RPC 2018 - THE XIV WORKSHOP ON RESISTIVE PLATE CHAMBERS AND RELATED DETECTORS

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Other Institutes

Book of Abstracts

XIV Workshop on Resistive Plate Chambers and related detectors
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Simulations and Modeling / **77**

A Geant4 simulation to estimate the RPC sensitivity to neutral radiation

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The experiments at the Large Hadron Collider (LHC) operate in a large radiation background. With the increase of the luminosity of the LHC, estimates of the signal rate caused by neutral radiation should be assessed in order to infer the signal rate per unit area due to radiation.
A Geant4 simulation has been developed to estimate the sensitivity to gamma and neutrons of a double-layer RPC, modelling the ones installed in the ATLAS detector.
Primary gamma and neutron beams with energies varying in the region of interest for the LHC cavern background have been simulated. An analysis of the interactions occurring in the RPC materials has been carried out in order to extract the RPC sensitivity as a function of the energy of the impinging radiation.
The assumptions made to extract the results will be discussed, whose impact is particularly relevant for neutrons with energy below the keV. Preliminary results on the RPC sensitivities to gamma and neutrons will be presented.

New Ideas / **13**

A Timing RPC with low resistive ceramic electrodes

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For precise start time determination a Beam Fragmentation T0 Counter is under development for the Time-of-Flight Wall of the Compressed Baryonic Matter Spectrometer [1]. This detector will be located around the beam pipe, covering the front area of the Projectile Spectator Detector. The fluxes at this region are expected to exceed 10^5 cm-2s-1.
Ceramic RPCs [2] could be use because of their high rate capabilities and radiation hardness of material. Efficiency (over 97%), time resolution (about 90 ps.) and rate capability over 10^5 cm-2 s-1 were confirmed during many tests with high beam fluxes of relativistic electrons at ELBE and with heavy ions at SPS. We confirm the stability of characteristic with low resistive Si3N4/SiC floating electrodes for a prototype of eight small RPCs, where each of them contains six gas gaps. The active RPC size amounts 20x20 mm2 produced on basis of Al3O2 and Si3N4/SiC ceramics. Newest test results obtained at ELBE with PADI10 FEE will be presented in the talk.

[1] P. Senger, Journ. of Phys. G 28 (2002) 186
[2] A. Akindinov et al., Nucl. Instr. Meth. A 845 (2017) 757

Poster Session / **15**

A neural network based algorithm for MRPC time reconstruction

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Multi-gap Resistive Plate Chamber(MRPC) is a widely used timing detector of which the typical time resolution is about 50ps. This makes MRPC an optimal choice for triggering in many large physics experiments such as STAR and CBM. The prior work of improving the time resolution of MRPC has focused on altering the structure of the detector. However, the algorithm of reconstructing a more precise time has not been fully explored. Normally the signal of the detector will be discretized with the time over threshold(ToT) technique, and since the fluctuations of the charge induced by different events generate a time walk, the threshold reaching time from the digitization will be corrected with "Walk Correction". This work proposes a new time reconstruction algorithm based on the deep neural networks(NN) which gives a much better result than the walk correction. Discrete points on the signal waveform around the threshold are feed into the network, and it is trained with different network architectures to find the best prediction. Labels in the NN are the truth time when particles start losing energy in the detector. This work is based on a standalone simulation of a 5-gap MRPC detector. To get a more precise simulation of ionization energy loss in very thin gas absorbers(250um), we use the Photo Absorption Ionization (PAI) model offered by Geant4 instead of the well known Landau model. The neural network based algorithm is proved to be around 25% better than the walk correction. As MRPC detectors are going to be used in more and more high energy experiments with a higher energy frontier, the improvements of time resolution gained from the neural network in this work will be a lot more valuable.

Poster Session / **85**

ASSEMBLY AND CONSTRUCTION OF A MULTI-GAP RESISTIVE PLATE CHAMBER FOR THE DETECTORS LAB OF UNAM

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In this work we report the procedure of the design, manufacture and assembly of a Multigap Resistive Plate Chamber at the detectors lab of ICN-UNAM. This detector consists of a stack of 5 parallel thin resistive plates (glass). The array is placed inside a hermetic box which is filled with a gas mixture of 5% SF6 and 95% freon. The main objective of this project is to reproduce technology which is used in ALICE's Time Of Flight (TOF) system[1] at the lab and introduce young students to high energy physics research.

[1] A. Akindinov et al., "Construction and test of the MRPC detectors for TOF in ALICE", Nucl. Inst. Meth. A602 (2009) 658-664.

Vidyo?:

Key talk / **82**

About the possibility of an international ground-based Very High Energy particle detector experiment in Ecuador

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We discuss the possibility of hosting a big Astrophysics ground-based experiment in Ecuador, aimed to detect VHE particles. Ecuador location makes possible to see both the Northern and Southern sky. An additional geographic feature is the presence of one of the highest American mountains, the Chimborazo (6310 masl), that happen to be the highest point on Earth measured from the center of the planet. In the last decade Ecuadorian government has invested resources in higher education and research, with an important policy of training abroad. The effect has been that now many researchers in Physics, Astrophysics, and Engineering are working in universities across the country and collaborating with important experiments like CMS at CERN, Pierre Auger in Argentina, HAWK in Mexico and in LAGO project. All these features make Ecuador an ideal place to host a big VHE particle detector experiment in South America.

Poster Session / 28

Beam test of CBM-ToF MRPC prototype

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The Compressed Baryonic Matter spectrometer(CBM) is expected to be operational in the year 2024 at the Facility for Anti-proton and Ion Research(FAIR) in Darmstadt, Germany.CBM aims to study strongly interacting matter under extreme conditions.The key tool providing hadron identification at incident energies between 2 and 10AgeV is a Time-of-Flight(TOF) wall covering the polar angular range from 2.5°–25° and full azimuth. According to simulations, the necessary particle identification capabilities require of a TOF wall system time resolution of 80 ps at high efficiency. The existing conceptual design foresees a 120 □² ToF-wall composed of Multi-gap Resistive Plate Chambers (MRPC) which is subdivided in five rate depending concentric arranged regions named A to D where A is the area having fluxes below 1 kHz/□□² in average. For this region A which covers approximately 55% of the total area we developed a Multistrip-MRPC containing thin float glass as resistive electrode material. In this talk I will present the structure of this prototype MRPC and in particular results obtained during in beam tests at E3line at Beijing.

Poster Session / 11

Beam test study of the MRPC-based T0 detector for the CSR external-target experiment

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A new T0/Trigger detector based on multi-gap resistive plate chamber (MRPC) technology has been constructed and tested for the exteranl target experiment (ETE) at HIRFL-CSR. It measures the multiplicity and timing information of particles produced in heavy-ion collisions at the target region, providing necessary event collision time (T0) and collision centrality with high precision. Monte-Carlo simulation shows a time resolution of several tens of picosecond can be achieved at central collisions. The experimental tests have been performed for this prototype detector at the CSR-ETE. The preliminary results are shown to demonstrate the performance of the T0/Trigger detector
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New Ideas / **75**

CALPRO, a unconventional calorimetry project

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We propose a unconventional calorimetry approach. The method is based on an idea that has been used for the first time in the energy determination of extensive air showers (EAS) at very high energy (> 100 TeV). It has some peculiar characteristics which that can be summarized in the following two points: a) measurement of the shower energy by means of a single sampling; b) measurement of the lateral density distribution of charged particles around the shower axis. Given the feature b) the method requires measurement of high charged particle densities, which encounters with the RPC capabilities of supporting up to 8×10^8 particle/m^2. We validated this measurement technique to lower energies (100 GeV - 10 TeV) by MC calculationt. Results on the extension to low energies are the subject of the presente contribution.

Poster Session / **61**

CMS RPC Condition Data Automation

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To increase the potential of fast withdrawal of RPC condition data and to eliminate the necessity of constantly decreasing manpower to run various tools, a new RPC data automation utility is being developed. Its goal is to rearrange the RPC detector currents, originally stored asynchronously in the CMS_RPC_PVSS_COND schema on cms_omds_lb database, into a new synchronous format in the CMS_RPC_COND schema on the same database. The new format is designed to ease all RPC current related data analysis. Data tagging is being realized to include into a single binary flag information from external database schemas such as CMS Magnetic Field and LHC Instantaneous Luminosity presence. This makes it trivial to disentangle CRUZET, CRAFT and COLLISIONS RPC detector currents. In addition, the automation utility is able to identify blocks of data with particular importance such as HV channel OFFSETS, HV CONDITIONING periods when the voltages are slowly ramped, RAMP UP and RAMP DOWN periods that require further smoothening before being recorded into the final RPCCURRENTS table. Finally, the utility includes packages for specific current related data analysis such as RPC integrated charge, RPC Currents vs LHC Luminosity, RPC Current Decay after Beam Dump, RPC Current Evolution in time, Dynamically Define the RPC detector Operation mode (Off, Single-gap, Double-gap) and automatic analysis of the RPC HV Conditioning data. The initial idea to develop a tool to deal with RPC Currents can expand to automation of other condition data such as RPC rates, efficiency, occupancy, cluster size etc.

Poster Session / **62**

CMS RPC Integrated Charge

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CMS RPC Integrated Charge is a current related data analysis which provides one of the most significant physical parameters crucial for monitoroing the detector ageing quantities. Using the new format of storing RPC detector currents in the CMS_RPC_COND detabase schema on cms_omds_lb provides a boost in the fast calculation of the current integrated in time for every single HV channel. The poster will present updated plots of the RPC Detector Integrated Charge as of the end of the operational 2017 and extrapolated charge to 3000 fb-1.

Performance Reports / **56**

CMS RPC background studies during LHC run II

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The CMS muon system is operating in the conditions of increasing instantaneous luminosity. During run2 the energy of the collisions in the center of mass is 13 TeV. This leads naturally to very high level of the radiation from different sources – collision and beam induced background and activation of the materials, as well. Particles that scatter around in the cavern and are reflected back to the muon system may affect the electronics and also the efficiency and rate capabilities of the detectors. Because of this adding additional shielding layers and investigation of their effect is important and necessary part of the detector performance analysis. The RPC hit rate and currents as function of the instantaneous luminosity have been studied in order to monitor the performance of RPCs, to analyze the background in different detector parts and to investigate an attenuation of it after the installation of new shielding layers. The extrapolation to the HL-LHC conditions will be presented as well.

Poster Session / **60**

CMS RPC efficiency measurement using the Tag and Probe method

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We measured the efficiency of CMS RPC detectors in pp collisions at 13TeV using the tag and probe method. A muon from Z boson decay is selected as a probe of efficiency measurement, reconstructed using the CMS inner tracker and the rest of CMS muon systems. The overall efficiency of CMS RPC chambers during the 2016-2017 collision runs are measured to be 96% for a group of high-efficiency chambers.

New Ideas / **29**

Characteristic Study and Development of Surface Resistivity Measuring Device for Resistive Plate Chamber Detector

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The India based Neutrino Observatory (INO) experiment is an approved mega science project to build a huge magnetized Iron Calorimeter (ICAL) detector with largest (~ 30,000) number of Resistive Plate Chamber (RPC) detectors. Cavern of this ICAL will be under the mountain having overburden of ~1.5 km. The ICAL primary motive is to understand the atmospheric neutrinos and related parameters. The RPC was a parallel plate gaseous detector and it provides good spatial resolution (<1cm) with a time resolution, better than ns, comparable to that of scintillator detector. We report, the work done at the RPC stack, IICHEP Madurai and performance study of the advance surface resistivity-scanning device. The study involves the characterization of RPC detector, such as surface resistivity measurement, high voltage test and Gas leak test of 2m × 2m size RPC detectors made up of the Saint Gobain glass and Saint Gobain Company, Chennai (India), makes gas gaps. We also report the performance study of the advance automatic surface resistivity-scanning system, which is fully designed and developed by us for the surface scanning of ~60000 electrodes. This AASS's jig is modified and equipped with a Force Sensing Resister (FSR), which is able to sense the contact force between jig and RPC electrode's surface. Therefore, resistance measurement of RPC electrodes can be done at nearly constant contact force and without fluctuation.

Reference.
[1] A. Kumar et al.,Invited review: Physics potential of the ICAL detector at the India-based Neutrino Observatory (INO), Pramana – J. Phys.88, **79** (2017)
[2] N. Marimuthu, V.Singh, et al., Proceedings of the DAE Symp. on Nucl. Phys. PP-1042-1043 **62** (2017).
[3] A. Panday, V.Singh et al., Proceedings of the DAE Symp. on Nucl. Phys. PP-1080-1081 **62** (2017).

RPC Detectors / **88**

Construction and testing of an RPC in Puebla

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Vidyo?:

RPC Detectors / **81**

Construction of multi-gap resistive plate chambers at the detectors lab of the National University of Mexico

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In this work we report on the construction and performance (efficiency) of a multi-gap resistive plate chamber (MRPC) consisting of a stack of 6 parallel thin glass plates (thickness of 400 μm). We

followed the construction procedure of the chambers which were designed for the ALICE Time-Of-Flight detector [1]. Spacers (fishing line) between the resistive plates define a series of gas gaps of size 260 μm. A high voltage (between 9 and 15 kV) is applied to the electrodes which are placed on the outer surfaces of the outermost resistive plates. The device is placed inside a hermetic box which is filled with a gas mixture of 5% SF6 and 95% freon. The detector is tested using atmospheric muons. A coincidence with two scintillation horoscopes is required for measuring the MRPC efficiency. The results are presented as well as the further plans of this project.

[1] A. Akindinov et al., "Construction and test of the MRPC detectors for TOF in ALICE", Nucl. Inst. Meth. A602 (2009) 658-664.

High Rate / New electronics / 25

Design a TDC in SiGe for the Front-end electronics for the RPCs used in a high-rate experiment.

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With the new RPC's generation, it is possible to work with induced signals of hundreds μV, hence the front-end electronics is an important and delicate part of the detector order to get a detectable signal. The electronic chain is made up of an amplifier, a discriminator, a TDC. The new front-end is realized by the use of silicon-germanium (SiGe) components, provided by IHP microelectronics. With this technology, it is possible to implement BJT and MOS transistors on the same chip. The benefit of this improvement is minimized: power consumption of the channels ($2 \div 3$ $\frac{mW}{ch}$), noise (500 e^- ▯.▯.▯), radiation hardness (10 ▯▯▯,10^3 $\frac{n}{cm}$) and it maximizes the speed of response electronics. In this talk I will show the first results of TDC prototypes. The TDC uses a local oscillator, that has an oscillation range between $0.6 \div 3$ GHz, and a the temporal jitter of 15 ps. The data output from the TDC are presented in binary in order to lighten data processing to the acquisition system. Moreover, we are studying a way to minimize system latency. This optimization involves the adding a serializer (PISO) that sends the TDC data output to the acquisition system at 2 GHz.

RPC Detectors / 20

Development of 6 gap Bakelite Multi-gap Resistve Plate Chamber.

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The Multi-gap Resistive Plate Chamber (MRPC) is an advanced form of
Resistive Plate Chamber (RPC) detector where the gas gap is divided into
sub-gaps. MRPCs are known for their good time resolution and detection
efficiency for charged particles. The MRPCs that are being used nowadays are developed with glass electrodes. We have made an attempt to develop a 6-gap MRPC using bakelite electrodes. The outer electrodes are of dimensions 15 cm × 15 cm × 0.3 cm and the inner electrodes are of dimension 14 cm × 14 cm × 0.05 cm. The
glossy finished electrode surfaces have not been treated with any lubricants
like linseed oil, silicone oil for smoothness. The performance of the detector
has been studied measuring the efficiency, noise rate and time resolution with
cosmic rays. Details of the development procedure and performance studies
will be presented.

High Rate / New electronics / 7

Development of a new Front-End electronics in Si and Si-Ge technology for the Resistive Plate Chamber (RPC) detector for high rate experiments

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The upgrade of the Resistive Plate Chamber (RPC) detector, in order to increase the detector rate capability and to be able to work efficiently in high rate environment, consists in the reduction of the operating voltage along with the detection of signals which are few hundred μV small. The approach chosen by this project to achieve this objective is to develop a new kind of Front-End electronics which, thanks to a mixed technology in Silicon and Silicon-Germanium, enhance the detector performances increasing its rate capability.
The Front-End developed is composed by a preamplifier in Silicon BJT technology with a very low inner noise (1000 e^- rms) and an amplification factor of 3-4mV/fC and a new kind of discriminator in SiGe HJT technology which allows a minimum threshold of the order of 0.5 mV.
The performances of this kind of Front-End will be shown. The results are obtained by using the CERN H8 beamline with a full-size RPC chamber of 1 mm gas gap and 1.2 mm thickness of electrodes equipped with this kind of Front-End electronics.

New Ideas / 24

Development of gaseous particle detectors based on semi- conductive plate electrodes

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A radiation hard detector with sub-nanosecond time resolution capable of working in high rate environment (order of MHz/cm 2) is under development.
Some gaseous detector prototypes made using planar Semi-conductive electrodes are being studied.
The prototypes have the same structure as an RPC detector but employ SI-GaAs electrodes with resistivity up to 10^8 Ω·cm.
In this presentation some results as efficiency and time resolution of the configurations under test are described.

Vidyo?:

yes

Eco Friendy Gases / **51**

Development of new gas recirculation and recuperation systems for Resistive Plate Chamber operation with new environmental friendly gases

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Resistive Plate Chamber (RPC) detectors are widely used thanks to their excellent time resolution and low production cost. The large RPC systems at the CERN-LHC experiments are operated in avalanche mode thanks to a Freon-based gas mixture containing C2H2F4 (R134a), SF6 and iC4H10. The first two gas will be phased out from production in the near future due to their high global warming potential (GWP). Even if R134a and SF6 will always be available for research purposes, their cost could increase as the interest of industry and market will decrease.

To reduce greenhouse gas (GHG) emission, several gas mixtures based on new environmental friendly gases have been tested in the past few years. R&D studies on this topic are still ongoing. Some additional results will be presented.
A parallel strategy for a reduction of GHG emission is focused on the development of new gas recirculation and recuperation systems. The present contribution describes preliminary results of a test performed in laboratory on RPC operated with new environmental friendly gas mixture and a new gas recirculation system.
The layout of a prototype recuperation system for R134a and other GHG gases will be also discussed.

High Rate / New electronics / **70**

Development of seminconductor solid-state detectors with sub-100ps time resolution.

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Large area silicon pixel detectors have been traditionally used in high-energy physics experiments for particle tracking, with a time resolution typically ranging from few to some tens of ns.
Presently, the silicon pixel community is targeting sub-ns time measurements.
A first direction is the development of Low-Gain Avalache diodes, with a time resolution down to 30ps for large pixels. Another research, which is the one that we do within TT-PET collaboration, is the development of the first monolithic pixel detector with 100ps time resolution for m.i.p.s in a commercial SiGe Bi-CMOS process.
The status and future perspectives of the development of fast silicon detectors will be presented.

Eco Friendy Gases / **4**

Effect of variations in the gas mixture compositions on the timing and charge of glass RPC

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The India-based Neutrino Observatory (INO) is a mega science project aimed at building a large underground laboratory to study the atmospheric neutrinos. INO will host a 50 kton magnetized iron calorimeter detector (ICAL) in which Resistive Plate Chambers (RPCs) will be the active detector elements. In ICAL, 28,800 glass RPCs of 2 m $\times$ 2 m size will be operated in the avalanche mode. The performance of RPCs will be changed by a small variation in the gas mixture compositions. Study of the charge distribution of the RPCs at different gas compositions is necessary to optimize the gas mixture.

An RPC made with glass samples of dimension 30 cm $\times$ 30 cm was operated in avalanche mode with a gas mixture of $C_2H_2F_4/C_4H_{10}/SF_6$. We have studied the performance of these RPCs at the same ambient conditions. The percentages of the C_4H_{10} or SF_6 are varied and its effect on the RPC were studied. The study of the charge distribution and time resolution of the RPC signals at different gas compositions will be presented in the conference.

High Rate / New electronics / **68**

Fast timing measurement for CMS RPC Phase II upgrade

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With the increase of the LHC luminosity foreseen in the coming years many detectors currently used in the different LHC experiments will be dramatically impacted and some need to be replaced. The new ones should be capable to provide time information to reduce the data ambiguity due to the expected high pileup.

We propose to equip CMS high eta muon chambers with doublets of RPC detectors read out by long pickup strips PCB. The precise measurement (<150ps) of the signal induced by particles crossing the detector on both ends of each strip will give an accurate measurement of the position of the incoming particle along the strip. The absolute time measurement, determined by RPC signal (around 1 ns) will also reduce the data ambiguity due to the highly expected pileup and help to identify Heavy Scalar Charged Particles (HSCP).

Principle of the measurement, implementation in front-end electronic boards (Petiroc front-end ASIC, wave-union TDC and PCB design) will be presented associated with first results on prototype chambers.

APPLICATIONS: Theraphy / **39**

Feasibility study for development of a PET device based on Multi-gap Resistive Plate Chambers

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The Multi-gap Resistive Plate Chambers (MRPCs) provide excellent timing as well as position resolutions at relatively lower cost. Therefore, they can be used in medical imaging applications such as PET where precise timing is a crucial parameter of measurement. We have designed and fabricated several six-gap glass MRPCs and extensively studied their performance. In this paper, we describe the detector, electronics and the data acquisition system of the setup. We present here the data analysis procedure and initial results of our studies to measure the absolute position of a radioactive source (Na-22) using time of flight (TOF) as well as hit position information and hence to demonstrate their potential applications in medical imaging. We also present the Geant4 based simulation results on the efficiency of our detector as a function of number of gaps and the converter thickness.

Simulations and Modeling / **42**

Garfield simulation to study the improvement of time response of RPC in different configurations

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The proposed ICAL detector [1] at India-based Neutrino Observatory will use Resistive Plate Chambers (RPC) [2], stacked in 150 layers with iron plates sandwiched between them, as the tracking device for the muons created by the atmospheric neutrinos through their charged current interaction with the iron nuclei. Fast and efficient measurement from each RPC layer is an important factor

for this kind of set-up, which will help to properly tag the events as well as distinguish up-going muon tracks from the down-going ones.
The detection efficiency and timing performance of RPC depends on proper signal generation within the detector which is critically dependent on the device geometry, used gas mixture as well as on the applied voltage. A Multi-gap RPC (MRPC) [3], having more than one gas gap with smaller gap width is popular for its very good time resolution (~50 ps) compared to a single gap RPC (~2 ns) and is used as a trigger device in many experiments and also for Time-of- Flight measurements.
In the present work, numerical calculations have been performed to get an insight on the working principle of RPCs and MRPCs and the results have been compared to available experimental data to establish the efficacy of the simulation framework. Garfield simulation framework [4] has been used to perform the calculations. The calculation of time response of an RPC [5] has been extended here to a standard MRPC geometry. First, the dependence of average signal amplitude and the timing parameters on the gap width of a RPC has been found out. Then the effect of the increase in the number of gas gaps on signal amplitude as well as timing parameters has been calculated. Finally, the time response of a standard 6-gap MRPC geometry has been calculated at different operating conditions and compared with available experimental data.

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GAS Studies / **52**

Gas mixture quality monitoring for the RPC detectors at the LHC experiments

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Resistive Plate Chamber (RPC) detectors are widely employed in the muon trigger systems of three experiments at the CERN Large Hadron Collider (LHC) thanks to their excellent time resolution. The LHC RPC systems are operated under gas recirculation to reduce operation cost and greenhouse gas emissions since their gas mixture is based on C2H2F4, which has a high global warning potential. Extensive gas analysis campaigns have been performed during LHC Run 2 for the CMS RPC and ALICE Muon Trigger (MTR) systems to verify the gas mixture quality and possible accumulation of impurities.
A particular attention has been addressed to the ALICE MTR system, which has been operated under gas recirculation from the end of 2015. In order to validate the system ensuring good detector operation, the gas recirculation has been increased in steps: 30%, 60% and 70%. Detector currents and gas mixture quality have been closely monitored.
A gas chromatograph and mass spectrometer (GC/MS) station has been installed to analyze the MTR gas mixture in different points of the gas system: fresh gas from the mixer, detectors output and output of the purifier module. Several impurities have been found and identified. Most of the impurities are created inside the detector gas gap due to the fragmentation of the C2H2F4 molecule

under the effects of electric field and radiation. The GC/MS analyses have been regularly performed in 2016 and 2017. It has been demonstrated that impurities concentration (at the level of tens of ppm) increases with the increase of the gas recirculation fraction. GC/MS analyses have been also performed after the purifier module showing that some impurities are filtered while others not. In parallel, the RPC currents have been constantly monitored, and their trend showed no correlation with the gas recirculation fraction.
In 2017 an Ion Selective Electrode station was installed to measure the fluoride (F-) concentration in the MTR RPC gas mixture. Indeed the products of the C2H2F4 fragmentation not always recombine and F- species can stay free in the gas mixture. The analyses show that F- are present in the mixture exiting the RPCs and their concentration increases with the increase of luminosity, even if it stays at the level of ppb per day.
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.

High Rate / New electronics / 67

High rate, high time precision RPC detector for LHC

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With the increase of the LHC luminosity foreseen in the coming years many detectors currently used in the different LHC experiments will be dramatically impacted and some need to be replaced. The new ones should be capable not only to support the high particle rate but also to provide time information to reduce the data ambiguity due to the
expected high pileup.

RPC using low-resistivity materials are proposed to equip the very forward region of the CMS detector. In their single-gap version they can stand rates of few kHz/cm2. Their time precision of about 1ns can allow to reduce the noise contribution leading to an improvement of the trigger rate.

New electronics equipped with excellent timing precision measurement are being developed to read out the RPC detectors from both side of the strips to allow good spatial resolution along them. First results of this electronics will be presented.
Tests at Gamma Irradiation Facility (GIF) and SPS at CERN was performed to validate the capability of such detectors to support high irradiation environment with limited consequence on their efficiency. Results of these tests will be presented and discussed.

Key talk / 89

Highlights and summary

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Vidyo?:

Eco Friendy Gases / 32

Investigation on RPC Performance with Argon-based Gas Mixtures

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Content:
The Iron Calorimeter (ICAL) at the India-based Neutrino Observatory (INO) is designed to study various aspects of the neutrino oscillation, in particular, the neutrino mass hierarchy using the matter effects independent of CP phase [1,2]. The magnetized calorimeter will be populated with an alternate array of iron plates and Resistive Plate Chambers (RPCs) for tracking the muons produced from the charged current interaction of atmospheric neutrinos with the iron. About thirty thousand RPCs will be operated in avalanche mode using Freon based gas mixture for extracting the position and timing information of the muons. However, the high global warming potential (GWP) of the gas mixture (~ 1403) calls upon to search for an alternative with low GWP that can substitute the present mixture without compromising the ICAL objectives.

In this work, the feasibility of using Argon based gas mixtures for operating the RPC was investigated. The dynamics of charge development in an RPC was simulated using a code [3] based on COMSOL Multiphysics software [4] which was suitably modified to test the eligibility of Argon based gas mixtures and determine the parameters for avalanche mode operation for those mixtures. To complement the numerical results, some experimental measurements were carried out using a Bakelite RPC. The numerical as well as the experimental investigations for the qualification of the proposed gas mixtures were compared to that of the standard Freon based mixtures.

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New Physics Experiments / **21**

Long term Experience in Autonomous Stations and production quality control

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Large area arrays composed of dispersed stations are of major importance in experiments where Extensive Air Shower (EAS) sampling is necessary. Among those dispersed stations it is mandatory to have detectors that require very low maintenance and show good resilience to environmental conditions. In 2012 our group started to work on RPCs that could become acceptable candidates to operate within these conditions. Since that time, more than 50 complete detectors were produced, tested and installed in different places, both indoor and outdoor. Results can be found in [1 - 3].

The data and analysis to be presented are mainly related to the tests made in the Auger [4] site, where two RPCs are under test in real conditions for more than two years. The results confirm the capability to operate such kind of RPCs for long time periods under harsh conditions at a stable efficiency.

In the last years, LIP and USP – São Carlos started a collaboration that aims to install an Engineering Array at Auger site to better study and improve the resilience and performance of RPCs in outdoor experiments and to prove the physics capabilities of such innovative detectors. The organization of such collaboration and the work done so far will be presented.

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High Luminosity / High Rate / 54

Longevity studies for the CMS-RPC system

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In the next decades, the Large Hadron Collider (HL-LHC) will run at very high luminosity (5*10^34 cm^-2 s^-1). During this period the CMS RPC system will be subjected to high background conditions which could affect the performance inducing aging effects. A dedicated consolidation program is ongoing which must certify the present CMS RPC system for the HL-LHC running period. At the CERN Gamma Irradiation Facility (GIF++) few RPC detectors are exposed to intense gamma radiation for a period equivalent to the expected integrated charge at HL-LHC. The main parameters (currents, rate, resistivity) are under monitoring as a function of the integrated charge and the performance studied with muon beam. After having collected a significant amount of the total irradiation preliminary results will be presented.

Poster Session / 80

MRPC readout from one side

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We have tested the performance of a long MRPC(Multigap Resistive Plates Chamber) with a new type of readout of the signal induced by the minimum ionizing particles. The detector consists of 2 stacks of 6 gas gaps of 220 microns. The signal pick-up electrodes are 16 strips 8mm wide and 180cm long. One ends of the half of the 16 strips are connected to the ends of the other half using 8 LEMO cables of the same length. This allows the signal at both ends of one strip to be read out from only one side. The number of electronics channels needed is reduced by a factor of 2. The resolution of the average of time measured at both ends is 155ps(sigma), and the resolution of the difference in two time valures is 79ps(sigma) at 15kV.

Eco Friendy Gases / **43**

MRPC with eco-friendly gas

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The Multi-gap Resistive Plate Chambers(MRPC) are used as a timing device in several collider experiments and a cosmic ray experiment. The MRPC is a gaseous detector and operates essentially with a mixture of gases. The gas mixture of MRPC at current experiments is based on the greenhouse gases (GHG) such as freon of Hydro-Fluoro-Carbon (HFC) group. The studies to reduce the amount of emission of the warming gas in high energy experiments are underway, and the present contribution has been performed as part of this effort. The results have been obtained from the beam test of a small MRPC which has 6 gaps of 220 μm and an efficient area of 20cm $\times$ 20cm. It has been operated with the ecological HFO-1234ze gas, and with the conventional freon-based gas mixture as well. We have found that the eco-gas can substitute for the freon-based gas mixture without significantly compromising the current level of performance.

RPC Detectors / **5**

MRPC3b for CBM-ToF

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The Compressed Baryonic Matter (CBM) experiment will be one of the major scientific pillars of the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt. Multi-gap Resistive Plate Chamber (MRPC) is adopted to construct the Time of Flight (ToF) Wall and a system time resolution of 80ps is necessary for hadron identification. MRPC3b as defined in the CBM ToF TDR has been designed for the outer region of the Tof system. In general, the MRPC3b is a two-stack, 10 gas gaps, 32 strips and double-end strip readout MRPC. This detector has an active area of 32cm × 27.6cm and the detector size is 354mm long, 324mm wide and 22mm thick.Figure 1 shows the readout pattern and the dimensions.

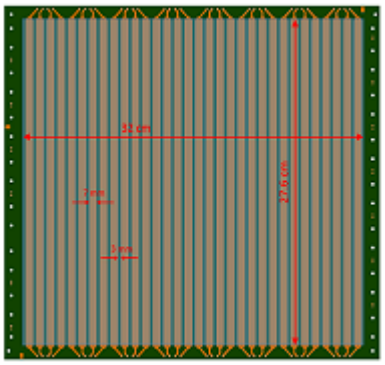

Figure 1: The readout pattern and the dimensions

In this presentation, the design details will be discussed. The mass production has already started from the spring of 2017. The assembly procedures and QA&QC methods will also be presented. The performance achieved from the cosmic ray test shows that the efficiency is better than 92% and the resolution is about 60ps with 90% Freon, 5% iso-butane, and 5% sulfur hexafluoride gas mixture. The preliminary results are shown in Figure. 2.

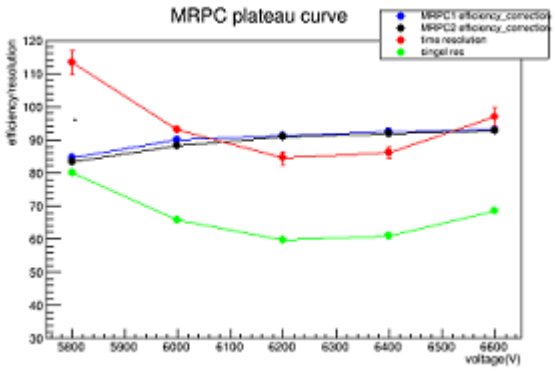

Figure 2: The performance of MRPC3b

Simulation: Imaging and Muon Tomography / 31

Material Identification with Cosmic Ray Muons using RPCs

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High energy cosmic ray muons are a suitable source for imaging larger and denser materials due to their high penetration power and considerably large life time (~2.2 μs). We plan to build an imaging setup for material identification utilizing the Coulomb scattering of cosmic ray muons due to their interaction with the materials and tracking their trajectories with RPCs. To begin with, we consider a setup of six RPCs stacked in a parallel manner to read the position and timing information of the

muons before and after their interaction with a phantom of a given material using a set of three RPCs for each phase. Here we present a simulation work carried out to study the image formation of a phantom of several materials produced in the present setup. A detailed modeling of the imaging system along with the RPCs is done using GEANT4 1. Several materials across a wide range of atomic numbers like Al, Fe, Pb, U, are considered as phantoms of a given dimension. Monte Carlo simulations are used to generate cosmic ray muons with the appropriate distribution of energies and momenta. The muon track reconstruction is done following two well established methods, Point of Closest Approach (PoCA) and Maximum Likelihood Scattering method (MLS) 2. The performance of the image discrimination method based on the muon scattering is studied by receiver operating characteristics (ROC) analysis. The number of events and the time required to discriminate different materials and producing the image of the phantoms are estimated.
Currently, the imaging system along with six Bakelite RPCs with 2 mm gas gap and area 30x30 cm^2 are under construction. The readout plane for each RPC is equipped with parallel strips of width 1 cm and pitch 1 mm. The corresponding front-end electronics (FEE) and data acquisition system (DAQ) development is going on. A few preliminary test results on the developmental work are expected to be presented in the workshop.

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Vidyo?:

yes

Key talk / **87**

Mathusla

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Vidyo?:

APPLICATIONS: Theraphy / **1**

Measurements of beam-induced photons for particle therapy

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Multi-gap resistive plate chamber are studied for range verification in particle therapy. Four- and six-gap glass RPCs were constructed with 0.45- and 1.1-mm-thick floating glass and tested with 662-keV gamma rays emitted from a 5-GBq Cs-137 source and high-energy photons induced by 44-MeV proton beams provided by the MC50 cyclotron at the Korea Institute of Radiological Accelerator Medical Sciences (KIRAMS). The two-dimensional images of the gammas were obtained by using a 5-cm-thick lead collimator with 10-mm-pitch 4-mm-diameter holes. The gamma images of a beam-activated area formed in a 2-cm-thick acrylic phantom agree well with data predicted using GEANT4 simulations.

Simulation: Imaging and Muon Tomography / 23

Muon Scattering Tomography of Spent Fuel Dry Storage

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In recent years, the cosmic-ray muon imaging technique has been widely used in industrial practical application, such as the nuclear reactor monitoring and the container internal scanning. However, it is restricted by the lagging imaging algorithm technology, resulting in poor image quality and time-consuming. In our study, a cosmic-ray imaging system of Gas Electron Multiplier (GEM) has been constructed with the help of Filter Back Projection (FBP) algorithm. Aiming at the dry spent fuel storage drums of Westinghouse MC-10, two different imaging algorithms are carried out. Two reasons are proposed by comparing their effects on the constructed image quality. The results demonstrate that the scattered reconstructed image is more sharply resolved than the transmitted one, and the sharpness of the edge is increased by 20%. The outline and missing part of the fuel assembly in the barrel can be clearly displayed by using this method, even if the position resolution of the gas detector is only 300 μm.

Simulation: Imaging and Muon Tomography / 41

Muon Tomography imaging improvement using optimized scattering tracks data based on Maximum Likelihood Method.

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Point of colsest Approche algorithm (PoCA) based on the formalism of muon radiography using the Multiple Coulomb scattering (MCS) as information source is previously used to obtain the reconstruction images of high Z materials. The low accuracy of reconstruction image is caused by two factors: the flux of natural muon and the assumption of single scattering in PoCA algorithm. In this paper, the maximum likelihood method based on the characteristics of Gaussian-like distribution of muon tracks by MCS is used to predict the optimal track of outgoing muon. The receiver operating characteristic (ROC) and the localization ROC (LROC) are used as two analysis methods to evaluate the quality of reconstruction image. From the results of simulation, the perfect discrimination of longitudinal materials could be well achieved by maximum likelihood algorithm and the discriminate ratio that is predicted by the maximum likelihood method is about 20% higher than that of predicted by the PoCA algorithm method. It is seen that the maximum likelihood method can greatly improve the accuracy of the muon reconstruction image. At the end of this paper, the preliminary results of spatial resolution and APV25 multichannel electronics in TripleGEM detector are presented, which will prepare the muon imaging based on the TripleGEM detector in the later stage.

New Ideas / 26

Neutron imaging with 10B4C-lined thin-gap RPCs: A multilayered architecture for high detection efficiency

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Recently LIP has introduced a new type of position sensitive thermal neutron detector (PSND) based on the combination of thin-gap RPCs (Resistive Plate Chambers) and solid-state neutron converters containing Boron-10. This detection technology offers a much lower cost per unit area compared to He-3 based detectors. The potential of this emergent detector technology is currently being evaluated for neutron scattering science in the framework of the SINE2020 project (EU project 654000).
One of the main challenges of using Boron-10 converters is to overcome the low thermal neutron detection efficiency of a single layer, which typically ranges from 5% to 10% depending on the neutron energy. Here we propose a PSND design with 10B4C-lined thin-gap RPCs in a multilayered architecture with the potential to achieve an overall detection efficiency above 50% for thermal neutrons.
To evaluate this multilayered architecture we have designed and constructed a detector prototype with a stack of 10 double-gap RPCs (DG-RPCs), having 20 layers of 10B4C in total. Each DG-RPC consists of two resistive anodes made of float glass and an aluminium cathode. The cathode is coated on both sides with a ≈1 micron thick layer of 10B4C.
To pick-up the induced signals, a thin multilayer polyimide PCB is inserted between each pair of DG-RPCs. The PCBs have three planes of metallic strips: The external ones are used to read the X coordinate for the events in the corresponding neighbouring DG-RPCs, and the middle plane of strips, which provides the Y coordinate, is shared by both adjacent DG-RPCs. The strips are read out individually by charge sensitive preamplifiers and the distribution of the induced charge is used to compute the event position by the centroid (CoG) algorithm. The cathodes, read individually, provide the signals to trigger the DAQ system and to identify the DG-RPC in which the neutron was converted (Z coordinate of the event).
Here we report preliminary experimental results obtained with the detector prototype in the TREFF neutron beamline (λ=4.7 Å) at FRM-II research reactor in Munich. The results are very promising: a detection efficiency > 50% and a spatial resolution below 0.35 mm FWHM (X and Y directions) were measured for 4.7 Å neutrons. We also present results of a Monte Carlo simulation study targeting optimization of the number of 10B4C layers and their thickness, as well as the impact of the neutron scattering by the detector materials on the detector performance.
The high detection efficiency, very good spatial resolution and fast timing capability (sub-nanosecond range) opens the possibility of applying the 10B4C lined thin gap RPCs in time-resolved or energy-resolved (TOF) neutron imaging.

Eco Friendy Gases / **38**

New Eco-gas mixtures for the Extreme Energy Events MRPCs: results and plans

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The Extreme Energy Events Observatory is an extended muon telescope array, covering more than 10 degrees in latitude and longitude. The 53 muon telescopes are equipped with tracking detectors based

on MRPCs technology with time resolution better than 200 ps. The current MRPCs are six gas gaps detectors, 300 micron each. The chambers are filled with a mixture of 98% of tetrafluoroethane and 2% of sulfur hexafluoride and are operated in avalanche mode. A new bunch of 24 MRPC chambers have been produced in 2017 for the observatory upgrade: they are again 6 gaps MRPCs with a thinner gap size of 250 micron.

The recent restrictions on greenhouse gases require studies for new gas mixtures in compliance with the law requirements. A set of tests with new mixtures have been carried out at the T10 test beam at CERN, where a hadron beam of intensity 104-106 h/s allows for intermediate rate tests. Both the new EEE MRPCs (6 gaps, 250 micron width) and a new prototype with a double-stack of 10+10 gaps, 220 micron size, have been tested with the standard mixture and with new mixtures of tetrafluoropropene and carbon dioxide or sulfur hexafluoride. Tetrafluoropropene is one of the candidates for the tetrafluoroethane substitution, showing a Global Warming Power 300 time lower.

Several mixture compositions have been tested, measuring efficiency curves, charge distributions, discharge fractions and time resolutions. Results are presented for the whole set of mixtures and operating conditions. A set of tests on a real EEE telescope, with cosmic muons, are being performed at the CERN-01 EEE telescope. The tests are focused on identifying a mixture with good performance at low rates, at the standard operating conditions.

Vidyo?:

Performance Reports / **19**

PID performance of the MRPC-based ALICE-TOF detector

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The ALICE Time Of Flight (TOF) detector is based on Multigap RPC. The TOF covers the ALICE central barrel by means of an array of 1638 MRPC strips for more than 150000 readout channels, for a total active area of $140\ m^2$. Thanks to its excellent time resolution and efficiency, the TOF provides a fundamental contribution regarding the Particle IDentification (PID) in p-p, p-Pb and Pb-Pb collisions for physics analyses. The TOF provides PID in the intermediate momentum range; it achieves a separation better than $3\ \sigma$, up to a particle momentum of $p \sim 2.5\ GeV/c$ and $p \sim 4\ GeV/c$ for π/K and K/p, respectively. The TOF has been fully operational since more than five years; we report on the outstanding detector performances observed. Moreover we present the results obtained via a new calibration which led to a significant improvement in the time resolution - down to 60 ps - very close to the value observed in beam test measurements. In addition we present the results of a dedicated study where the same performance was eventually reached also in multi-hit events. Finally we report on the performance reached for the determination of the event collision time: it is an important ingredient of the overall quality of the PID performance of the TOF. Efficiencies, resolution and the improvement of the particle identification separation power of the methods used are presented for the different LHC colliding systems (pp, p-Pb and Pb-Pb).

High Luminosity / High Rate / **72**

Performance Study of HL-LHC ATLAS RPC Prototype

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A new type of RPC chamber prototype, consisting of a triplet of 50x100 cm^2 RPCs, having 1 mm gas gap, 1.2 mm electrodes and new high sensitivity front end electronics, has been designed for the HL-LHC ATLAS upgrade program. Beam test of this prototype chamber was performed in GIF++ using 100 GeV muons and a 14 TBq 137Cs gamma source to simulate the HL-LHC environment. The amplified analog signals of the chamber have been read out by 32 channels of high speed digitizer, permitting to study in details the various aspects of the detector physics in different condition of gamma background and field applied in the gas. Analysis methods and results of these data will be presented, illustrating in details the most relevant features of this new detector: ~98% efficiency, 400ps~500ps time resolution and ~0.1 cm spatial resolution, cross talk in between the singlets and cluster size.

New Ideas / **18**

Performance of a real-size Mosaic MRPC developed for CMS upgrade

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The Compact Muon Solenoid (CMS) is one of the two general purpose detectors built at the Large Hadron Collider (LHC).In view of the High Luminosity LHC phase, the CMS detector requires upgrades to preserve the efficiency, resolution, and background rejection of the detector. To overcome the limited particle rate capabilities of the present RPC, a new electrode material, the low resistive silicate glasses with a bulk resistivity about 1010 Ωcm produced in China has been considered. By the use of improved multi-gap RPCs, the excellent timing precision below 100 ps can be used for pileup mitigation, and to provide an excellent signature and mass measurement for hypothetical heavy stable charged particles (HSCP).The initial prototype has been designed by jointing two pieces of glass together and the beam test at Helmholtz-ZentrumDresden-Rossendorf (HZDR) shows that it can reach 95% efficiency and 60 ps time resolution in the active area. Based on previous experience and attempt, a real-size Mosaic Multi-gap Resistive Plate Chamber (MRPC) has been developed. This chamber, also made of the low resistive glasses, has a 5-gap and 6 pieces of glass mosaic design. It has been tested with 30 MeV electron beam at HZDR. The working gas is a mixture of 90% C2H2F4, 5% iso-C4H10 and 5% SF6. At rate of 10 kHz/cm2, its efficiency reaches 95% at ±7000 V, with time resolution around 55 ps. Position scan is also carried out and shows that there is about 5% efficiency loss at vertical mosaic interface.Cosmic ray test at CERN 904 shows that its efficiency can reach above 95%. This prototype was also tested with CMS dry gas(95.2% C2H2F4, 4.5% i-C4H10, 0.3% SF6) at the CERN Gamma Irradiation Facility (GIF++) where an high energy muon beam (150 GeV) combined with a 14 TBq 137Cs gamma source and a set of moveable shields. Efficiency results calculated by a simple tracking method show that it can keep the performance at the rate from 0 to 10 kHz/cm2.

Performance Reports / **30**

Performance of the Multigap Resistive Plate Chambers of the Extreme Energy Events Project

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The muon telescopes of the Extreme Energy Events (EEE) Project are made of three Multigap Resistive Plate Chambers (MRPC). The EEE array is composed, so far, of 53 telescopes and is organized in clusters and single telescope stations distributed all over the Italian territory. They are installed in High Schools with the aim to join research and teaching activities, by involving researchers and students in the construction, maintenance, data taking and data analysis. The unconventional working sites, mainly school buildings with non-professional electrical lines, non-controlled environmental parameters and heterogeneous maintenance conditions, are a unique test field for checking the robustness, the low-aging features and the long-lasting performance of the MRPC technology for particle tracking and timing purposes. The measurements performed with the EEE array require excellent performance in terms of time and spatial resolution, efficiency, tracking capability and stability. The data from two recent coordinated data taking periods, named Run 2 and Run 3, have been used to measure these quantities and the results are described, together with a comparison with expectations and with the results from beam test performed in 2006 at CERN.

Performance Reports / **47**

Performances of the ATLAS RPC Level-1 Muon trigger during the Run-II data taking

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The Level-1 Muon Barrel Trigger is one of the main elements of the event selection of the ATLAS experiment at the Large Hadron Collider.
Its input stage consists of an array of processors receiving the full granularity of data from Resistive Plate Chambers in the central area of the ATLAS detector (”Barrel”).
The RPCs, placed in the barrel region of the ATLAS detector, are arranged in three concentric double layers and operate in a strong magnetic toroidal field.
RPC detectors cover the pseudo-rapidity range $|\eta|<1.05$ for a total surface of more than 4000 m2 and about 3600 gas volumes.

The Level-1 Muon Trigger in the barrel region allows to select muon candidates with respect to their transverse momentum and associates them with the correct bunch-crossing number.
The trigger system is able to take a decision within a latency of about 2 μs.
We illustrate the selections, strategy and validation for an unbiased determination of the efficiency and timing of the RPC and the L1 from data; and show the results we obtain and that are fed back into the ATLAS simulation to model real data.

GAS Studies / **14**

Precise Measurement of Gas Parameters in RPC Probes with Laser Induced Electrons

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All types of RPC are operating in very strong and homogeneous electric fields from 50 to 160 kV/cm and gas mixtures at atmospheric pressure. The width of the gas gaps vary between 140 μm and 2 mm.

Especially crucial is the selection of gas mixtures to prevent permanent gas discharges and aging of the electrodes.
For a deeper understanding of the gas discharge under RPC conditions a high precision Laser test facility has been developed at the Helmholtz-Zentrum Dresden-Rossendorf.
In this work we present the performance of the test facility to create micro plasma inside gas gaps with a width of 300 µm up to 1 mm.
The new results for Electron drift velocity and Townsend coefficient will be compared with data from 1 at 100 kV/cm and from 2 at 50 kV/cm for gas-mixtures of R134a/SF6/iso-butane. The Townsend coefficient at 100 kV/cm still remains to low in comparision to Magboltz simulations [3]. Comparison of our results with Chiodini's measurements at 50 kV/cm shows deviations for both the electron drift velocity and the Townsend coefficient.
The test facility allows a fast and precise evaluation of gas mixtures for their suitability for RPC. This is also important for the substitution of all gases with a high global warming effect.

1 L. Naumann et al., JINST 9 (2014) C10009
2 G. Chiodini et al., Nucl. Instrum. Meth. A 602 (2009) 757
[3] W. Riegler et al., Nucl. Instrum. Meth. A 500 (2003) 144

High Luminosity / High Rate / **55**

R&D results of iRPC tested at GIF++ for CMS Phase II upgrade

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In the future Phase-2 LHC runs, LHC instantaneous luminosity will reach a maximum value of 7×10^34 cm^-2 s^-1 and the CMS muon system will be extended up to η (pseudo rapidity) region of 2.4 where the expected maximum particle rate is 600 Hz cm^-2. In view of the expected background conditions, we have studied high-sensitive thin phenolics double-gap RPC models to improve the rate capability in the past few years. The improved Resistive Plate Chambers (iRPCs) has been studied with cosmic muons and with 100-GeV SPS H4 muon beams at CERN at the new Gamma Irradiation Facility (GIF++). The performance of iRPC was tested with a maximum gamma rate of about 4 kHz cm^-2 by using dedicated algorithm for clustering and tracking and fairly satisfies the operational condition required in the future Phase-2 LHC.

Eco Friendy Gases / **22**

R&D studies on eco-friendly gas mixtures for the ALICE Muon Identifier

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Resistive Plate Chambers (RPCs), used for the Muon Spectrometer of the ALICE experiment at CERN-LHC, are currently operated in maxi-avalanche mode with a low threshold value and without amplification in the front-end electronics. The gas mixture is made up of $C_2H_2F_4$, SF_6 and iC_4H_{10}. Since the first two gases have high global warming potentials (GWP), they will probably be phased out of production in the next years, due to the recent restrictions and regulations of the European Union; meanwhile their cost is progressively increasing. The iC_4H_{10} is present in the mixture for ALICE with such a concentration that makes it flammable.

RPC detectors have shown a good operation stability with the current gas mixture during the entire Run 1 and the ongoing Run 2 at the LHC. Nevertheless, finding a new eco-friendly gas mixture will become extremely important in order to reduce the emissions of greenhouse gases. In addition, components in non-flammable concentrations would be advisable to make the operation of detectors simpler and safer. In order to identify a gas mixture with the above characteristics and suited to cope with the requirements of the ALICE Muon Identifier in the forthcoming High-Luminosity runs, a dedicated experimental set-up has been used to carry out R\&D studies on promising gas mixtures with small-size ($50 \cdot 50 \cdot 0.2\ cm^3$) RPCs.

Hydrofluoroolefins (HFOs) are appropriate candidates to replace $C_2H_2F_4$ thanks to their very low GWPs, especially the $HFO1234ze$ which is not flammable at room temperature and has a GWP lower than 1. Several tests on HFO-based mixtures with addition of various gases are ongoing and encouraging results have already been obtained. Furthermore, the use of CO_2 as a quencher has been studied as it might represent a valid solution to avoid flammability of the mixture. Finally, medium-term stability of detectors exposed to the cosmic-ray flux will be shown.

Poster Session / **66**

RE3/1 and RE4/1 chambers integration with Forward region of CMS Muon spectrometer

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By 2027, the Large Hadron Collider luminosity should increase from 1.5 × 1034 cm−2 s −1 to 5 × 1034 cm−2 s −1. For this purpose two more long shutdown (LS) periods are scheduled to give the machine and the experiments the necessary time to anticipate these luminosity increases: Long Shutdown 2 (LS2) in 2018/2019 and Long Shutdown 3 (LS3) in 2023/2025. During these long shutdown periods the CMS Collaboration intends to upgrade several subsystems. In particular, the muon system of CMS detector will be extended in both Endcaps to ensure efficient muon triggering and reconstruction in that region at high luminosity. In the Endcap regions, CMS detector is using Cathode Strip Chambers (CSCs) as muon tracking and trigger detectors and Resistive Plate Chambers (RPCs) serve as dedicated trigger detectors and improve the muon reconstruction by providing the excellent timing resolution for identification muon particles. At the present, the four Endcap discs are not fully equipped: RPCs are missing completely and cover only Endcap disks up to |η| = 1.6. During LS3 these Endcap stations will be instrumented further with new RPCs and Gas Electron Multiplier detectors which will be covering the region of 1.8 <|η| < 2.4. Nowadays, the final design of iRPC chambers and the concept to integrate and to install of these new detectors in the CMS Muon System are developed. In this report, the main results of work about the implementation and the installation of new iRPC detectors in the CMS Muon System at high pseudorapidity η region will be presented.

Poster Session / **64**

RPC Background Simulations in the CMS Experiment at the HL-LHC

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The high luminosity expected from the HL-LHC will be a challenge for the CMS detector. The increased rate of particles coming from the collisions and the radioactivity induced in the material of the detector could cause significant damage and could result in progressive degradation of its performance. Simulation studies are very useful in these scenarios as they allow one to study difficult radiation environments and the impact on the detectors. GEANT4 is used to study the sensitivity of the RPCs to different kinds of radiation particles as a function of their energy.

Poster Session / **53**

RPC Detector Simulation Based on CST

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An early test shows serious "crosstalk" in the strips of the RPC detector for ATLAS Phase II. The unexpected signals on non-main strips increase the invalid counts and system load. To find the orgin of the "crosstalk", we decide to simulate the RPC detector and change relate parameters to eliminate the "crosstalk".
CST (Computer Simulation Technology) is a powerful simulation platform for all kinds of electromagnetic field problems and related applications. CST is suitable for our simulation.We tested some models like high surface resistivity of graphene,add isolating bars between strips or segment the graphene.According to the result of simulation,increase the resistivity of graphene or segment the graphene is effective.

High Rate / New electronics / **9**

RPC performance v.s. Front-End electronics and detector parameters

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The status of the art in realizing and upgrading the RPC performance is presented as an optimal combination of the detector and the front-end electronics features.
We show here a combined analysis of the different parameters characterizing the detector and the FE electronics, in order to obtain the best performance in terms of space and time resolution as well as of rate capability, in different applications.

Upgrade & Longevity / **69**

RPC upgrade project for CMS Phase II

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The Resistive Plate Chambers (RPC's) will be extended to the high pseudo-rapidity region, a challenging region for muon reconstruction in terms of background and momentum resolution, of the CMS muon system where only the Cathode Strip Chambers (CSC) are present. During the last years, several studies on the performance of new technologies and configurations have been done using Monte-Carlo simulations and testing new detectors in the Gamma Irradiation Facility at CERN. The results indicate that the technology to be used for the extension of the RPC system is HPL double gap RPC. The RPC Upgrade Phase II program will be finished with the installation of the chambers during the Yearly Technical Stops at the end of 2022 and 2023. A general talk describing the CMS Phase II upgrade will be presented.

New Physics Experiments / **58**

Search for Heavy Stable Charged Particles in the CMS Experiment using the RPC phase II upgraded detectors

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Several theoretical models inspired by the idea of supersymmetry (SUSY) accommodate the possibility of HSCPs (Heavy Stable Charged Particles). The phase-II upgrade of the CMS-RPC system will allow the trigger and identification of this kind of particles exploiting the Time of Flight Technique with the improved time resolution that a new DAQ system will provide (~2ns). Moreover, new RPC chambers will be installed to extend the acceptance coverage up to $\eta < 2.4$ with similar time resolution and better spatial resolution to complement this search.

In this talk a trigger strategy to detect HSCPs with the RPC detectors is presented, its performance is studied with Monte Carlo simulations and the expected results with the High Luminosity LHC data are shown.

Eco Friendy Gases / **50**

Search for new RPC gases

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Present RPC gas mixtures are all based on the H2C2F4 molecule (tetrafluoro ethane, commercially known as Suva 134a) as the main component. This is characterized by a GWP=1400, which makes it potentially dangerous for the atmosphere. We study here new mixtures based on the H2C3F4 molecule (tetrafluoro propene, commercially known as HFO) which is expected to substitute the tetra-fluorine-ethane for industrial uses. Our study is mainly focused in the efficiency and the avalanche-to-streamer transition measurements. It starts from the binary mixture H2C3F4/CO2, with a CO2 content ranging from 50% to to zero, to which a further quenching molecule is added. The results obtained with different quenchers are presented.

Poster Session / **6**

Simulation and optimization of RPCs read-out panel used in high-rate experiment

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With the upgrade of the RPCs and the increase of its performances, the study and the optimization of the read-out panel is necessary in order to maintain the signal integrity and to reduce the intrinsic crosstalk.
Through Electromagnetic Simulation, performed with CST Studio Suite, new panels design are tested and their crosstalk property are studied.
The behavior of different type of panel is shown, in particular a panel with
grounded strips between the signal strips is presented,
furthermore a panel with this strip connected through their characteristic impedance to the ground plane is simulated to try to minimize the crosstalk signal.

Special Announcement / **84**

Special Announcement

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New Ideas / **2**

Status of MRPC TOF technology

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Time of flight system (TOF) based on MRPC technology is widely used in modern physics experiments, and it also plays an important role in particle identification. With the increase of accelerator energy and luminosity, TOF system is required to indentify definite particles precisely under high rate environment. The MRPC technology TOF system can be defined as three generation. The first generation TOF is based on float glass MRPC and its time resolution is around 80ps, but the rate is relatively low (typically lower than 100Hz/cm2). The typical systems are TOF of RHIC-STAR, LHC-ALICE and BES III endcap. For the second generation TOF, its time resolution is in the same order with the first generation, but the rate capability is much higher. Its rate capability can reach 30kHz/cm2. The typical experiment with this high rate TOF is FAIR-CBM. The biggest challenge is on the third generation TOF. For example, the momentum upper limit of K/PI separation is around 7GeV/c for JLab-SoLID TOF system under high particle rate as high as 20kHz/cm2, the time requirement is around 20ps. The third generation can be called high rate and ultra high time resolution TOF system. In order to reach high rate and 20ps time resolution, we have to develop very narrow gap MRPC, fast preamplifier and high frequency (>5GHz) pulse sampling circuit such as SCA.
In the talk, I will describe the mechanism of MRPC detector and TOF system, the status of the art of three generation TOF will also be discussed.

Performance Reports / **48**

Status of the present ATLAS RPC system and overview towards HL-LHC.

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The RPC system covers the barrel region of the ATLAS muon spectrometer in the pseudo-rapidity range of |eta|<1.05 with six independent detector layers, and

solely provides the L1 trigger signal and the track coordinate in the non-bending plane of the muon candidates.

The system has been designed to operate up to the nominal LHC luminosity (1e34cm-2s-1) which has been already exceeded thanks to the excellent performance of the collider.

The experience in operating the present RPC system, up to the maximum instantaneous luminosity of 2.05 x 1e34 cm-2 s-1 reached in 2017, is reported. The performance of the system, in the severe background and pileup conditions of the last data taking period, is presented together with the improved tools implemented in order to have an effective monitoring of the detector status.

The plans to successfully operate the present system during the HL-LHC phase are also introduced.

Eco Friendy Gases / **10**

Streamer studies in RPCs

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The work presented here is an update of the presentation given in the previous RPC workshop, aimed at finding an eco-friendly gas mixture for streamer operation of RPCs. Indeed the streamer working regime is still suitable for building large RPC systems dedicated to low rate applications, such as cosmic ray and neutrino physics.
As a completion of the gas mixture already considered, the quenching power of CF4, a gas widely used in other gaseous detector, has been investigated in RPCs.
In addition to the gas composition, the effect of the gas gap thickness on discharge quenching has been studied. This is an important check because thin gas gaps of 1 mm, one half of the typical value previously used, have been introduced for the needs of LHC applications.
Finally preliminar results about streamer to avalanche delay are reported. These measurements could be exploited to disentangle between different models of streamer formation.

Vidyo?:

GAS Studies / **79**

Study of flow and control of gas mixture for the Resistive Plate Chamber (RPC) performance

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The RPC performance dependence on several factors like the flow rate, quality of the gas mixture, environment etc. Some simulation studies (CDF) for flow distribution of gas inside the RPC is done which show that, there are some “dead zones”, where the gas does not reach some pockets inside the RPC. The nozzle positions dependence is also observed in the simulation studies. The flow resistors namely the capillaries of different dimensions that could be used to control the flow of gas mixture inside an RPC also studied in detail.
We would like to present the above studies.

New Ideas / **3**

Study of high spatial resolution MRPC for muon tomography

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The muon tomography system built with the 2-D readout high spatial resolution Multi-gap Resistive Plate Chamber (MRPC) detector is a project of Tsinghua University. In 2013 we have developed a prototype of muon tomography system named TUMUTY, and we now try to use more large sensitive scale position resolution MRPC to upgrade the system. The sensitive area is more than 1m2 and it has 864 readout strips. The readout pitch is set to 2.54mm and tripe width is 1.1mm for both X and Y dimension. Because of the low rate muon at sea level and big mounts of readout strips of the system, an encoding readout method based on the fine-fine configuration is used to reduce the number of the readout electronics and thus reducing the complexity and the cost of the system. The fine-fine geometry consists of two sets of readout channels, A and B. All of the even strips are connected to A and the odds to B. This paper study the 12 MRPC’s performance under the encoding readout. The cosmic test shows MRPCs have a working point at 8100V to 8200V when the working gas consists of 95%Freon, 5%SF6 and 5%i-C4H10. The efficiency is around 97% and the cluster size is about 3.6. An X-ray machine is used to measure the spatial resolution. The X-ray beam is collimated with the slotted tungsten and lead bricks. The slotted 2 mm thick tungsten plate is located above and below the lead bricks with a width of 126 μm. The X-ray generator is placed 50 cm above the MRPC and only 81th and 82th strip can be irradiated by the collimated X-ray. The rest area of MRPC is protected by 3mm thick lead plate. The test result shows that the detector’s position resolution are all below 800um and some detector can even reach 500um.All of these results show that MRPC is a good choice for high precision muon imaging system.

GAS Studies / **12**

Study of outgassing in the resistive plate chamber detectors for the INO-ICAL experiment.

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Resistive Plate Chambers are the gaseous detectors and uses gas as their active medium for the detection of charge 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. In order to fulfill the physics goal, about 29,000 RPCs will be used for 20 long years. The quality and purity of the gas play vital role in the stable operation of RPC detectors. 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.

New Ideas / 17

Study on Cosmic Test and QC method of high-rate MRPC for CBM-TOF

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Abstract: In the near future, the CBM (Compressed Baryonic Matter) experiment constructed at FAIR (Facility for Anti-proton and Ion Research) at GSI, Darmstadt, Germany, will provide unique research opportunities to explore the phase diagram of nuclear matter. As one of the core detectors in the CBM experiment, the Time-of-Flight (TOF) system applies MRPC (Multi-gap Resistive Plate Chamber) for a precise particle identification for all the incident charged hadrons. In order to acquire data for rare probes such as charmed hadrons, multiple strange baryons, di-electrons and di-muons, the CBM-TOF will be operated at ion beam intensity up to 10^9 /s. This means the particle fluxes on the TOF wall can reach an unprecedentedly high rate, up to 30 kHz/cm2. Almost half of the MRPC counters are from inner region of the TOF wall, and they will be assembled with low-resistive glass which enables it to work under such high rate. This is the first time of the large scale application of these low-resistive glass MRPCs into the nuclear and high-energy physics experiments. It is especially important to study on the production and test procedure to keep the good performance of all these counters. The design of this MRPC is a double stack counter with 2x4 gas gaps, each 250 μm wide. There are 32 double-ended readout strips on the counter, and each strip is 270 mm long, 7 mm wide with the 3 mm interval. A real-size prototype has already been produced and tested with 30 AGeV Pb beam in SPS Nov 2015 beam test. The observed 98% efficiency and 60 ps time resolution prove that the type of counter fully meet the requirement of CBM-TOF. 750 counters are expected to be ready in one and a half years. For this mass production, we have developed a set of specified manufacturing procedures and quality control method to guarantee the performance of all the counters. A newly developed method to check the uniformity of the gas gap with help of the projection imaging technique has been first applied. In the HV carried out after the assembling, counters are considered qualified with dark current below 50 nA and noise rate below 2 Hz/cm2. A cosmic-ray test system based on TRB board, FPGA TDC and PADI10 front-end electronics are established in our lab. It can provide 256 channels and support 3 MRPCs to be tested with cosmic-ray at the same time. Until now, 40 MRPCs have been produced for the eTOF project in the BESII detector upgrade at STAR. Calibrated and analyzed by the CBM-Root, all the produced counters show a stable performance of 60 ps time resolution and 98% efficiency. An X-ray test also shows the counter's rate ability. All these information from the production and test process are consistent with our expectation. Written into the barcode on the counter and a data recording website, these information are available to anyone who needs. The study on the mass production of the low-resistive plate chamber will provide experience for MRPC widely applied in the high rate experiment in the future. In this paper, the counter design, manufacturing procedures, quality control methods and test results for this MRPC counter are described in a detailed way.

Keyword: MRPC; CBM-TOF; Time-of-Flight; Mass Production; Quality Control; Cosmic Test; High Rate.

High Rate / New electronics / 65

Study the self-noise and detection efficiency in new prototype iRPC

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For the Phase-2 upgrade of the CMS Muon System at high pseudorapidity η, at CERN the large size trapezoidal improve resistive plate chamber (iRPC) prototype with 1.4 mm double-gas gap was developed to test new electronics. The new long trapezoidal PCB (with length of 1645 mm) consisting of 88 stripes with 10 mm wide and thickness of dielectric layer around 550 μm has been installed in this prototype. During December 2017, the large iRPC detector by using DT5742 digitizer from CAEN has been tested in COSMIC stand at CERN. During testing, the self-noise level of the chamber, the detection efficiency and the cluster size were studied.

Withdraw / 37

Systematic Study on a Six Gap Bakelite MRPC in Streamer Mode

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Multi-Gap Resistive Plate Chambers (MRPC) are gas detectors specially used as time of flight (TOF) detector for their excellent time resolution. Mostly, glass based MRPCs have been developed all over the world. To explore parallel possibilities, we have made an effort to build a six-gap MRPC using bakelite electrodes. The MRPC has dimension 15 cm x 15 cm x 1.0 cm. Each gas-gap thickness is $\sim$ 250 μm. Melamine based high pressure laminated (HPL) resistive plates of 3 mm and 500 μm thickness have been used as outer and internal floating electrodes respectively. The detector has shown efficient performance when operated with Freon (R134a) based gas mixtures in avalanche mode. As Bakelite is well known for it's good performance in streamer mode, we have also studied the MRPC in Ar-based streamer mode gas mixture at the cosmic ray setup at VECC. Measurements of efficiency, charge distribution, noise rate, time resolution etc have been performed. Moreover, to develop a detailed understanding of the detector parameters for Multi-Gap bakelite RPCs, we have also started numerical study. The details of the fabrication process of the detector, its performance in streamer mode, the results of numerical study and the future possibilities will be discussed.

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Test Contribution

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New Physics Experiments / **71**

Test of Resistive Plate Chambers as a tracking device for the MATHUSLA experiment

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In the quest for particle dark matter and physics beyond the Standard Model, the possibility of the existence of neutral long-lived particles (LLPs) has been proposed. The MATHUSLA project has been designed to detect possible LLPs produced in LHC collisions with a surface detector built by exploiting existing technologies. The detector will be installed above one of the high-luminosity interaction regions of the LHC before the beginning of the Phase-2 operation. A small-scale MATHUSLA test detector implemented with two stations of scintillators from the D0 experiment and three stations of Resistive Plate Chambers originally designed for the ARGO experiment was installed and operated above the ATLAS interaction point in November 2017. Each RPC station consisted of two detector layers, about 7 m^2 each, with orthogonal read-out strips. The results of the test run will be presented.

Upgrade & Longevity / **45**

The ATLAS RPC system upgrade for the High Luminosity LHC and beyond

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The architecture of the present RPC trigger system in the ATLAS muon barrel was designed according to a reference luminosity of 1034 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 of detector performance and longevity demand. Moreover, the present muon trigger acceptance in the barrel 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 2019 and can be considered as 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, in SiGe technology. 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.

Upgrade & Longevity / **46**

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

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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 (2019-2020).
The BIS78 project proposes to 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 in view of the High Luminosity upgrade of the LHC during Long Shutdown 3 when an additional full layer of new RPC triplets is expected to complement the full barrel region in the innermost plane.

This presentation aims at illustrating the state of art of the project, going through the relevant R&D achievements, tests of prototypes, and chamber design. Details on the 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.

New Physics Experiments / **73**

The CBM Time-of-Flight wall

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The Compressed Baryonic Matter (CBM) experiment aims at exploring the QCD phase diagram at large baryon densities in the beam energy range from 2 A GeV to 11 (35) A GeV at the SIS100 (SIS300) accelerator of FAIR/GSI. For charged particle identification that is required by many observables that are sensitive to the phase structure like collective flow, phase space population of rare hyperons, fluctuations of conserved quantities, - a high performance Time-of-Flight (TOF) wall with a granularity of about 120.000 channels and a system timing resolution of better than 80 ps is being built. The most demanding challenge, however, is the enormous incident particle fluxes between 100 Hz/cm^2 and 25 kHz/cm^2 generated at the highest interaction rates (10 MHz) that CBM is designed for. Part of the wall (∼10.000 channels) will be installed in the forward hemisphere
(1.0 < η < 1.5) of the STAR experiment at RHIC/ BNL during the beam energy scan (BES II) campaign

planned for 2019/2020. This project, called eTOF, is in the scope of the FAIR phase 0 program.
The status and the performance regarding time resolution, efficiency, cluster size and rate capability of the TOF system and in particular of the eTOF system will be discussed.
Work was supported by BMBF 05P15VHFC1

Performance Reports / **59**

The CMS RPC Detector Status and Operation at LHC

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The CMS experiment, located at the CERN Large Hadron Collider, has a redundant muon system composed by three different detector technologies: Cathode Strip Chambers (in the forward regions), Drift Tubes (in the central region), and Resistive Plate Chambers (both its central and forward regions). All three are used for muon reconstruction and triggering. The CMS RPC system confers robustness and redundancy to the muon trigger.

The detector operation in the challenging background and pileup conditions of the LHC environment is presented together with the problems encountered and their corresponding solutions. The CMS RPC collaboration has exploited data samples collected during 2017 at 13 TeV for detector and trigger performance studies. The overall performance results at 13 TeV, plans for the consolidation of the CMS RPC system, in view of the increased luminosity expected in HL-LHC, development status about new RPC data automation utility for the fast withdrawal of RPC condition data to eliminate the necessity of constantly decreasing manpower to run various tools, are reported.

Poster Session / **63**

The CMS RPC system calibration

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The RPC detector system consists of a total of 1056 double-gap chambers, installed both in the barrel and endcap regions. Thus covering the pseudo-rapidity region up to $|\eta| \leq 1.9$, the system contributes to all muon track finders. Establishing the correct HV working points is of primary importance in order to ensure a stable performance reaching optimal efficiency and in the same time to keep the average cluster size of 2 further to the trigger requirements. During 2016 and 2017 data taking, three HV scans have been performed, exploring proton-proton collision data at \sqrt(s) = 13 TeV, different instantaneous luminosity and also with different concentration of Isobitane in the working gas mixture. The latest results from the HV scan in 2017 will be reported.The stability of the detector and comparison with previous scans during Run1 and Run2 will be presented as well.

Poster Session / **74**

The MRPC3b mass production for CBM-TOF and eTOF at STAR

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Abstract: The Compressed Baryonic Matter spectrometer(CBM) is expected to be operational in the year 2024 at the Facility for Anti-proton and Ion Research(FAIR) in Darmstadt, Germany. CBM aims to study strongly interacting matter under extreme conditions. The key element providing hadron identification at incident energies between 2 and 10AGeV (30 AGeV) at SIS100 (SIS300) is a Time-of-Flight (TOF) wall covering the polar angular range from 2.5°−25° and full azimuth. The existing conceptual design foresees a 120 m^2 ToF-wall composed of Multi-gap Resistive Plate Chambers (MRPC) which is subdivided into a high rate region, a middle rate region and a low rate region. The Multistrip-MRPCs, foreseen to be integrated in the low rate region, have to cope with fluxes up to 1 kHz/□cm□^2and therefore will be constructed with thin float glass (0.230mm) as resistive electrode material. In the scope of the FAIR phase 0 program it is planed to install about 36% of this type of counters, called MRPC3b, in the east endcap region of the STAR experiment ar BNL as an upgrade for the Beam Energy Scan campaign (BESII) in 2019/2020.
In this poster we present the design of the MRPC3b counter and report on the CBM-TOF MRPC3b mass production status at USTC, as well as the QC&QA procedure. The MRPC3b counters are integrated in modules at the Heidelberg University and all necessary counter information are stored in a component database. The structure of this database will be explained in this contribution.

New Physics Experiments / **78**

The RPC technology in the SHiP experiment

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SHiP (Search for Hidden Particles) is a new experiment proposal designed to search for particles foreseen in many extensions of the Standard Model and to study neutrino physics. The experiment plans to use the high-intensity SPS proton beam at CERN, dumping in five years 2 x 10^20 protons on a heavy target. A hadron absorber and a muon sweeper are located downstream of the target to reduce down to less than 10^5 muons the output of each 1s-long proton spill. In such a clean environment, a neutrino detector is located to study in particular tau neutrino physics and to observe the interactions with atoms of new particles. Downstream of the neutrino detector, a decay vessel is located to let these new particles decay and a detector is on purpose located downstream of the vessel. The two detectors located in front and downstream of the decay vessel plan to use for different purposes the RPC technology. We will revise the SHiP physics potential and the role played by the RPCs, including a status report of the technology choice done for a few prototype chambers under development. These prototypes will be used for the measurement of the charm cross-section in 400 GeV proton interactions, planned at the SPS in Summer 2018.

New Physics Experiments / **33**

The upgrade of the Extreme Energy Events experiment

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The Extreme Energy Events experiment is the largest system in the world implemented completely with Multigap Resistive Plate Chambers (MRPC). Presently, it consists of a network of 57 muon telescopes, each made of 3 MRPC, located at high schools in Italy, devoted to the study of secondary cosmic rays. The stations, sometimes hundreds of kilometers apart, are synchronized at a few nanoseconds level via a GPS clock. The data collected during centrally coordinated runs are sent to INFN CNAF, where they are reconstructed and made available for analysis. Thanks to the

online monitoring and data transmission, they operate as a single coordinated system spread over the whole Italian territory.

In 2017, the EEE collaboration started an important upgrade programme, aiming to extend the network with 20 additional stations, with the option to have 10 more in the future. This implies the construction, testing and commissioning of 60 chambers, for a total surface of about 100 m2, comparable to the one of the Time-Of-Flight system of ALICE at LHC. Peculiarly, the EEE chambers are built by the students taking part in the project during dedicated internships at CERN; the students also take care of the daily operation and monitoring of the muon stations in their schools.

In this presentation, all the aspects related to this challenging endeavor will be covered, starting from the technological solutions chosen to build these state-of-the-art detectors, to the quality controls and the performance tests performed at CERN and on site.

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High Rate / Infraestructure / **27**

The upgrade of the RPC-based ALICE Muon Trigger

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The muon trigger of the ALICE experiment is currently yielded by 72 Bakelite single-gap Resistive Plate Chambers operated in maxi-avalanche mode (low threshold value, without amplification in the FE electronics), arranged in four 5.5x6.5 m2 detection planes. In order to meet the requirements posed by the forthcoming LHC high luminosity runs from 2020 onwards, in which ALICE will be read out in continuous mode, the Muon Trigger (renamed as Muon IDentifier in the framework of this upgrade) will undergo a major upgrade. In the current setup, signals from 21k strips are discriminated by 2400 non-amplified Front End (FEE) cards, whose thresholds are provided by external reference voltages (one for each chamber side). All these cards will be replaced with discriminators equipped with a pre-amplification stage, so called FEERIC cards, which will allow a reduction in the operating HV of the detectors, thus prolonging their lifetime. Furthermore, the FEERIC thresholds will be set via I2C using wireless allowing the tuning of the values at the single card level , if ongoing validation tests are satisfactory. Moreover, the 24 most exposed RPC chambers will be replaced with new ones, equipped with high-quality (i.e. smoother surface) Bakelite laminates. The tests performed on the FEERIC cards, used both in a test bench and on detectors, and on the new RPC chambers (with cosmic rays) will be reported.

High Rate / New electronics / **40**

ZDAQ a light data acquisition system for beam and laboratory tests

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ZDAQ is a light data acquisition system, based on
ZeroMQ and mongoose-cpp networking frameworks. Providing binary data collection, events building, web accessible finite state machine and process control, it is well suit to manage distribute data source of laboratory or beam test. It provides a simple event building (one unique process, no parallel building) with flexible data writing formats.
It is intensively used for the tests of the Semi Digital HCAL (RPC+Fe) prototype of ILD and also for the tests of the new electronic for improved RPC (CMS upgrade). In this talk, we will present the architecture, some examples and performances of this framework.