.

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Presenter: Dr MARGATO, Luís (LIP-Coimbra, Departamento de Física, Universidade de Coimbra)

Session Classification: New Ideas

Contribution ID: **37** Type: **Oral Contribution**

Aging study on Resistive Plate Chambers of the CMS muon detector for HL-LHC

Wednesday, February 12, 2020 11:40 AM (20 minutes)

In the next years, during the High Luminosity LHC (HL-LHC) program, the instantaneous luminosity will increase up to 5x10^34 cm-2 s-1 which means factor five more than the nominal LHC luminosity. During this period the present CMS Resistive Plate Chambers (RPC) system will be subjected to high background rates and operating conditions much harder with respect those for which the detectors have been designed. Those conditions could affect the detector properties and induce aging effects. To study if the present RPC detectors can survive the hard background conditions during the HL-LHC running period, a dedicated longevity test is set up at the CERN Gamma Irradiation Facility (GIF++), where few spare RPCs are exposed to a high gamma radiation for a long term period to mimic the HL-LHC operational conditions. During the longevity test the main detector parameters are monitored as a function of the integrated charge. Preliminary results of the study after having collected a sufficient amount of the expected integrated charge will be presented.

Primary author: COLLABORATION, CMS

Presenter: ALY, Reham (BA)

Session Classification: Ageing and Gas Studies

Contribution ID: **38** Type: **Oral Contribution**

Towards a two-dimensional readout of the improved CMS Resistive Plate Chamber with a new Front End electronics.

Thursday, February 13, 2020 12:20 PM (20 minutes)

As part of the CMS Phase-II program, new Resistive Plate Chambers (RPC) will be installed in the forward region. High background conditions are expected in this region during the high-luminosity phase of the Large Hadron Collider (HL-LHC), therefore an improved RPC design has been proposed with a new front-end electronics to sustain a higher rate capability and better time resolution. A mixed silicon-germanium technology is used in the front-end electronics resulting in very low achievable thresholds in the order of several fC. Crucial in the design of the improved RPC is the capability of a two-dimensional readout in order to improve the spatial resolution, mainly motivated by trigger requirements. In this work the first performance results towards this two-dimensional readout are presented, based on data taken on a real-size prototype chamber with two embedded orthogonal readout strips. Furthermore, dedicated studies of the muon cluster size as a function of the graphite resistivity are discussed.

Primary author: COLLABORATION, CMS

Presenter: MEOLA, Sabino (NA)

Session Classification: Electronics and DAQ

Contribution ID: **40** Type: **Poster Session**

CMS RPC background studies and measurements

Thursday, February 13, 2020 4:54 PM (8 minutes)

The RPC (Resistive Plate Chamber) system at CMS detector operates successfully during Run-1 and Run-2 of the LHC program. During 2018 data taking, the instantaneous luminosity reached values of about of 2x10^34 cm^{-2}s-1. During the planned HL-LHC period the instantaneous luminosity is expected to reach up to 5x10^34 $cm^{-2}s^{-1}$ in the base scenario, and up to 7.5x10^34 $cm^{-2}s^{-1}$ in the ultimate scenario, leading to very high expected radiation background. The exposure to such a high radiation levels can affect the system performance leading to a faster ageing and reduced detector performance. From the other side, the expected particle fluxes and fluence are directly related to the detector rate capability requiring strong radiation hardness of the readout electronics. It may lead to a drastically increase of the trigger rates. Different approaches have been used to study and analyze the RPC rates during data taking periods. The experimentally measured rates have been extrapolated to higher luminosity scenarios. In the present document we are reporting the RPC rates measured in 2018 and the expectations for the HL-LHC period. A comparison to the MC expectation is included as well.

Primary author: COLLABORATION, CMS

Presenter: HADJIISKA, Roumyana Mileva (University of Sofia)

Session Classification: Poster Session

Contribution ID: **41** Type: **Oral Contribution**

Improved RPC for CMS muon system upgrade for HL-LHC

Wednesday, February 12, 2020 9:50 AM (20 minutes)

During the High Luminosity LHC (HL-LHC), the instantaneous luminosity would be increased to $5 \times 10^{34} cm^{-2} s^{-1}$ delivering integrated luminosity of 3000 fb^{-1} over 10 years of operation starting from 2026. In view of HL-LHC, CMS muon system will be upgraded to sustain efficient muon triggering and reconstruction performance. Resistive Plate Chambers (RPC) are served as dedicated detectors for muon triggering due to their excellent timing resolution, hence RPC's will be extended upto pseudo rapidity of 2.4. Before long shutdown 3 (LS3), RE3/1 and RE4/1 stations of endcap will be equipped with a new improved Resistive Plate Chambers (iRPCs) having different design and geometry wrt presnt RPC system. The iRPC geometry configuration allows to improve the rate capability and hence to survive the harsh background condition during HL-LHC. Also, new electronics equipped with excellent timing precision measurement (<150ps) are developed to read out the RPC detectors from both side of the strips to allow good spatial resolution along them. The performance of iRPC has been studied with gamma radiation at Gamma Irradiation Facility (GIF++) at CERN. The longevity study is ongoing which must certify the iRPC for the HL-LHC running period. The main detectors parameters (currents, rate, resistivity) are regularly monitored as a function of the integrated charge. The preliminary result of the detetcor performace will be presented.

Primary author: COLLABORATION, CMS

Presenter: KUMARI, Priyanka (Ph.D)

Session Classification: Large systems and Upgrades

Contribution ID: **42** Type: **Oral Contribution**

Experiences from the RPC data taking during the CMS Run-2

Monday, February 10, 2020 12:10 PM (20 minutes)

The CMS experiment collected 160fb^-1 of proton-proton collision data at sqrt(s)=13TeV during the Run-2 data taking period. Successful data taking at increasing instantaneous luminosities with the evolving detector configuration was a big achievement of the collaboration. The CMS RPC system provided redundant information for the robust muon triggering, reconstruction and identification. To ensure the stable data taking, the CMS RPC collaboration has performed detector operation, calibration and performance studies. Various software and related tools are developed and maintained accordingly. In this presentation, the overall performance of the CMS RPC system and experiences of the data taking during the Run-2 period are summarized.

Primary author: COLLABORATION, CMS

Presenter: SHAH, Mehar Ali

Session Classification: Large systems and Upgrades

Contribution ID: **44** Type: **Oral Contribution**

Front End electronics for CMS iRPC detectors

Thursday, February 13, 2020 2:20 PM (20 minutes)

A new generation of RPC chambers capable to withstand high particle fluxes (up to 2000 Hz/cm2) and instrumented with a precise timing readout electronics is proposed to equip two of the four high eta stations of the CMS muon system. Doublet RPC detectors each made of two 1.4 mm HPL electrodes and separated by a gas gap of the same thickness are proposed. The new scheme reduces the amount of the avalanche charge produced by the passage of a charged particle through the detector. This improves the RPC rate capability by reducing the needed time to absorb this charge. To keep the RPC efficiency high a sensitive, low-noise and high time resolution Front-End Electronics is needed to cope with the low charge signal. An ASICS called PETIROC that has all these characteristics is proposed to read out the new chambers. Thin (0.6 mm) Printed Circuit Board (PCB), 160 cm long, equipped with pickup strips of 0.75 cm pitch will be inserted between the two RPC detectors. The strips will be read out from both ends, using the arrival time difference to determine the Y position. The absolute time measurement will be also used with the aim to reduce the data ambiguity due to the expected high pileup at the future HL-LHC. The results from RPC chamber equipped with the new readout system and exposed to muon beams in high irradiation environment at GIF++ at CERN will be presented. An excellent efficiency at high fluxes is measured. The excellent time resolution of the new system leads to a position resolution better than 2 cm. Finally, an absolute time resolution of the new RPC chamber equipped with the new electronics of better than 400 ps was measured.

Primary author: COLLABORATION, CMS

Presenter: SHCHABLO, Konstantin

Session Classification: Electronics and DAQ

Contribution ID: **45** Type: **Oral Contribution**

A new approach for CMS RPC current monitoring using Machine Learning techniques

Thursday, February 13, 2020 10:10 AM (20 minutes)

Monitoring the RPC current stability proves to be a tedious work in CMS experiment where one needs to deals with more than a thousand individual high voltage (HV) channels. The current depends from several parameters (applied voltage, luminosity, environmental parameters, etc.) and sometime it's not obvious if it changes due to variation of the external parameters or if it's due to a chamber malfunction.

We present a new Machine Learning (ML) approach to monitor and spot possible HV problems. A Generalized Linear Regression algorithm is trained to recognize the behavior of the HV current of a given chamber. Then the algorithm is used to predict the HV current at given data taking conditions and environmental parameters. The divergence between the predicted and the measured HV current is an indication for a problem.

The results for several chambers would be shown. The algorithm is trained and tested on 2017 and 2018 data. The software development is on "proof of concepts"level and the results are encouraging.

Primary author: COLLABORATION, CMS

Presenter: PETKOV, Peicho Stoev

Session Classification: New software approaches to data analysis

Contribution ID: **46** Type: **Poster Session**

Development of high resolution TDC for RPC new link system

Thursday, February 13, 2020 5:42 PM (8 minutes)

In the CMS experiment, RPCs, which have an excellent intrinsic resolution within a few nanoseconds for double-gap chambers, are mainly used for accurate timing and fast triggering. This particularly allows for the identification of corresponding bunch crosses. However, since the data-taking chain and DAQ system record the hit time within 25 ns, the intrinsic time resolution of RPCs is thus not fully utilized. One of the main goals in upgrading the link system is to improve the timing resolution of the Muon hits at the level of RPC intrinsic resolution. To serve this goal, a 96-channel Time-to-Digital Converter (TDC) was implemented into a Xilinx Field-Programmable Gate Array (FPGA). The TDC was designed based on the combination of the logic elements with the uniform and solid digital Input Serializer and Deserializer (ISERDES) primitives inside the FPGA. Each TDC channel comprised of 16 bins where each bin had a time scale of one sixteenth of the 25 ns. The experimental results showed that there existed a 1.56 ns resolution for the implemented TDC channels, and that the non-linearity errors within the bins were well below 0.006 LSB and 0.01 LSB for the differential non-linearity and integral non-linearity, respectively.

Primary author: COLLABORATION, CMS

Presenter: BOGHRATI, Behzad (Institute for research in Fundamental Science (IPM))

Session Classification: Poster Session

Contribution ID: **47** Type: **Oral Contribution**

The SHiP timing detector based on MRPC

Monday, February 10, 2020 4:50 PM (20 minutes)

SHiP (Search for Hidden Particles) is a new general-purpose experiment 1 to be installed in a beam dump facility at the SPS at CERN to search for hidden particles as predicted by a very large number of recently elaborated models of Hidden Sectors which are capable of accommodating dark matter, neutrino oscillations, and the origin of the full baryon asymmetry in the Universe.

The SHiP detector consists of two complementary apparatuses, the scattering and neutrino detector (SND) and the hidden sector (HS) decay spectrometer. The HS decay spectrometer aims at measuring the visible decays of HS particles by reconstructing their decay vertices in a 50 m long decay volume of a pyramidal frustum shape. The decay volume is followed by a large spectrometer with a rectangular acceptance of 5 m width and 10 m height. The spectrometer is composed by a tracker station, designed to accurately reconstruct the decay vertex, the mass, and the impact parameter, a timing detector, to reduce the muon combinatorial background and identify the particle decays products, an electromagnetic calorimeter followed by a muon detector in order to provide particle identification which is essential in discriminating between the very wide range of HS models.

The timing detector will cover an area of 5 m x 10 m $= 50$ m^2 providing ~ 100 ps timing accuracy together with high efficiency. One possible technology for the timing detector is the timing multigap RPC. A first real size prototype of around 2 m ^{2} has beam built and tested in beam showing a timing accuracy $<$ 60 ps and an efficiency $> 98\%$ over the entire active area. In this work, the design and result of this prototype will be presented.

\hfill

1 A facility to Search for Hidden Particles (SHiP) at the CERN SPS, Sergey Alekhin et al 2016 Rep. Prog. Phys. 79 124201

Primary authors: BLANCO CASTRO, Alberto (LIP-Coimbra); FRANCO, Celso (LIP, Laboratório de Instrumentação e Física Experimental de Partículas); LOUREIRO, Custodio (LIBPhys, Departamento de Física, Universidade de Coimbra); CLEMENCIO, Filomena (Escola Superior de Saúde do Politécnico do Porto); SOARES, Guilherme (LIP, Laboratório de Instrumentação e Física Experimental de Partículas); SARAIVA, João (LIP Coimbra); LOPES, Luis (Lip-Coimbra); LEONARDO, Nuno (Purdue); FONTE, Paulo (LIP-Laboratório de Instrumentação e Física Experimental de Partículas)

Presenter: BLANCO CASTRO, Alberto (LIP-Coimbra)

Session Classification: New Experiments

Contribution ID: **48** Type: **Oral Contribution**

Studies of gas gaps current density in the ATLAS RPC detector during 2018 data taking at Large Hadron Collider

Monday, February 10, 2020 2:40 PM (20 minutes)

The ATLAS Resistive Plate Chamber (RPC) detector is a tracking trigger, used to primarily select high momentum muons in the ATLAS barrel region (|\eta|<1.05) at the 40 MHz collision rate, and to provide muons azimuthal coordinates. The RPC system consists of about 3700 gas volumes covering a sensitive surface of about 4000 m^2. It is arranged in three concentric double layers distributed on a radial distance of about 5m and operating at approximately 0.5 Tesla toroidal magnetic field. RPCs provide 6 points along the muon track with a space-time resolution of about 1cm^2 x 1ns. This work studies systematically gas gaps current as a function of the electric field applied on the gas, and environmental parameters both without/with the LHC beam induced background and up to an instantaneous luminosity L_inst =2x10^34 cm^-2 s^-1 (twice larger the design LHC luminosity). These measurements have been used to study the RPC working condition and to extrapolate the detector response to High Luminosity LHC regime with L_inst=7.5x10^34 cm^-2 s^-1.

Primary author: KRASNOPEVTSEV, Dimitrii (ATLAS Collaboration)

Presenter: KRASNOPEVTSEV, Dimitrii (ATLAS Collaboration)

Session Classification: Large systems and Upgrades

Contribution ID: **49** Type: **Oral Contribution**

Performance of the ATLAS RPC detector and L1 Muon Barrel trigger at $\sqrt{s} = 13$ TeV

Monday, February 10, 2020 2:20 PM (20 minutes)

The ATLAS experiment at the Large Hadron Collider utilises a trigger system consisting of a first level hardware trigger and a higher level software trigger. The Level-1 muon trigger system selects muon candidates with six transverse momentum thresholds and associate them with a correct LHC bunch crossing. The Level-1 Muon Barrel Trigger uses Resistive Plate Chambers (RPC) detectors to generate trigger signals for selecting muon candidates within the pseudorapidity range of up to 1.05. The RPC detectors are arranged in three concentric double layers and consist of 3700 gas volumes, with a total surface of more than 4000 square meters, that operate in a toroidal magnetic field. This contribution will discuss the performance of the RPC detector system and of the Level-1 Muon Barrel trigger during the 2018 data taking period. Measurements of the RPC detector response and time resolution, obtained using muon candidates produced in LHC collisions, will be presented. Trigger performance and efficiency measurements that are obtained using Z boson decays to a muon pair will be also discussed. Finally, studies of the RPC detector response at different high voltage and threshold settings will be presented, in the context of expected detector response after the High Luminosity LHC upgrades.

Primary author: LI, Heng (ATLAS Collaboration)

Presenter: LI, Heng (ATLAS Collaboration)

Session Classification: Large systems and Upgrades

Contribution ID: **50** Type: **Oral Contribution**

The ATLAS RPC system upgrade for the High Luminosity LHC

Wednesday, February 12, 2020 10:10 AM (20 minutes)

The present RPC trigger system in the ATLAS muon barrel was designed according to a reference luminosity of 10^34 cm-2 s-1 with a safety factor of 5, with respect to the simulated background rates, corresponding to about 300 fb-1 integrated luminosity. HL-LHC will reach a 7.5 times higher luminosity, and correspondingly higher rate, an expected integrated luminosity of 5000 fb-1 and a total duration extended until at least 2040, largely increasing the detector performance and longevity required.
Moreover, the present muon barrel trigger acceptance is just above 70%, due to the presence of the barrel toroid support structures.

The ATLAS muon Collaboration approved a major RPC upgrade plan, involving both detector and trigger-readout electronics, to guarantee the performance required by the physics program for the 20 years scheduled. This plan pivots on installing a layer of 272 new generation RPCs in the inner barrel (BI), to increase the redundancy, the selectivity, and provide almost full acceptance. The first 10% of the system, corresponding to the edges of the inner barrel even sectors (BIS78) will be installed in 2020-2021 and is a pilot of the phase-2 project. To match the performance requirements, the new RPCs will have a different structure, materials and a high performance front-end electronics. The new BI chambers and readout electronics, will substantially increase the redundancy and flexibility of the trigger algorithm, increasing its selectivity and efficiency and at the same time lowering the performance demand on the legacy RPCs, extending thus their longevity to match the HL-LHC target.

We will illustrate the performance of the new detectors and trigger system, as well as the impact on the ATLAS physics performance.

Presenter: SUN, Yongjie (Dr.)

Session Classification: Large systems and Upgrades

Contribution ID: **51** Type: **Oral Contribution**

The BIS78 Resistive Plate Chambers upgrade of the ATLAS Muon Spectrometer for the LHC Run-3

Monday, February 10, 2020 2:00 PM (20 minutes)

Resistive Plate Chambers are used in the ATLAS experiment and provide the muon trigger and two coordinate measurements in the barrel region |n|<1.05
In preparation for the coming years of LHC running at higher luminosity, besides the New Small Wheel project which is expected to complement the ATLAS Muon spectrometer in the end-cap regions, a smaller size project, known as BIS78, is being developed aiming at the installation during the LHC Long Shutdown 2 (2019-2021).

The BIS78 project will reinforce the fake rejection and the selectivity of the muon trigger in the transition region between the ATLAS barrel and the endcaps (1<|eta|<1.3) by adding 32 RPC triplets along z on the edges of the inner barrel even sectors (BIS7 and BIS8) as this region is characterized by high rate due to secondary charged tracks generated by beam halo protons and a lack of detector instrumentation.

Due to the narrow available space, the project foresees to replace the existing MDTs in this area with integrated muon stations formed by small diameter tubes MDT (sMDT) and a new generation of RPC chamber, capable of withstanding the higher rates and provide a robust standalone muon confirmation.

These new RPCs are based on novel design of the gas volume with thinner gas gap (1mm vs 2mm of the legacy RPCs), thinner resistive electrodes, a lower operating voltage and new high gain front-end electronics.

Besides the use in Run-3 and onwards, this project is also of particular relevance as a pilot test for the High Luminosity upgrade when an additional full layer of new RPC triplets is expected to complement the full barrel region in the innermost plane.

The state of art of the project will be presented, the production and tests. Details on the detector infrastructure and services along with a roadmap towards the final installation and commissioning during the Long Shutdown 2 (2019-2020) are also discussed.

Primary author: MASSA, Lorenzo (ATLAS Collaboration)

Presenter: MASSA, Lorenzo (ATLAS Collaboration)

Session Classification: Large systems and Upgrades

Contribution ID: **52** Type: **Oral Contribution**

Design and construction of the mechanical structure for thin-gap RPC triplets for the upgrade of the ATLAS muon spectrometer

Wednesday, February 12, 2020 9:10 AM (20 minutes)

The advent of thin-gap RPCs with 1 mm gas gaps instead of 2 mm in the present RPCs opened the possibility to instrument the inner barrel layer of the ATLAS muon spectrometer where there is very limited amount of space in radial direction from the beam line. The environment is particularly dense in the barrel end-cap transition region. A compact mechanical structure coping with the expected thickness variations of the assembled RPCs is needed to fit into the limited available space. At the same time the mechanical structure must be sufficiently rigid to keep the deformations of the RPC packages within the allowed envelopes. The tight space constraint makes it impossible to achieve the required rigidity with thick paper honeycomb plates as used in the present ATLAS RPCs. For the phase I upgrade of the barrel end-cap transition region of the ATLAS muon spectrometer three 1 mm gap RPCs are put into an aluminium frame. In this frame the RPC triplet is compressed with pre-bent 2~mm thick aluminium plates. The rigidity of the frame is achieved by stiffening rods connecting the lateral structure of the frame. The same concept can be used for the phase II upgrade of the inner layer of the muon spectrometer.

Primary author: KORTNER , Oliver (ATLAS Collaboration)

Presenter: KORTNER , Oliver (ATLAS Collaboration)

Session Classification: Large systems and Upgrades

Contribution ID: **53** Type: **Oral Contribution**

Performance of the BIS78 RPC detectors: a new concept of electronics and detector integration for high-rate and fast timing large size RPCs

Thursday, February 13, 2020 12:00 PM (20 minutes)

The reduction of the average charge per count in the gas along with the capability to discriminate very small avalanche signals, can allow an efficient and long-term Resistive Plate Chamber detector operation, in high radiation background environment. This goal has been reached during the R&D program of the BIS78 ATLAS upgrade project, through the deep integration of a fast (100 ps peaking time) and sensitive (as small as 100 μV threshold) Front-End electronics (FE) with a very large size detector structure. This innovative RPC integration concept pivots on a newly conceived faraday cage, embedding the readout strips and the FE, tightly wrapped around a 1 mm gas gap RPC with 1.2 mm thick electrodes, as a fully independent singlet structure.
We studied the performance of BIS78 production triplet chambers, made of 3 independent singlets of 2 m2, each providing a 2D+time information, showing a minimum threshold achievable of 2pC of average charge per count produced inside the gas gap.
We show that these chambers grant a record combined performance of better than 95% single gap efficiency, time resolution of 350 ps and ~10 kHz/cm^2 rate capability.

Primary author: PIZZIMENTO, Luca (ATLAS Collaboration)

Presenter: PIZZIMENTO, Luca (ATLAS Collaboration)

Session Classification: Electronics and DAQ

Contribution ID: **54** Type: **Oral Contribution**

Linearity and rate capability measurements of RPC with semi-insulating crystalline electrodes operating in avalanche mode

Tuesday, February 11, 2020 3:50 PM (20 minutes)

The intrinsic rate capability and the ageing properties of the Resistive Plate Chambers are closely related to the electrodes material and to the front-end electronics threshold. Thanks to the development of a low noise pre-amplifier, the intrinsic rate capability of High Pressure Laminate (bakelite) RPC has been improved up to $\sim 10\ kHz/cm^2$, nevertheless the effective rate capability is significantly limited by the electrodes ageing. To further improve the effective rate capability new materials are investigated.
A Resistive Plate Chamber with crystalline semi-insulating Gallium Arsenide electrodes has been characterized with high energy electrons beam at the Beam Test Facility (INFN National Laboratory of Frascati, Italy). The response of the Resistive Plate Chamber to multiple bunched electrons was measured operating the detector in avalanche mode. The linearity limit it is expected to increase up to $\sim\ 8 \times 10^5\ particles/m^2$. The prompt charge and the time resolution have been studied as a function of the beam intensity up to $\sim 22 \times 10^6\ particles/m^2$.
The intrinsic rate capability has been also measured operating the detector in a uniform gamma radiation field.

Primary authors: ROCCHI, Alessandro (ROMA2); CARDARELLI, Roberto (ROMA2); LIBERTI, Barbara (ROMA2)

Presenter: ROCCHI, Alessandro (ROMA2)

Session Classification: New Ideas

Contribution ID: **55** Type: **Oral Contribution**

Characterization of new eco friendly gas mixtures for RPCs mainly based on HFO

Thursday, February 13, 2020 3:30 PM (20 minutes)

Present RPC Standard Mixture $C_2H_2F_4/C_4H_10/SF6$=94,7/5/0.3 has an high Global Warming Potential which requires searching for more eco friendly gases. In this work we present results of several tests performed with different gas mixture having HFO as the main component. The RPC performance in terms of efficiency, charge and time resolution will be presented. We tried also to interpret the results obtained in terms of the physical and chemical properties of each component.

Primary author: Mrs PROTO, Giorgia

Presenter: Mrs PROTO, Giorgia

Session Classification: Ageing and Gas Studies

Contribution ID: **56** Type: **Poster Session**

CMS RPC activities during Long Shutdown 2

Thursday, February 13, 2020 5:34 PM (8 minutes)

The second LHC long shutdown period (LS2) is an important opportunity for CMS Resistive Plate Chambers (RPC) to realize their consolidation and upgrade projects. The consolidation includes detector maintenance in terms of gas tightness, HV, LV and slow control operation. All services for the RPC Phase-II upgrade, namely RE3/1 and RE4/1, were anticipated for installation to LS2. The upgrade of the gas system comprises big pipework from the service through the experimental cavern and up to the CMS detector as well as significant modification of some of the existing gas racks. The cooling system for the RE4/1 detector is branched off from the existing YE3 mini manifolds while the RE3/1 chambers will be connected in series with the existing RE3 cooling loops. Thousands of kilometres of HV, LV cables and optical fibres are to be installed for servicing the new detectors and reading their signals. For optical fibres it is foreseen to carry out quality control tests before and after installation (in situ) using an optical time-domain reflectometer (ODTR). The hardware including racks, crates, power distribution boxes, service and communication lines for the upgrade power system should be prepared during LS2. HV and LV power board upgrade is planned for LS2 in view of replacing already obsolete or to-become-obsolete components and be ready for a post-LS2 production.

Primary author: COLLABORATION, CMS

Presenter: SHAH, Mehar Ali

Session Classification: Poster Session

Contribution ID: **57** Type: **Oral Contribution**

CMS RPC upgrade phase-II of new Link system

Thursday, February 13, 2020 11:40 AM (20 minutes)

The High-Luminosity Large Hadron Collider (HL-LHC) increases the rate of luminosity in proportion to the rate of the collisions occurring instantaneously. The HL-LHC produces more data and reveals the rare physical events for the purpose of examination. These features of the HL-LHC sets the high-speed transfer of the fast-incoming data to the next layer. The development of the FPGA technology has given support to high-speed data transfer systems. The significance of using high-speed serial transceivers is that these transceivers help exchange a large amount of data with no need to transmit the clock signal. Therefore, the process of clock recovery on the receiver side can be considered as an advantage of high-speed serial transceivers. The receiver clock data recovery circuits inside the gigabit data transceiver units recover both the clock and the data from the incoming data stream. The starting points of detecting the boundary of each bit from the incoming data stream and converting the serial streams into the parallel data have a significant impact on the phase of the recovered clock. Using the recovered clock and compensating for the phase difference allow us to have a synchronous clock and achieve fixed latency in the data taking system. In this work, the proposed architecture provides fixed and deterministic latency in each power-up by distributing the synchronous clock in the new link system for CMS RPCs and compensating for the phase difference between the receiver and the transmitter.

Primary author: COLLABORATION, CMS

Presenter: BOGHRATI, Behzad (Institute for research in Fundamental Science (IPM))

Session Classification: Electronics and DAQ

Contribution ID: **58** Type: **Oral Contribution**

RPC system in the CMS Level-1 Muon Trigger

Tuesday, February 11, 2020 2:40 PM (20 minutes)

The CMS experiment implements a two-level triggering system composed of Level-1, instrumented by custom-design hardware boards, and a software High Level Trigger. To cope with the more challenging luminosity conditions, a new Level-1 architecture has been deployed during run II. This new architecture exploits in a better way the redundancy and complementarity of the three muon subsystems: Cathode Strip Chambers (CSC), Drift Tubes (DT) and Resistive Plate Chambers (RPC). In this talk, the role of each subsystem in Level-1 muon trigger will be described, with highlight on the contribution from the RPC system. Challenges brought by the HL-LHC environment and new possibilities coming from detector and trigger upgrades will also be discussed.

Primary author: COLLABORATION, CMS

Presenter: FRANCOIS, Brieuc Arnaud Loic

Session Classification: Large systems and Upgrades

Contribution ID: **59** Type: **Poster Session**

Effects of the electronic threshold on the performance of the RPC system of the CMS experiment

Thursday, February 13, 2020 5:10 PM (8 minutes)

Resistive Plate Chambers (RPCs in the following) play a very important role as the dedicated system for muon triggering both in the barrel and in the endcap of the CMS experiment at the Large Hadron Collider. It is therefore of primary importance to tune the operating voltage and the electronic threshold of the front-end boards reading the signals from these detectors in order to optimize the RPC system performance. In this study we present the results of a threshold voltage scan, and in particular the effects of changing the electronics threshold voltage on the RC efficiency, cluster size and detector intrinsic noise rate. According to this study, decreasing the applied threshold voltage by 5 mV results in an average efficiency gain of about 0.9% in the barrel without any significant increase of the cluster size and the noise rate.

Primary author: COLLABORATION, CMS

Presenter: ELMETENAWEE, Walaa (Istituto Nazionale di Fisica Nucleare)

Session Classification: Poster Session

Contribution ID: **60** Type: **Oral Contribution**

The TRISTAN detector - 2018-2019 latitudinal survey of cosmic rays

Tuesday, February 11, 2020 2:20 PM (20 minutes)

In 2018-2019 a latitudinal survey of the rate of cosmic rays at sea level was performed by the TRISTAN detector, an autonomous system composed by three planes of RPCs (120x150 cm²). The detector made a two-way journey on board of the Spanish Sarmiento de Gamboa vessel between Vigo (Spain) and Punta Arenas (Chile), measuring continually the cosmic ray rate throughout the Atlantic crossing. In this work, we present the results of the first way journey, correlating the obtained variation of the cosmic ray rate with the vertical cutoff rigidity, as well as presenting some details of the autonomous system used during this campaign.

Primary authors: SARAIVA, João (LIP Coimbra); BLANCO CASTRO, Alberto (LIP-Coimbra); GARZON, Juan A. (Univ. Santiago de Compostela); GARCÍA-CASTRO, Damian (LabCAF, IGFAE. Universidade de Santiago de Compostela (Spain)); LOPES, Luis (Lip-Coimbra); VILLASANTE, Víctor (IGN, Madrid (Spain))

Presenter: SARAIVA, João (LIP Coimbra)

Session Classification: Large systems and Upgrades

Contribution ID: **61** Type: **Oral Contribution**

Performance studies of RPC detectors with new environmentally friendly gas mixtures in presence of LHC-like background radiation

Thursday, February 13, 2020 2:40 PM (20 minutes)

Resistive Plate Chamber (RPC) detectors are widely used at the CERN LHC experiments as muon trigger thanks to their excellent time resolution. They are operated with a gas mixture containing $C_2H_2F_4$ and SF_6, both greenhouse gases (GHG) with a very high global warming potential (GWP). The search of new environmentally friendly gas mixtures is necessary to reduce GHG emissions and costs as well as to optimize RPC performance. Several recently available gases with low GWP have been identified as possible replacements for $C_2H_2F_4$ and SF_6. In particular, HFO-1234ze has been studied as a possible replacement for $C_2H_2F_4$ and several gases like Novec fluoroketones, C_4F_8O and CF_3I were tested as a replacements of both $C_2H_2F_4$ and SF_6. More than 60 environmentally friendly gas mixtures have been investigated on 2 mm single-gap RPCs. The RPC detectors have been tested in laboratory conditions and a selected mixture was tested at the CERN Gamma Irradiation Facility (GIF++), which provides a high energy muon beam combined with an intense gamma source allowing to simulate the background expected at HL-LHC. The performance of RPCs were studied at different gamma rates in a presence of muon beam by measuring efficiency, streamer probability, rate capability, induced charge, cluster size and time resolution. To finalize the studies, the RPCs are now operated under gas recirculation with the selected new gas mixture and exposed to the intense gamma radiation of GIF++ for evaluating possible long-term aging effects, gas damage due to radiation and compatibility of LHC gas system with new gases.

Primary authors: RIGOLETTI, Gianluca (CERN); Dr MANDELLI, Beatrice (CERN); Dr GUIDA, Roberto (CERN)

Presenter: RIGOLETTI, Gianluca (CERN)

Session Classification: Ageing and Gas Studies

Contribution ID: **62** Type: **Oral Contribution**

Gas mixture quality studies for the CMS RPC detectors during LHC Run 2

Monday, February 10, 2020 3:00 PM (20 minutes)

Resistive Plate Chamber (RPC) detectors are widely employed in the muon trigger systems of three experiments at the CERN Large Hadron Collider (LHC). They are operated with gas mixture recirculation systems to reduce operational costs and greenhouse gas emissions since their gas mixture is based on C2H2F4, which has a high global warning potential. It is well known that the C2H2F4 molecule can breaks under the effect of radiation and electric field. This leads to the creation of several impurities and free fluoride ions (F-), which could accumulate under gas recirculation and potentially attach to the RPC surface. For these reasons, an extensive gas analysis campaign has been performed during LHC Run 2 for the CMS RPC system to verify the gas mixture quality and possible accumulation of impurities.

During all LHC Run 2, a gas chromatograph has been used to analyze the RPC gas mixture in different points of the gas system: quality of pure C2H2F4, fresh gas from the mixer, gas at the output of the detectors and after the purifier module. Several impurities have been found and identified. Few impurities are already present in the C2H2F4 bottle, as residual of the industrial production of this refrigerant. Nevertheless, it was found out that some of these impurities as well as others, are created inside the detector gas gap due to the fragmentation of the C2H2F4 molecule under the effects of electric field and radiation.
During 2018 LHC Run several gas analysis points were added to measure the fluoride ions production in different sector of the RPC detector system. Indeed the products of the C2H2F4 fragmentation do not always recombine and F- species can stay free in the gas mixture. F- analysis were performed on the gas at the output of the detectors both for barrel and endcap regions, where radiation levels and operational conditions were different. In this way it was possible to correlate the F- production with integrated charge and gas mixture. In parallel, the RPC currents have been constantly monitored to look for possible correlations.
Fluoride measurements have also been performed at GIF++ to better understand the correlation between F- production, radiation levels and gas volume exchanges.

A comprehensive overview of the results obtained from the different types of gas analyses and possible correlation with RPC currents and LHC luminosity will be presented.

Primary authors: MANDELLI, Beatrice (CERN); GUIDA, Roberto (CERN)

Co-authors: GELMI, Andrea (BA); PUGLIESE, Gabriella (BA)

Presenter: GUIDA, Roberto (CERN)

Session Classification: Large systems and Upgrades

Contribution ID: **63** Type: **Oral Contribution**

Development of new gas recuperation and recirculation systems for RPC detectors

Thursday, February 13, 2020 4:10 PM (20 minutes)

The large RPC systems at the CERN-LHC experiments are operated with a gas mixture containing C2H2F4 (R134a), SF6 and iC4H10. The first two gasses have a very high global warming potential (GWP) and their availability, as well as price, might be subject to Fluorinated gas Regulations in the near future.

Several gas mixtures based on new environmentally friendly gases are being tested by RPC community to look for a suitable replacement of R134a. Nevertheless, these R&D studies are still ongoing, and a clear positive conclusion seems to be difficult to achieve in a short timescale.

The reduction of GHG emissions, from all research activities, i.e. not only RPC, is an objective of paramount importance for CERN. Four different strategies have been identified to achieve it.
Concerning the LHC RPC systems, GHG reduction can be achieved by optimizing the existing gas recirculation systems and with the development of recuperation systems for R134a and SF6.
During Run 2 the gas mixture recirculation rate of the RPC detector systems was limited to 85–90% due to the presence of leaks at the detector level. LS2 will give a unique chance to repair as many leaks as possible as well as to study possible upgrade of the gas systems to compensate for the observed detector fragility. Several tests have been performed on different modules.
A prototype system for R134a recuperation has been developed and successfully tested at the end of Run 2 for the ATLAS RPC gas system and it is nowadays installed in the CMS experiments for validation at higher flow, storage and re-use of recuperated gas. Final test will be concerning the effectiveness in the separation of RPC specific impurities.
The development of small gas recirculation units for laboratory purposes continued.

The present contribution describes the different strategies, the on-going developments and the achievements for the reduction of GHG emissions of the LHC RPC gas systems.

Primary authors: GUIDA, Roberto (CERN); MANDELLI, Beatrice (CERN)

Co-authors: CORBETTA, Mara; RIGOLETTI, Gianluca (CERN)

Presenter: GUIDA, Roberto (CERN)

Session Classification: Ageing and Gas Studies

Contribution ID: **64** Type: **Oral Contribution**

New advances in very low gas consumption

Thursday, February 13, 2020 3:50 PM (20 minutes)

The carbon footprint is of main importance for the sustainability of man kind. We must all want to contribute to the reduction of carbon emissions, and gas radiation detectors should not be a privileged island. Many efforts have been done during the last years in our community: searching for new ECO-friendly gases; implementing recovery and/or re-circulation systems; improvements in detector tightness; use of new materials and approaches in detector conception and operation; and the reduction of gas flow rates are the main ones.

In this work the results and conclusions of our efforts during the last years will be presented. Showing how important is the selection of the materials used in chamber construction and how this is relevant in very low gas consumption.

Primary author: LOPES, Luis (Lip-Coimbra)

Presenter: LOPES, Luis (Lip-Coimbra)

Session Classification: Ageing and Gas Studies

Contribution ID: **65** Type: **Oral Contribution**

Secondary Cosmic Ray detection with RPCs: a state-of-art review and possible application in Space weather studies

Monday, February 10, 2020 5:10 PM (20 minutes)

Resistive Plate Chambers RPCs detectors are mainly used in particle accelerators due to its fast response and high time resolution. In the past few years some research groups all over the world are exploring the application of RPCs in secondary cosmic ray CR detection.
The present work reviews relevant literature available about the application of RPCs as CR detectors and summarizes the main characteristics that a RPC-based CR detector must have in particular for Space Weather and Solar Physics applications in the southern hemisphere.

Primary authors: CAZAR RAMIREZ, Dennis (Universidad San Francisco de Quito); SANTONICO, Rinaldo (ROMA2)

Presenter: CAZAR RAMIREZ, Dennis (Universidad San Francisco de Quito)

Session Classification: New Experiments

Contribution ID: **66** Type: **Oral Contribution**

Factors that influence the timing properties and rate capability of Multigap Resistive Plate Chambers

Tuesday, February 11, 2020 12:00 PM (20 minutes)

The Multigap Resistive Plate Chamber (MRPC) is now the timing device of choice especially when large area coverage is required. In this presentation I will cover the factors that are important to generate excellent timing. Related to this is the growth of the avalanche within the gas gap: measurements of the total charge observed in the MRPC will be presented. Front-end electronics plays an important role for optimal timing and various techniques currently in use will be considered

Primary author: Prof. WILLIAMS, Crispin (cern)

Presenter: Prof. WILLIAMS, Crispin (cern)

Session Classification: Large systems and Upgrades

Contribution ID: **67** Type: **Oral Contribution**

A new generation of RPCs for next generation experiments

Monday, February 10, 2020 4:10 PM (20 minutes)

Searches for new and elusive physics phenomena with present and future HEP experiments will require increasingly performant techniques, for the ability to detect high particle fluxes with high granularity and space-time resolution.
The present upgrade effort of the HL-LHC programme offers solid ground and use-cases to develop such techniques. In the case of classic large area RPCs, outstanding developments in the detector integration concept, involving at the same time the front-end electronics and the sensor itself, permitted to design a new generation of RPCs enhancing most of the detector features by about an order of magnitude, without increasing the construction cost and complexity. This represents a new de facto standard reference for future colliders experiments, and already adopted for the Phase-1 and Phase-2 ATLAS RPC upgrade projects.
New significant use cases concern recent proposals of dark matter search experiments, conceived as a smart complement of LHC detectors, such as CODEX-B (COmpact Detector for EXotics at LHCb) and ANUBIS (AN Underground Belayed In-Shaft search experiment). In both cases, these new RPCs being used for the ATLAS upgrades have been chosen as turnkey technology for the detector design, due to a very good matching between requested and offered performance at a cost per unit surface compatible to instrument large areas.
The technical features of this new generation of RPCs will be analysed for the CODEX-B and ANUBIS use cases, and how the discovery potential of this experiments critically depends on the new RPCs performance. Potential avenues for further adjustments of RPC performance and cost to the use case of CODEX-b and ANUBIS will be outlined.

Primary authors: AIELLI, Giulio (ROMA2); CARDARELLI, Roberto (ROMA2)

Presenter: AIELLI, Giulio (ROMA2)

Session Classification: New Experiments

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

Welcome

Monday, February 10, 2020 10:50 AM (10 minutes)

Presenter: DI CIACCIO, Anna (ROMA2)

Contribution ID: **73** Type: **Oral Contribution**

Keynote1

Monday, February 10, 2020 11:00 AM (35 minutes)

Presenter: SANTONICO, Rinaldo (ROMA2)

Contribution ID: **74** Type: **Oral Contribution**

Keynote2

Monday, February 10, 2020 11:35 AM (35 minutes)

Presenter: CARDARELLI, Roberto (ROMA2)

Contribution ID: **75** Type: **Oral Contribution**

Summary talk

Friday, February 14, 2020 12:00 PM (40 minutes)

Presenter: Prof. WILLIAMS, Crispin (cern)

Contribution ID: **76** Type: **Oral Contribution**

Exploring the lifetime and cosmic frontier with the MATHUSLA detector

Monday, February 10, 2020 5:30 PM (20 minutes)

The MATHUSLA detector to be installed on the surface above and somewhat displaced from the CMS interaction point (IP) will cover an area of 100X100 sq. meter containing many layers of scintillators planes to establish the space and time coordinates of charged particle tracks. This is an unprecedented detector in terms of size and continuous sensitivity over an area of 104m. This talk describes the present MATHUSLA detector concept that is sensitive to both long-lived particles produced in the LHC collisions in CMS and cosmic ray extended air showers (EAS). The ability to improve significantly cosmic ray studies by adding a 10,000 sq. meter layer of RPCs that have both digital and analogue readout suitable for high-multiplicity EAS events will be discussed.

Primary author: ALPIGIANI, Cristiano (University of Washington)

Presenter: ALPIGIANI, Cristiano (University of Washington)

Session Classification: New Experiments