XVI Workshop on Resistive Plate Chambers and Related Detectors

Monday, 26 September 2022 - Friday, 30 September 2022

CERN

Book of Abstracts

Contents

New detector applications / **3**

Glass multi-gap RPCs for gamma-ray inspection

Author: Kyong Sei Lee[1]

Co-authors: Giuseppe Iaselli [2]; Dayron Ramos Lopez [2]; Gabriella Pugliese [2]; Youngmin Jo [1]; Minho Kang [1]

[1] *Korea University (KR)*

[2] *Universita e INFN, Bari (IT)*

Corresponding Author: kyong.sei.lee@cern.ch

In the present R&D, multi-gap resistive plate chambers (MRPCs) are studied for non-destructive inspection of small airport cargos. A six-gap RPC of a line-scan type was constructed using soda-lime glass whose bulk resistivity is measured as 7 x 10^11 Ωcm. The thicknesses of the gaps and the glass plates were 0.55 and 0.52 mm, respectively. The typical detector characteristics such as the efficiency and the strip multiplicity were measured using 661.7-keV gamma rays emitted from a Cs-137 source with a current activity of 4.8 GBq. The efficiency for the 661.7-keV gammas measured by the vertically mounted line-scan MRPC detector at a working-point (WP) high voltage of 12.1 kV is about 6% which well agrees with a simulation result performed by using a GEANT program. In order to demonstrate the quality operation of the MRPC detector, we deduced gamma-transmission images for various objects such as spanners, bottles, and fire extinguisher with a spatial resolution of about 2 mm.

Eco-friendly mixtures for RPC detectors / **4**

Eco-friendly Resistive Plate Chamber detectors for future HEP applications.

Corresponding Author: luca.quaglia@cern.ch

Resistive Plate Chamber detectors are largely used in current High Energy Physics experiments being typically operated in avalanche mode with large fractions of Tetrafluoroethane (C2H2F4), a gas recently banned by the European Union due to its high Global Warming Potential (GWP).
An intense R&D activity is ongoing to improve RPC technology in view of future HEP applications. Since a few years the RPC EcoGas@GIF++ Collaboration is putting in place a joint effort between the ALICE, ATLAS, CMS, LHCb/SHiP and CERN Communities to investigate the performance of present and future RPC generations with eco-friendly gas mixtures.
Detectors with different layout and electronics have been operated with ecological gas mixtures, with and without irradiation at the CERN Gamma Irradiation Facility (GIF++). Results of these performance studies together with plans for aging test campaign will be presented.

New experiments / **5**

Test results of a real-size RPC for 3rd and 4th stations of Muon Chamber of the Compressed Baryonic Matter Experiment.

Author: Rajesh Ganai[1]

Co-authors: Abhijit Bhattacharyya [2]; Jogender Saini [3]; Souvik Chatterjee [4]; Subhasis Chattopadhyay [3]; Zubayer Ahammed [3]

[1] *University of Calcutta (IN)*

[2] *University of Calcutta*

[3] *Department of Atomic Energy (IN)*

[4] *VECC*

Corresponding Author: rajesh.ganai.physics@gmail.com

A real-sized trapezoidal Resistive Plate Chamber (RPC) has been developed for the Muon Chamber (MuCh) detector set-up in the upcoming Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR), Darmstadt, Germany. The detector has been tested for its performance with dedicated self-triggered electronics and DAQ chain in presence of a very harsh photon environment at GIF++ facility, CERN, Switzerland during November-2021 beamtime followed by particle rate handling capability test at the m-CBM set-up at GSI, Darmstadt, Germany. At GIF++, the detector was tested for its muon detection efficiency and other related properties in presence of different photon flux incident on it as a background ranging from 0 MHz/cm2 to 2.72 MHz/cm2. Voltage scan and threshold scan were performed at different locations of the incident muon beam on the detector. Previously the performance of the detector was tested in the local laboratory with cosmic rays to optimize its operational parameters.
The various successful test results and future perspectives of the development will be presented.

Detector electronics and simulation / **6**

Development of a sealed MRPC with mylar spacers for high luminosity TOF systems

Authors: Botan Wang[1]; Kai Sun[1]; Xiaolong Chen[2]; Yi Wang[1]; Dong Han[1]; Baohong Guo[1]

[1] *Tsinghua University*

[2] *Tsinghua University (CN)*

Corresponding Author: btwang1998@qq.com

The high luminosity Time-of-Flight (TOF) systems call for timing detectors with both good time resolution and adequate rate capability, which have been fulfilled by the Multigap Resistive Plate Chamber (MRPC) assembled with low-resistive glass electrodes. However, recent tests and operations with high rate MRPCs have given evidence to the luminosity effects, such as the dark current rise and related higher noise rate, which may vitiate the stability in experimental operations. This work conducts a comparative test and confirms the fishline spacers as a source of dark current rise. Then, a sealed MRPC with mylar spacers instead is proposed, developed, and tested. The prototype showed good luminosity tolerance during the X-ray test, and its performances of 95% efficiency and 80 ps time resolution have been validated in cosmic tests.

Poster session / **7**

Angular Dependence of Cosmic Muon Flux - Experimental Measurement and Simulation

Author: Souvik Chattopadhay[1]

Co-authors: Rajesh Ganai [2]; Zubayer Ahammed [3]

[1] *Variable Energy Cyclotron Centre, Kolkata*

[2] *Department of Physics, university of Calcutta, 92, Acharya Prafulla Chandra Rd, Kolkata-700009, India.*

[3] *Variable Energy Cyclotron Centre*

Corresponding Author: souvik.c@vecc.gov.in

Cosmic muon flux and its angular distribution have been measured using Resistive Plate Chamber(RPC) at Kolkata (22° 36' 6.71" N, 88° 25' 7.89" E) at 8 m elevation. Zenith angle was varied upto 90o in clockwise and 900 in anticlockwise direction with respect to zenith direction. The similar scenario was also simulated using cosmic flux following cosnθ distribution. Experiment and simulated result were compared. Details of the measurement technique along with simulation result will be presented.

Detector electronics and simulation / 9

R&D on signal transmission on thin-gap RPC

Authors: Zirui Liu[1]; Xiangyu Xie[1]; Yongjie Sun[1]

[1] *University of Science and Technology of China (CN)*

Corresponding Author: zirui.liu@cern.ch

Thin-gap RPCs with 1 mm gap size are introduced in ATLAS upgrade. Smaller avalanche charge due to the reduced gap size raises concerns for signal integrity. Analytical study of signal transmission process in lossless condition is implemented for RPC. Modelling and simulation will be discussed in detail. Simulated characteristic impedance has been compared with the measured value to validate this model. Different RPC design parameters are studied to evaluate the crosstalk level as well as the signal reflection.

Eco-friendly mixtures for RPC detectors / 11

The ecological transition of the Extreme Energy Events experiment

Author: Marcello Abbrescia[1]

[1] *Universita e INFN, Bari (IT)*

Corresponding Author: marcello.abbrescia@cern.ch

The need of reducing the emission of gases even potentially contributing to the greenhouse effect and climate change has impacted many fields, including scientific research. The Extreme Energy Event collaboration started, already several years ago, a series of tests devoted at finding the ideal replacement of the gases used in the Multigap Resistive Plate Chambers of its network, with other more eco-friendly ones.

After this test phase, successfully concluded with the identification of two very promising binary gas mixtures, data taking has begun with a subset of the telescopes of the EEE network, since January 2022, making of EEE the first experiment in the world completely implemented with MRPCs and running with eco-friendly gas mixtures. Here both results of the tests, and a comparison of the telescope performance measured with the old and the new eco-friendly gas mixtures are presented and discussed.

RPC@LHC / 12

Commissioning and first performances of the ALICE MID RPCs

Author: Livia Terlizzi[1]

[1] *Universita e INFN Torino (IT)*

Corresponding Author: livia.terlizzi@cern.ch

ALICE (A Large Ion Collider Experiment) at the CERN Large Hadron Collider (LHC) is designed to study proton-proton (pp) and heavy-ion (Pb-Pb) collisions at ultrarelativistic energies. The main goal of the experiment is to assess the properties of the quark-gluon plasma (QGP), which is a state of matter reached in extreme conditions of temperature and energy density, where quarks and gluons are deconfined.
One of the main observables used to study the QGP is the production of heavy quarkonia in Pb-Pb collisions. Quarkonia are bound states of a heavy quark (c or b) and the corresponding anti-quark. In order to detect quarkonia via their dimuon decays, ALICE is equipped with a forward muon spectrometer.
During the LHC Run 1 and Run 2 the selection of interesting events for muon physics in ALICE was performed with a dedicated muon trigger system based on Resistive Plate Chambers operated in maxi-avalanche mode. During the long shutdown 2 of LHC that ended this year, ALICE had a major upgrade of its apparatus: from Run 3 (started in July 2022) on, in order to fully profit from the increased interaction rate of Pb-Pb collisions (from 10 kHz to 50 kHz), the ALICE experiment will run in continuous readout (triggerless) mode and the Muon Trigger became the Muon IDentifier (MID).
In order to reduce the ageing and make the RPCs lifetime comparable to the experiment data taking period, and to increase the RPCs rate capability, it was chosen to use the same avalanche mixture, but at lower gain, to reduce the charge released per hit inside the gas gap. The front-end and readout electronics has been upgraded, in order to optimize the detector performance in the new running conditions.
A detailed description of the MID upgrades, together with the results and performance of the RPCs from the commissioning with cosmic rays and the first LHC pp collisions data at the unprecedented center-of-mass energy of 13.6 TeV, will be presented in this talk.

Detector R&D / **13**

High rate, high time resolution, 2D-position sensitive and aging effect suppression Multi-Strip Multi-Gap Resistive Plate Counter

Author: Mariana Petris[1]

[1] *Horia Hulubei National Institute of Physics and Nuclear Engineering (RO)*

Corresponding Author: mpetris@nipne.ro

Compressed Baryonic Matter (CBM) is a fixed target experiment at the future Facility for Anti-proton and Ion Research (FAIR), dedicated to explore the phase diagram of QCD matter at high net baryon densities. With the goal to perform high precision measurements of very rare probes with enough statistics in heavy ion collisions at $\sqrt{s_{NN}}$=2-5 GeV, CBM is designed to run at unprecedented interaction rates of 10^7 interactions/s. Therefore, CBM-TOF wall, based on Multi-gap RPCs (MRPCs), will be exposed at the low polar angles to challenging high counting rates up to 30 kHz/cm^2. Designed to cope with the mentioned high counting rates, the Multi-Strip, Multi-Gap Resistive Plate Counters (MSMGRPCs) developed for the inner zone of the CBM-TOF wall will be equipped with electrodes made of lower resistivity material (~10^{10} Ωcm). The MSMGRPC prototypes shows an efficiency better than 90% with ∼50 ps single counter time resolution up to 30 kHz/cm^2 (highest delivered counting rate in the in-beam test), exposing the whole active area. As it is well known, the long period operation of MRPCs with $C_2H_2F_4$ and SF_6 based gas mixtures leads to aging effects. For this reason, detailed studies of the effect of the high density avalanches induced by a high irradiation dose on a MSMGRPC were performed. The gas pollution effect was evidenced by the deposition of the different radicals produced by polymerization on the anode surface and by the ablation/etching processes on the cathode surface of the resistive electrodes. Enhanced depositions and higher dark rates were also observed around the spacers used for defining the gas gaps between resistive electrodes. Such effects might limit the counter lifetime, therefore it is desirable to keep the

electrode surfaces as clean as possible. In the reported aging studies, the gas exchange in the counter gas gaps occurred via the diffusion process. It is well known and also indirectly evidenced by our measurements that an enhanced gas exchange into the gaps is expected to decrease the chemical radical deposition on the surfaces of the glass plates. Based on these considerations, a MSMGRPC prototype with a directed gas flow through the gas gaps and minimization of the number of spacers in the electric field was developed as mitigation solution of the observed effects. Construction details and results of the comprehensive tests performed with the new developed architecture will be reported.

Detector electronics and simulation / **14**

CMS iRPC FEB development and validation

Corresponding Author: maxime.gouzevitch@cern.ch

The improved RPC (iRPC) chambers, designed using thin low resisitivity High Pressure Laminate gaps, are proposed to equip the very forward region of the CMS detector. They can stand rates of few kHz/cm^2. New electronics equipped with excellent timing precision measurement (< 150 ps) has been developed to read out the RPC detectors from both sides of the strips to allow good spatial resolution along them. A special Front End Boards (FEB), developed to redout the iRPC chamber, is presented. It uses a dedicated version of the PETROC ASIC to amplify and discriminate the signal, and a custom version of delay chain TDC implemented in a Cyclone V FPGA. The design concept and R&D will be described as well as the validation steps on test bench.

RPC@LHC / **16**

The CMS RPC system readiness for LHC Run 3 data taking

Corresponding Author: mariana.vutova@cern.ch

During Run 3, the LHC is preparing to deliver instantaneous luminosity in the range from 5 x 10^34 cm^-2s^-1 to 7 x 10^34 cm^-2s^-1. To ensure stable data taking, providing redundant information for robust muon triggering, reconstruction and identification, the CMS RPC collaboration has used the opportunity given by the LHC long shutdown 2 (LS2), to perform a series of maintenance and preparation activities for the new data taking period, as well as future upgrades (Phase II upgrade). The activities included power, gas and online systems maintenance, as well as installation of gas pipes and kilometers of service cables for future chambers in preparation for Phase II. Thorough detector commissioning with dedicated cosmic data taking periods was performed. The overall performance during the LS2 commissioning period, as well as all activities in preparation for future data taking will be presented.

Poster session / **17**

ML-based tool for CMS RPC currents quality monitoring

Corresponding Author: elton.shumka@cern.ch

The CMS experiment has 1056 Resistive Plate Chambers (RPCs) in its muon system. Monitoring their currents is the first essential step towards maintaining the stability of the CMS RPC detector performance. An automated tool to carry out this task has been developed. It utilises the ability

of Machine Learning (ML) methods in the modelling of the behavior of the current of these chambers. Two types of ML approaches are implemented: Generalized Linear Models (GLM) and Autoencoders. In the GLM case, a set of parameters such as environmental conditions, LHC parameters and high voltage working point are used to characterize the behavior of the detector current. In the autoencoder case, the set of currents for all of the high-voltage channels of the RPC system are used as input and the autoencoder network is trained to reproduce these inputs on the output neurons. Both approaches show very good predictive capabilities, with accuracy of the order of 1-2 μA. These predictive capabilities are the basis for the monitoring tool, which is going to be tested during Run 3. Periodic comparisons between the predicted and measured currents makes possible to notice chamber misbehavior and notify the shifter. All the developed tools are integrated in a framework that can be easily accessed and controlled by a specially developed Web User Interface that allows the end user to work with the monitoring tool in a simple manner.

Poster session / **18**

An FPGA-based clusterization algorithm for the CMS iRPC detector

Corresponding Author: qingfeng.hou@cern.ch

New improved RPC detectors will be installed in CMS stations 3/1 and 4/1 to increase the redundancy of the muon system. Electronics with precise Time-to-Digital converters(TDC) read out signals at both ends of the strips has been developed. The time difference between both ends can be used to calculate the radial position. Clusterization algorithm implemented on Backend electronics is essential to cluster single hits, generate the iRPC trigger primitives and transmit them to EMTF. Distinguished from the formal RPC clusterization algorithm, the new clusterization algorithm takes both strip number and radial position into account when generating the Trigger Primitives - TPs, which is helpful to eliminate the ambiguity in high pile-up conditions. This talk will cover the idea and implementation of how to use position information to form clusters, and some test results will also be provided.

RPC@LHC / **20**

Improved Resistive Plate Chambers for Phase 2 upgrade of CMS

Corresponding Author: amrutha.samalan@cern.ch

In view of HL-LHC, the CMS muon system will be upgraded to sustain efficient muon triggering and reconstruction performance. Resistive Plate Chambers (RPC) serve as dedicated detectors for muon triggering due to their excellent timing resolution. RPC system will be extended up to pseudo rapidity of 2.4. Before long shutdown 3 (LS3), RE3/1 and RE4/1 stations of the forward muon system will be equipped with new improved Resistive Plate Chambers (iRPCs) having different design and geometry w.r.t present RPC system and 2D readout. The iRPC geometry configuration allows to improve the rate capability and hence to survive the harsh background condition during HL-LHC. iRPC demonstrator is installed in CMS during LS2 to study the detector behavior under real LHC conditions. This talk summarizes the iRPC project and its schedule including the status of the iRPC production sites, details of the quality control procedures and results of the commissioning of the demonstrator.

Detector R&D / **22**

Latest results of Longevity studies on the present CMS RPC system for HL-LHC phase.

Corresponding Author: mrm.29691@cern.ch

The present Compact Muon Solenoid (CMS) Resistive Plate Chambers (RPC) system has been certified for 10 years of Large Hadron Collider (LHC) operation at maximum background rate of 300 Hz/cm^2 and integrated charge of 50 mC/cm^2. In the next years, during the Phase 2 of the LHC physics program, called High Luminosity LHC (HL-LHC), the accelerator will increase the instantaneous luminosity up to factor five more than the nominal LHC luminosity, providing to experiments an additional integrated luminosity of about 3000 fb^-1 over 10 years of operation. At HL-LHC phase, the expected rate and integrated charge are about 600 Hz/cm^2 and 840 mC/cm^2, respectively (including a safety factor of three) based on Run 2 data and assuming a linear dependence of the background rates as a function of the instantaneous luminosity. Therefore, the HL-LHC phase will be a challenge for the RPC system since the expected operating conditions are much higher with respect to those for which the detectors have been iliadesigned, and could introduce non-recoverable aging effects which can alter the detector properties. A longevity test is then needed to estimate the impact of HL-LHC conditions on the RPC detector performance in order to confirm that the RPC system will survive the harsher background conditions expected at HL-LHC. A dedicated long term irradiation program has been started at CERN Gamma Irradiation Facility (GIF++) since 2016, where few RPC detectors are exposed to intense gamma radiation for long term to mimic the HL-LHC operational conditions. The main detector parameters (currents, rate, resistivity) are continuously under monitoring as a function of the collected integrated charge and the detector performance has been studied with muon beams. The latest results of the irradiation test will be presented.

23

CMS iRPC Backend and Front-End Electronics joint test

Author: CMS Collaboration[None]

CMS has started Phase 2 upgrade to prepare for the High-Luminosity LHC (HL-LHC). The improved Resistive Plate Chambers (iRPC) will be installed in the challenging forward region with new Front-End Electronics (FEE) to read each strip from both ends. The Backend Electronics(BE) provides fast/slow control for the FEB and performs trigger primitives, data acquisition, and readout. A joint test system was set up to verify the BE functionalities. The slow control based on IPbus was developed to realize functions like powering up and TDC correction for the FEE and configuration for the BE. Besides, the system efficiency was measured and cross-checked with the Lyon FC7 system to ensure the BE works normally.

Detector electronics and simulation / 24

96-channel Time-to-Digital converter (TDC) for the CMS Phase 2 Upgrade of the RPC Link System

Corresponding Author: behzad.boghrati@cern.ch

We describe a 96-channel Time-to-Digital converter (TDC) and its intended state-machines, implemented in field-programmable Gate Array (FPGA) for the CMS Phase 2 upgrade of the RPC Link System. It is realized as a 6U card, called Link Board and will be used at the High Luminosity LHC (HL-LHC). The TDC system operates at an RPC intrinsic time resolution of 1.56 ns, a minimum input pulse width of 3.12 ns, and a minimum separation of 3.12 ns between input pulses. The complete edge-detection and time-stamping process take up to four LHC bunch crossings. The time response

of the TDC is four times shorter than the width of RPC output pulses. It guarantees that a pulse processing of each bunch crossing could be done real-time per each bunch crossing.

Poster session / **26**

Edge Effects in the CMS iRPC detectors

Author: CMS Collaboration[None]

Corresponding Author: borislav.pavlov@cern.ch

Improved Resistive Plate Chambers (iRPCs), designed using thin low resistivity High Pressure Laminate gaps, are proposed to equip the very forward region of the CMS spectrometer. They can withstand rates of a few kHz/cm^2. New electronics equipped with excellent precision timing measurements (< 150 ps) is developed to read out the RPC detectors from both sides of the strips to allow good spatial resolution along them. The iRPC chambers have a petal shape and are organized in rings. They will occupy the innermost ring of the third and fourth station in the muon endcap. To minimize the dead zones on the edges, the iRPC chambers will be installed in a staggered way. To better understand the behavior of the transition region between the chambers a dedicated study has been performed using a small collimated 137Cs radiation source and a cosmic test bench. Local space resolution and cluster size have been measured on the edges and compared to the center of the chamber. This work is showing the results from this study.

Poster session / **27**

Aging studies for the CMS Improved Resistive Plate Chambers

Corresponding Author: mapse.barroso.ferreira.filho@cern.ch

The CMS Phase 2 upgrade is an important project towards the High-Luminosity LHC (HL-LHC) phase. One of the main projects is the development of the new iRPC detectors that will be installed in the forward region of CMS. To validate the performance of the new gaps with HL-LHC radiation levels, experimental tests have been conducted at the CERN Gamma Irradiation Facility (GIF++) facility. One chamber equipped with electronics has been irradiated and its parameters are monitored in function of the accumulated charge. In this work we discuss the chamber performance and the future perspectives.

Poster session / **28**

New Slow Control Emulator for the CMS Phase 2 Upgrade of the RPC Link System

Corresponding Author: behzad.boghrati@cern.ch

In the CMS RPC system, the electronics upgrade for Phase 2 have been foreseen by the RPC community and has been approved in the CMS Muon technical report. This upgrade not only covers the replacement of the off-detector electronics of the present RPC chambers but also includes renovating the legacy Slow Controller with a new version. In this work, at first, we will review the architecture of the legacy RPC Slow Controller and its pros and cons. Then, the new Slow Controller's idea and its architecture will be explained. We also show how the new Slow Control emulator chains with the

new RPC Link System and how this chain is validated. Meanwhile, each of the firmware building blocks and its state machine will be explained.

Poster session / 29

New RPC Link System Remote Programming for the CMS Phase 2 Upgrade

Corresponding Author: behzad.boghrati@cern.ch

The CMS Phase 2 Upgrade has been decided to upgrade most of its subsystems. These subsystems will be modified with brand new electronics, and in some cases, some will install the new version of detectors. Based on this idea, the RPC subsystem plans to upgrade the electronics of the present RPC chambers in the η region up to |1.9| and install the new version of improved RPC chambers in the high η region. Installation of the new RPC Backendend electronics that support both electronics in these two regions has also been foreseen for the Phase 2 upgrade. The main focus of this work is to explain how the electronics of the present RPC chambers, known as the Link System, will be reprogrammed remotely. This electronics will be installed on the balcony of the CMS in the UXC cavern, and during the experiment run, no one will have access to it. As a result, developing a system that can remote program safely and flashback to its main original golden configuration in an unstable condition is mandatory. This work will explain how this remote programming procedure works, how it has been implemented into the new Link System Control Board, and how the new Slow Controller emulator handles these chains.

Poster session / 30

CMS Phase 2 Upgrade of the RPC Link System - Review of the Link Board and Control Board firmware and System validation

Corresponding Author: behzad.boghrati@cern.ch

The electronics upgrade Phase 2 of the present RPC chambers is ongoing in the CMS RPC system. According to the project baseline, this system will be deployed and fully operational at the CMS for Run 3 to fully cope with the HL-LHC condition. Regarding this goal, the design and prototyping of the new Link System has started a few years ago, and now the final prototyping of this system is ready for final validation. For this reason, we decided to review the electronics architecture of the new Link Board and Control Board, the main building blocks of the Link System, and explain in more detail their firmware and state machine controller. We also describe the idea of the low latency multi-hit capturing in the Link Board and will show how every hit gets a timestamp at the high precision time to the digital converter unit. Moreover, we explain how every two Link Board, known as Slave Link Board, send their data to their adjacent Link Board, called Master Link Board, through the internal local bus on the front panel board by the GBT-FPGA data transmission protocol. In the same way, we will review the slow control command controller on each of the Link Board and Control Board. The system diagnostic, including the hit rate histogramming, RPC signal raw data logging, and the beam timing profile histogramming will be presented.

Poster session / 31

RPC based tracking system at CERN GIF++ facility

Corresponding Author: kevin.mota.amarilo@cern.ch

With the HL-LHC upgrade of the LHC machine, an increase of the instantaneous luminosity by a factor of five is expected and the current detection systems need to be validated for such working conditions to ensure stable data taking. At the CERN Gamma Irradiation Facility (GIF++) many muon detectors undergo such studies, but the high gamma background can pose a challenge to the muon trigger system which is exposed to many fake hits from the gamma background. A tracking system using RPCs is implemented to clean the fake hits, taking profit of the high muon efficiency of these chambers. This work will present the tracking system configuration, used detector analysis algorithm and results.

Poster session / **32**

Strip Printed Circuit Board - PCB validation and properties for CMS iRPC during Phase 2 Upgrade

Corresponding Author: garde@ipnl.in2p3.fr

Designed using thin low resisitivity High Pressure Laminate gaps, the improved RPC (iRPC) chambers are proposed to equip the very forward region of the CMS detector, since they can stand rates of few kHz/cm^2. A dedicated three layers Printed Circuit Board (PCB), carrying 48 strips each, has been designed to collect the pick-up signal from both ends of each strip. It transmits the signal to the Front End Board (FEB) via internal return lines connected to an ERNI connector. Its large trapezoidal size (1m long and 30-60 cm large) for a total thickness of 600 micrometers, makes this device quite exceptional. A dedicated R&D is carried out to maximise the output signal strength: maximise the pickup charge, minimize the transition losses, keep a constant impedance inside the PCB to minimize the reflections and match this impedance to the one of the FEB. Results from the first prototypes will be presented: performance, impedance, speed of signal, pick-up charge attenuation and total attenuation during transit.

Poster session / **33**

Gas gain properties of the CMS iRPC chamber

Corresponding Author: tahany.abdelhameid@cern.ch

The improved RPC (iRPC) chambers are designed using thin low resistivity High Pressure Laminate gaps. They are proposed to equip the very forward region of the CMS detector, as they can stand rates of few kHz/cm^2. The gas gain of the chamber, corresponding to the total charge production for a MIP, has been carefully studied as a function of the rate and threshold. In particular the behaviour of the gain with atmospheric pressure has been parameterized. It is found to be similar to the actual RPC CMS chambers. The behaviour of the gain with the overpressure inside the gas gap have also been studied. This work presents all obtained results.

Detector electronics and simulation / **34**

Simulation of the avalanche creation in resitive circular chambers

Author: Oliver Kortner[1]

[1] *Max Planck Society (DE)*

Corresponding Author: kortner@mppmu.mpg.de

Resistive plate chambers (RPCs) are the ideal technology for the instrumentation of muon systems at high-energy particle colliders where excellent subnanosecond time resolution and reasonable spatial resolution of the order of 1 mm are required. Conventional RPCs with planar electrodes have the disadvantage that these cannot be operated at large overpressure. This limitation is overcome by the newly proposed so-called "resitive circular chambers" (RCC) where the planar gaps are replaced by gaps between two concentric cylinders. Another important advantage of an RCC is the fact that the electric field within the gap is not constant, but decreases slightly with increasing radius such that the avalanche creation is only suppressed due to shape of the electric field within the gap.
In order to optimize the geometrical dimension of an RCC and the gas mixture for an RCC a microscopic simulation of the avalanche creation within an RCC has been developed. The simulation programme uses the Garfield++ library with its interface to Magboltz for the electron atom cross sections. In this contribution the simulation programme, its predictions, and comparisons with measurements on RCC prototypes will be presented.

New detector applications / 35

A Large-Area RPC Detector for Muon Tomography

Author: Joao Pedro De Carvalho Saraiva[1]

Co-authors: Carlos Alemparte [2]; Daniel Belver [2]; Alberto Blanco [3]; Juan Callón [2]; Jose Collazo [2]; Alfredo Iglesias [2]; Luís Lopes [3]

[1] *LIP - Laboratorio de Instrumentação e Física Experimental de Partículas (PT)*

[2] *Hidronav Technologies SL*

[3] *LIP Coimbra*

Corresponding Author: joao.pedro.saraiva@cern.ch

A cosmic ray telescope equipped with four RPCs of almost 2 m² per plane was constructed at LIP Coimbra in partnership with the Hydronav company (Spain). In view of a possible application for muon scattering tomography, the telescope was tested during several days with high-atomic-number materials, such as tungsten and lead, located at the center of the telescope with two RPCs on each side. Designed to work outside the traditional lab environment, the telescope was afterward operated in an industrial environment. Some features of the specific design include for instance: (1) each detector plane and the respective instrumentation is confined in an aluminum enclosure requiring for operation only three connections to the outside: gas, power and communication, making the maintenance and possible replacements easier; (2) the glass stack of each RPC is encapsulated in a tight polypropylene plastic box, which has excellent water vapor blocking properties as well as good impermeability to atmospheric gases, allowing its operation in stable conditions with a gas flux around 1 cm³/min/m².
With an intrinsic efficiency of 98% and spatial resolution around 1cm, the response of the detector operated at low gas flow regime is shown in this communication. Additionally, preliminary results of the muon tomography performed with high-Z shielding will also be presented.

Poster session / 36

Characterization and Simulation of Glass Multigap RPCs

Author: Severiano Carpinteyro Bernardino[1]

Co-authors: Cecilia Uribe Estrada [2]; Jalil A. Villalobos Alba [1]; L. Michelle Ramos Regino [2]; Mateo Ramirez Garcia [1]; Victor O. Ramírez Beltrán [3]

[1] *Universidad Iberoamericana (MX)*

[2] *Autonomous University of Puebla (MX)*

[3] *Universidad Iberoamericana (MX*

Corresponding Author: bernardino.carpinteyro@cern.ch

Resistive Plate Chambers (RPCs) are inexpensive and easy-to-build gaseous detectors with very good spatial and temporal resolution. These features make them very attractive and they are largely used in high energy particle experiments. RPC electrodes can be made of different kinds of materials with baquelite and glass being the most common. We present the characterization and simulation results of a glass multigap resistive plate chamber (MRPC) with 6 (0.25mm) gaps using atmospheric muons.

New detector applications / **37**

An RPC-PET brain scanner: first results

Author: Paulo Fonte[1]

[1] *Laboratório de Instrumentação e Física Experimental de Partí(LIP-Coimbra)*

Corresponding Author: fonte@coimbra.lip.pt

We present first results from a prototype PET scanner based on Resistive Plate Chambers and specialized for brain imaging. The device features a 30 cm wide cubic field-of-view and each detector comprises 40 gas gaps with 3D location of the interaction point of the photon. Besides other imagery, we show that the reconstructed image resolution, as evaluated by an hot-rod phantom, is sub-millimetric, which is beyond the state-of-the-art of the standard PET technology for this application.

New experiments / **38**

The new HADES ToF Forward Detector

Authors: Alberto Blanco Castro[1]; Joao Pedro De Carvalho Saraiva[1]; Luís Lopes[2]; Paulo Fonte[None]

[1] *LIP - Laboratorio de Instrumentação e Física Experimental de Partículas (PT)*

[2] *LIP Coimbra*

Corresponding Author: alberto.blanco.castro@cern.ch

The HADES (High-Acceptance DiElectron Spectrometer) at GSI Darmstadt consists of a 6-coil toroidal magnet centered on the beam axis and six identical detection sections located between the coils and covering polar angles between 18° and 85°. The physics aims include the study of the properties of hot and dense hadronic matter—a key problem in heavy-ion physics—as well as elementary and pion-induced reactions.

To increase the acceptance of the HADES spectrometer, a new detector has been built to cover the very low polar angles, between 0.5° and 7°, in the forward region. This new forward detector (FD) is composed of a tracking detector and a TOF detector. The TOF detector, covering an active area of around 2 m², is composed by 128 strip-like shielded RPC cells, with two different widths 22 mm and 44 mm and 750 mm length distributed in four modules symmetrically placed around the beam axis. Each cell is composed by four gas gaps delimited by three (2 mm) aluminum and two (1 mm) glass electrode. In order to cope with the expected particle load of around 600 Hz/cm² close to the beam axis the detector is operated above room temperature (30°) in order to decrease the resistivity

of the glass and increase the count rate capability (one order of magnitude reduction on resistivity is expected every 25°).

The detector was operated in both, an engineering test beam and in a production beam time during six weeks in 2022. The system and the results concerning stability and timing precision of the system (~80 ps) when operated at 30 ° are described.

RPC@LHC / **40**

Optimization of the production procedures of thin-gap RPCs

Authors: Oliver Kortner[1]; Hubert Kroha[1]; Daniel Soyk[1]; Timur Turkovic[2]

[1] *Max Planck Society (DE)*

[2] *Max-Planck-Institut für Physik*

Corresponding Author: turkovic@mpp.mpg.de

Resistive plate chambers (RPCs) with thin gas gaps (~1 mm) between two high-pressure phenolic laminate plates offer excellent time resolution down to a few hundret picoseconds and a decent spatial resolution of the order of a few millimiters. As RPCs can be produced at relatively low costs they are the ideal choice for the instrumentation of large areas of many experiments. In order to set up a production at external companies we investitated several modifications of the established production procedures of RPCs in order to adapt it to the available devices at different companies and to facilitate the technology transfer to industry. In our contribution we will describe our studies and compare the different options for the individual production steps. We shall present the results of our a test production carried out in our institute and show the performance of the produced gaps obtained in tests with muons from cosmic rays.

Poster session / **41**

Test of materials for the production of thin-gap RPCs

Authors: Oliver Kortner[1]; Hubert Kroha[1]; Daniel Soyk[1]; Timur Turkovic[2]

[1] *Max Planck Society (DE)*

[2] *Max-Planck-Institut für Physik*

Corresponding Author: turkovic@mpp.mpg.de

Resistive plate chambers (RPCs) with electrodes of high-pressure phenolic laminate (HPL) are a well established technology for the instrumentation of muon systems at high-energy particle colliders. The gap between the HPL plates is electrodes is defined by spacers and lateral profiles made of polycarbonate. The outer surfaces are covered with sheets of polyethylene terephthalate PET.

It is known that PET foils are difficult to glue as most of the glues used for plastics can be easily ripped off the PET surface. We therefore compared different types of glues, ranging from EVA hotmelts to special glues for PET foils, regarding the quality of the glue bond and their outgasing properties.

At the moment there is only one certified producers for HPL plates that is able to provide plates with the required resistivity. We started a search for alternative suppliers of the HPL plates providing first samples with resistivity close to the required range.

In our contribution we will present our studies of different glues and the search for a new supplier of HPL plates.

New experiments / **42**

Development of a Precise Time and Position Resolutions TOF-tracker RPC for the pi20 Beamline at J-PARC

Author: Ryusuke Uda[1]

[1] *Department of Physics, Osaka University*

Corresponding Author: uda@ne.phys.sci.osaka-u.ac.jp

In hadron hall at J-PARC, we plan to measure the cross sections for exclusive Drell-Yan reaction ($\pi^- p \to \mu^+ \mu^- n$) for determining the generalized parton distribution function. We are developing a TOF-tracker RPC to identify muons in this reaction. To remove background muons from decays in flight of kaons and pions, precise time resolution (~100 ps) and precise position resolution (~1 mm) are required. We have developed a prototype TOF-tracker RPC with an area of 500 mm $\times$ 1000 mm and a strip pitch of 5 mm. We will report the performance of the prototype TOF-tracker RPC.

Detector electronics and simulation / **43**

The reflection readout method of RPC

Author: Yuexin Ding[1]

Co-authors: Xiangyu Xie ; Kunlin Han ; Yongjie Sun

[1] *University of Science and Technology of China (CN)*

Corresponding Author: yuexin.ding@cern.ch

The conventional readout method of the RPC detector uses two sets of orthogonal readout strips placed at the both sides of the gas gap to collect signals of opposite polarities to obtain space points. A new readout method utilizing the reflection signal is proposed which only requires one set of readout strips. The reflection readout method utilizes the differences in the arrival times of the direct and reflected signals to determine the hit position. Customized transmission cables are introduced to extend the propagation distance of reflected signals to ensure sufficient separation of the two signals. Because only one side of the readout panel is connected to the FE boards, reflection readout method could reduce the readout channels and simplify the RPC structure. Experimental setup and test results of this novel readout method will be presented.

Detector electronics and simulation / **44**

Parallelization of Garfield++ and neBEM to simulate space charge effects in RPCs

Author: Tanay Dey[None]

Co-authors: Nayana Majumdar [1]; Purba Bhattacharya [2]; Subhasis Chattopadhyay [3]; Supratik Mukhopadhyay [4]

[1] *Saha Institute of Nuclear Physics*

[2] *Department of Physics, School of Basic and Applied Sciences, Adamas University*

[3] *VECC*

[4] *Saha Institute of Nuclear Physics (IN)*

Corresponding Author: tanay.phyexam@gmail.com

The detailed avalanche, saturated avalanche, and streamer simulation can help understand the detector physics behind the Resistive Plate Chamber (RPC). From a 3D Monte Carlo simulation of an avalanche inside an RPC, the transition from avalanche to saturated avalanche (when electron gain and loss are almost the same) followed by a streamer may be understood in more detail. Such simulation is preferable to search for the optimum voltage and alternate gas mixtures.
Garfield++ with appropriate interfaces to Heed (primary ionization), Magboltz (transport properties), and neBEM (electric field) is a freely available C++-based software using which one can make the numerical geometry of a gas detector and examine the physics inside them. All the methods available in Garfield++ to generate an avalanche follow the 3D particle model. One of the advantages of the particle model is that one can extract information (drift velocity, energy, etc.) from every step of the avalanche with detailed tracking of each primary and secondary. Since the methods of GARFIELD++ are sequential, they are resource-hungry and time-consuming. This is especially true when attempts are made to study the effect of space charge accumulation within the device. At the same time, the space charge field plays a crucial role while an avalanche is developing. The dynamic change of the electric field inside the RPC due to space charges limits the gain of an avalanche, which is called the space charge effect.
In this work, the primary goal is to build a numerical model to calculate the dynamic space-charge field inside an RPC and implement it in the GARFIELD++ framework. The multithreading technique OpenMP has been applied to calculate electric field, drift line, electron gain, and space charge field to address the issue of extensive time consumption. Here, the space charge region is modeled by using several charged lines. Therefore, the field has been estimated for those line charges. The field calculations have also been verified with the neBEM. All these modifications in GARFIELD++ have been applied by introducing a new class, pAvalancheMC. An example is provided to show the performance of pAvalancheMC. Moreover, the details of the transition of an avalanche into a saturated avalanche have been discussed.

New detector applications / **46**

Study of time resolution of MRPC for cosmic rays and 0.511MeV photons

Authors: Jianing Liu[1]; Yi Wang[2]; Baohong Guo[None]; Yancheng Yu[None]; Yuanjing Li[None]

[1] *Tsinghua university*

[2] *Tsinghua University*

Corresponding Author: liu-jn20@mails.tsinghua.edu.cn

The traditional TOF-PET(Positron emission tomography) mainly uses the structure of a scintillator detector connected to a photomultiplier tube. The structure has the disadvantages that time resolution is not good enough (greater than 50ps), the thickness of the scintillator is large (greater than 3cm), and the reception is small, resulting in a waste of information, long detection time, and poor accuracy. The high cost of traditional TOF-PET limits its widespread use in medical and other fields. The excellent time resolution (about 20ps) of MRPC makes MRPC TOF-PET a good application prospect. This paper shows the time resolution of two 32-gap MRPCs with 128 μm gap thickness on cosmic rays and 0.511MeV photons. By using the fast amplifier and waveform digitizer system, the time resolution of 27 ps for cosmic rays and 72 ps for 0.511 MeV photons are obtained. The reason for the analysis is related to the different ways different particles act and the thickness of the detector.

New experiments / **47**

R&D of prototype iTOF-MRPC at CEE

Authors: Yingjie Zhou[1]; Xingjian Wang[1]; Dongdong Hu[1]; Ming Shao[1]

[1] *USTC*

Corresponding Author: zhouyingjie@mail.ustc.edu.cn

The Cooling Storage Ring (CSR) External-target Experiment (CEE) is a multipurpose nuclear physics experimental device to operate in the GeV energy range at the Heavy-Ion Research Facility (HIRFL-CSR) in Lanzhou, China. The primary goals of the CEE are to study the bulk properties of dense nuclear matter and to understand the quantum chromodynamic (QCD) phase diagram by measuring the charged particles produced in heavy-ion collisions at the target region with large acceptance. An inner time of flight (iTOF) system has been proposed to measure the multiplicity and time information of the charged particles. To meet the requirements of high granularity and high precision timing performance ($\sigma_t \sim 30$ ps)the multi-gap resistive plate chamber (MRPC) technology is used. In this report, we will report our approach to improving the time resolution of MRPC, including the optimization of MRPC structure, the consideration of signal integrity, and the improvement of readout electronics. The performance of iTOF-MRPC prototypes are presented according to the cosmic ray test. A timing resolution of better than 30 ps and an efficiency of better than 95% have been achieved.

New experiments / **48**

CODEX-b: a novel detector to probe the dark sector at the HL-LHC

Author: Biplab Dey[1]

[1] *Eotvos U.*

Corresponding Author: biplabdey@yahoo.com

The High Luminosity LHC will be a tremendous opportunity to search for long lived particles (LLPs) from an extended hidden/dark sector, feebly connected to the known SM sector. Such LLP searches will require special detectors, placed far away from the proton-proton collision point and shielded against SM backgrounds. The CODEX-b detector, to be placed behind a thick shielding wall inside the LHCb cavern, around 25m from the LHCb interaction point, provides a novel solution. A crucial aspect is the detector technology that can provide good resolutions in both tracking (~mm) and timing (~100ps), and be inexpensive to cover large volumes. RPCs are very attractive for this purpose. This talk will give an overview of the CODEX-b proposal and describe the ongoing and future R&D towards its construction.

New detector ideas / **50**

Development of ultra-low mass and high-rate capable RPC based on Diamond-Like Carbon electrodes for MEG II experiment

Author: Kensuke Yamamoto[1]

Co-authors: Atsuhiko Ochi [2]; Atsushi Oya [3]; Kei Ieki [4]; Masato Takahashi [5]; Rina Onda [1]; Sei Ban ; Wataru Ootani [6]

[1] *The University of Tokyo*

[2] *Kobe University (JP)*

[3] *University of Tokyo (JP)*

[4] *University of Tokyo*

[5] *Kobe University*

[6] *ICEPP, University of Tokyo*

Corresponding Author: kensukey@icepp.s.u-tokyo.ac.jp

A novel background identification detector is under development for the MEG II experiment, aiming at further sensitivity improvement in the $\mu \to e\gamma$ decay search. This detector needs to detect MIP positrons in a low-momentum high-intensity muon beam. Extremely low-mass design of radiation length of 0.1% is required because the muon beam of $28\ \mathrm{MeV}/c$ passes through the detector. In addition, high rate capability of up to $4\ \mathrm{MHz/cm^2}$ is required because the penetrating muon beam is at $10^8\ /\mathrm{s}$ in total.
This detector is Resistive Plate Chamber based on Diamond-Like Carbon electrodes (DLC-RPC). It has thin-film resistive electrodes based on DLC coating for low-mass design. A high efficiency for MIP of 85% and a good timing resolution of 200 ps have already been achieved with a small prototype detector.
In this study, DLC-RPC performance particularly in the high-rate muon beam and its scalability are studied. Avoiding voltage drop at high rate, segmented HV supply with 1 cm pitch and low DLC resistivity of $10\ \mathrm{M}\ /\mathrm{sq}$ are designed to fulfill rate capability requirement of $4\ \mathrm{MHz/cm^2}$. The segmentation is also necessary for scalability. We produced and tested new prototype detector with the segmented HV supply and the low DLC resistivity. High rate capability of first prototype detector will be presented. Moreover, the construction and performance of improved prototype detector will be presented.

New detector ideas / **51**

Development of Resistive Cylindrical Chambers

Authors: Alessandro Rocchi[1]; Roberto Cardarelli[1]

Co-authors: Anna Di Ciaccio [1]; Barbara Liberti [1]; Daniel Soyk [2]; Enrico Pastori [1]; Giorgia Proto [1]; Giulio Aielli [1]; Giuseppe Iacobucci [3]; Hubert Kroha [2]; Lorenzo Paolozzi [4]; Luca Pizzimento [1]; Luigi Di Stante [1]; Oliver Kortner [2]; Paolo Camarri [5]

[1] *INFN e Universita Roma Tor Vergata (IT)*

[2] *Max Planck Society (DE)*

[3] *Universite de Geneve (CH)*

[4] *CERN*

[5] *University of Roma "Tor Vergata"*

Corresponding Author: roberto.cardarelli@roma2.infn.it

A new generation of gaseous particle detectors named Resistive Cylindrical Chamber (RCC) has been developed to overcome the limitations of Resistive Plate Chambers and broaden their application range. The principle behind this new technology consists in the transition from a planar to a cylindrical geometry while maintaining an almost planar electric field. The cylindrical structure of the electrodes allows to reach the following goals: increase the gas pressure to improve the intrinsic efficiency of the detector even for thin gas gaps or light gas mixtures; design the detector in order to produce an electric field gradient useful to contain the development of the avalanche discharge. These feautures allow to design detectors of simple mechanical realization with time resolution comparable with that of MRPCs maintaining a high efficiency of detection on a single thin gas-gap.
The device pressurization also allows to use new gases in view of the transition to eco-friendly gas

Eco-friendly mixtures for RPC detectors / **52**

Characterization of a RPC prototype with 1mm of gas gap thicknesses

Author: Dayron Ramos Lopez[1]

Co-authors: Gabriella Pugliese [1]; Giuseppe Iaselli [1]; Jan Eysermans [2]; Kyong Sei Lee [3]; Minho Kang [3]; Youngmin Jo [3]

[1] *Universita e INFN, Bari (IT)*

[2] *Massachusetts Inst. of Technology (US)*

[3] *Korea University (KR)*

Corresponding Author: dayron.ramos.lopez@cern.ch

In the framework of the well-known improved rate capability and time resolution of Resistive Plate Chamber type detectors with thinner gap sizes, it has been carrying out the performance characterization of a new RPC prototype with 1mm gas gap thickness. The RPC prototype, with a single gap configuration, was tested in the GIF++ facility at CERN under a muon beam with a momentum range from 10 GeV/c up to the maximum SPS momentum of 450 GeV/c and high gamma radiation conditions produced by a Cs-137 source up to 12 TBq. Given the global warming potential of the standard gas mixture based on freon, it was also studied the detector response using gas mixtures based on HFO and CO2, with the aim to find a new eco-friendly gas mixture. During the test were obtained the maximum muon efficiencies for the standard*, ECO2**, and ECO3*** gas mixtures respectively. As well, were studied the muon and gamma cluster features and current density for each gas under study. Finally, it was measured the time resolution using the ToF method.

* R134a-95.2%, iC4H10-4.5%, SF6-0.3%
**HFO-35%, CO2-60%, iC4H10-4%, SF6-1%
***HFO-25%, CO2-69%, iC4H10-5%, SF6-1%

Poster session / 53

The readout panels for the BI-RPC project for ATLAS phase 2 upgrade

Corresponding Authors: marco.schioppa@cern.ch, schioppa@cs.infn.it

To take full advantage from the LHC upgrade to high luminosity in 2029, the ATLAS community has approved an intensive detector upgrade program that includes the construction of an additional trigger layer positioned close to the BI MDT chambers of the muon spectrometer. These chambers are RPC with thin gas gap, thin High Pressure Laminate electrodes coated with graphite on one side, and only use strips orthogonal to the beam-axis to reconstruct the eta and phi coordinates of the detector point where an ionizing particle passes. A detailed description of the construction and validation of these strip panels in China and Italy assembly sites, is presented here.

Poster session / 54

Development of new offline analysis for the monitoring of RPC detector at the ATLAS experiment parameters during LHC Run3

Corresponding Author: antonio.giannini@cern.ch

The ATLAS experiment at the LHC consists of several sub-detectors for triggering on particle candidates. The Level-1 muon trigger system uses Resistive Plate Chamber (RPC) detectors to identify muon trigger candidates in the barrel detector region. The ATLAS RPCs are arranged in three concentric double layers and consist of around 3700 gas volumes, with a total surface of more than 4000 square meters. Diverse sources of information regarding the RPC detector state are continuously

monitored in real-time using the Detector Control System (DCS). The DCS monitors RPC temperature, currents and gas flow parameters, as well high voltage and threshold settings. This information is archived and accessible for offline analysis. This contribution will first summarise measurements of RPC performance in 2018 that were published since the previous workshop. Then it will discuss new offline analysis procedures that are being developed for automatic monitoring of RPC detector parameters during Run 3. These procedures analyse RPC currents as a function of instantaneous luminosity, temperature, and pressure, in order to monitor RPC conditions during Run 3 operations. These procedures were applied to analyse archived DCS data from 2018 in order to identify RPCs with unusual response, for example due to a developing gas leak. Preliminary results for 2018 data and for new Run 3 collision data will be presented.

Poster session / **55**

Oil-free bakelite Resistive Plate Chambers- A solution to several age old problems.

Author: Rajesh Ganai[1]

[1] *GSI, Darmstadt, Germany*

Corresponding Author: rajesh.ganai.physics@gmail.com

Several experiments in High Energy Physics and Neutrino Physics use Resistive Plate Chambers (RPCs) made of bakelite electrodes for more than a couple of decades. There are several future experiments that may use bakelite RPCs. Most of these experiments use bakelite electrodes coated with polymerized linseed oil on their inner surfaces. It has been a common practice for ensuring the long-term stability of the RPC modules. However, oil-coated bakelite RPCs have several problems not only during developmental stages but also in their performances.
In the conference, how a noble idea of indigenous development of oil-free bakelite RPC has solved the problems associated with oil-coated RPCs, retaining the performance of these detectors will be presented. Also, the development of oil-free bakelite MRPC along with its performance will be discussed.

Poster session / **56**

Prototype of Industrialized RPC for J-PARC E50 experiment

Authors: Chia-Yu Hsieh[1]; Ming-Lee Chu[2]; Po-Lu Lin[3]; Wen-Chen Chang[2]

[1] *Academia Sinica (TW)*

[2] *Institute of Physics, Academia Sinica, Taiwan*

[3] *Institute of Physica, Academia Sinica, Taiwan*

Corresponding Author: cyhsieh0531@gmail.com

We build up a small 250mmx250mmx24mm prototype RPC to test
the possibility of the industrialized construction in order to reduce the man power and increase the stability during the mass construction. The concept of sensitive volume of SHiP RPC is adopted to our design with some modifications. The sensitive volume is composed of a 8mm-thick acrylic frame, two 8mm-thick PCB boards, and a single-stack-multi-gap RPC structure. Two 8mm-thick PCBs server as the end caps of the 8mm-thick acrylic frame to enclose the gas-tight sensitive volume by O-ring with two feed-troughs of gas. Compared to the design of SHiP RPC which hardly seal the sensitive volume with glue, we utilize O-ring to create the gas tight space which is more industrial and convenient way. In addition, we use two 8mm-thick PCBs instead of acrylic plates as the caps of sensitive volume reduce the material of active area particles pass through. The 8-mm thick PCB

is a multi-layer structure serve as the electrode, read-out strips, shielding plane. The electrodes are directed printed on PCB which is known as carbon-less electrodes. The carbon-less electrodes has been practiced and used in CMB experiment and it provides an industrialized way produce electrodes. Compared to the traditional electrodes made by carbon paint or carbon tapes, it is much cheaper and straight-forward. The difference between our design and CBM design is that both our electrode and readout strip are printed on one PCB, not separated like CBM RPCs. Furthermore, an extra shielding layer is designed in the PCB to prevent the noise from the environment to interfere the signals of readout strips. The read-out is 20mmx20mm strips with readout on both end. Both HV and FEE are directly connected to the outer surface of PCB which is decoupled from the gas volume. It makes the work of assembling, repair, and replacement of FEE much easier. Inside the gas-tight sensitive volume, it houses a one-stack RPC with ten gas gap defined by eleven 400um-thick alkali-free glass separated by 260um nylon fishing line with 200mmx200mm active area. The prototype will be equipped with low-jitter and high-gain FEE and tested with cosmic ray. The salient features of this prototype are to be implemented in constructing the RPCs for TOF and position measurement in the J-PARC E50 experiment.

Eco-friendly mixtures for RPC detectors / **57**

On a new environment-friendly gas mixture for Resistive Plate Chambers

Authors: Giorgia Proto[1]; Liberti Barbara[2]; Rinaldo Santonico[1]

Co-authors: Giulio Aielli [1]; Paolo Camarri [3]; Roberto Cardarelli [2]; Anna Di Ciaccio [1]; Luigi Di Stante [3]; Alessandro Paoloni [4]; Enrico Pastori [2]; Luca Pizzimento [2]; Alessandro Rocchi [2]

[1] *INFN e Universita Roma Tor Vergata (IT)*

[2] *INFN*

[3] *Università degli Studi di Roma Tor Vergata*

[4] *Laboratori Nazionali di Frascati (LNF)*

Corresponding Author: giorgia.proto@cern.ch

The standard gas mixture for the Resistive Plate Chambers (RPC), composed of $C_2H_2F_4$/i-C_4H_{10}/SF_6, allows the detector operation in avalanche mode, as required by the high-luminosity collider experiments. The gas density, the low total charge delivered inside the gas and the comfortable avalanche-streamer separation guarantee high detection efficiency, rate capability and slow detector ageing.
The standard RPC gas mixture is mostly based on Hydrofluorocarbons, HFCs, extensively used in the refrigeration industry. The Hydrofluorocarbons are now considered to be non-eco-friendly gases for their high Global Warming Potential (GWP). The SF_6 has the largest GWP, 22900, but, due to its low concentration, it contributes only with few tens of units to the total value. The major contribution comes from the main standard gas mixture component, the $C_2H_2F_4$ (GWP $\sim$ 1300). This gases are not recommended for industrial uses anymore, thus their availability will be increasingly difficult over time and the search for an alternative gas mixture with low-GWP is then of absolute priority within the RPC community.
In this presentation we report the performance of the RPC working with new environment-friendly gases with low GWP which could replace the standard mixture. In this work the standard mixture main component, the $C_2H_2F_4$, is replaced by a proper mixture of CO_2 (GWP = 1) and Tetrafluoropropene ($C_3H_2F_4$, GWP$\sim$6). The other high-GWP component, the SF_6, is replaced by a new molecule, the Chloro-Trifluoropropene ($C_3H_2ClF_3$, GWP $\sim$ 5) never tested in the RPC detectors. The mixtures studied have a total GWP $\sim$ 10.
We report, for several eco-gas mixtures, the detection efficiency, streamer probability, electronic and ionic charge as a function of the high voltage. Moreover the timing properties are studied and the detector time resolution is measured.
We also focus the attention on a new category of signals having intermediate properties between avalanche and streamer, called “transition events”. This category is negligible for the standard gas mixture but relevant for HFO/CO_2-based gas mixtures.
We show a direct comparison between SF_6 and $C_3H_2ClF_3$ to study in depth the possibility to replace an industrially very important molecule like SF_6.

Eco-friendly mixtures for RPC detectors / 58

Development of new gas recuperation systems for particle detectors using greenhouse gases

Author: Roberto Guida[1]

Co-authors: Beatrice Mandelli [1]; Gianluca Rigoletti [2]; Mara Corbetta [3]

[1] *CERN*

[2] *Universita & INFN, Milano-Bicocca (IT)*

[3] *AGH University of Science and Technology (PL)*

Corresponding Author: roberto.guida@cern.ch

Particle detectors at the LHC experiments are very often characterized by large detector volumes and by the need of using very specific gases. Since the early phase, the gas consumption optimization was one of the design criteria. CERN is today strongly committed to reduce GHGs emissions from particle detector operation. In addition, GHGs are now subject to a phase down policy in Europe that started to affect the market with price increase and, in the long term, may cause a decrease in their availability.
Four different strategies have been identified to optimize the GHGs usage: gas recirculation systems optimization, gas recuperation, new environmentally friendly gases, and gas abatement. This contribution will focus on results obtained for the present gas systems' optimization and on the R&D studies for the development of gas recuperation plants. Gas recuperation plants are systems designed to extract GHGs from the exhaust of gas recirculation systems allowing further re-use and, therefore, reducing drastically GHGs emissions without changing detectors operation conditions. Recent developments are concerning systems for CF4, C2H2F4 (also called R134a), C4F10 and SF6 recuperation.

A R&D studies to design a R134a recuperation plant is ongoing. The use of R134a for the ATLAS and CMS RPC detector systems operation represents about 80% of the GHGs emission from particle detectors at CERN experiments. The separation process resulted more complicated than expected because R134a and iC4H10 forms an azeotropic mixture. To overcome this complication, after removal of the most volatile components (i.e. air and SF6), the R134a and iC4H10 remaining mixture is firstly totally liquified and then it is sent to a volume kept at about 4 ℃: the azeotropic mixture present at the bottom of the second stage buffer enters the warm buffer and it is slowly heated up. During this process, the liquid is enriched of pure R134a while the vapor, enriched of the azeotrope, escapes from the exhaust. Several tests performed with an input RPC gas mixture flow from 100 to 400 l/h confirmed the good quality of the recuperated R134a. The overall recuperation efficiency is 80-85%. Final studies are on-going in order to develop a second prototype, which should pave the way for the final R134a recuperation systems, which will be installed in the ATLAS and CMS experiments during Run 3.

New detector applications / 59

Muon tomography with resistive plate chambers for geological characterization

Author: Raul Sarmento[None]

Corresponding Author: raul@lip.pt

Muon tomography is one of several fields of applied physics that have witnessed the successful use of particle detection based on Resistive Plate Chambers (RPC). In this work, we will report on an innovative project concerning transmission muography for geological characterization. For this purpose, a muon telescope built of four RPC planes was mounted on an adjustable structure and the telescope's response to atmospheric muons was studied. Data acquisition campaigns took place at different locations for producing muographic images of the building of the Physics Department

of the University of Coimbra, in Portugal. Recently, the detector was moved to an underground gallery of an old mine, where it is taking data to be assessed in combination with the results from conventional geophysics techniques.

New experiments / **60**

RPC-SDHCAL status

Authors: Francois Lagarde[None]; Francois Lagarde[1]; Imad Laktineh[2]

[1] *Shanghai Jiao Tong University (CN)*

[2] *Centre National de la Recherche Scientifique (FR)*

Corresponding Authors: imad.baptiste.laktineh@cern.ch, lagarde@sjtu.edu.cn, francois.lagarde@cern.ch

The CALICE technological RPC-based SDHCAL prototype that fulfils all the requirements of compactness, hermeticity and power budget of the future lepton accelerator experiments, has been extensively tested and has provided excellent results in terms of the energy resolution and shower separation.
New phase of R&D to validate completely the SDHCAL option for the International Linear Detector (ILD) project of the ILC and also the Circular Electron Positron Collider (CEPC) has started with the conception and the realization of new prototypes. One of the new prototypes is intended to host few but large active layers of the future SDHCAL. The new active layers, made of GRPC with sizes larger than 2 m2 will be equipped with a new version of the electronic readout fulfilling the requirements of the future ILD detector. The new GRPC are conceived to improve the homogeneity with a new gas distribution scheme. Finally, the mechanical structure will use the electron beam welding.
The second new prototype propose to exploit the excellent time resolution provided by RPC detectors in order to better build the hadronic showers with the aim to better separate them and also to single out the contribution of delayed neutrons.

The progress realized on the two prototypes will be presented and the future steps will be discussed.

New detector applications / **61**

A new readout scheme of reading out RPC and gaseous detectors

Author: Christophe Combaret[1]

Co-authors: Imad Laktineh [1]; Laurent Mirabito [1]

[1] *Centre National de la Recherche Scientifique (FR)*

Corresponding Author: imad.baptiste.laktineh@cern.ch

A new readout scheme allowing the exploitation of Resistive Plate Chamber (RPC) spatial precision and using a limited number of electronic channels is proposed. The new scheme which exploits the spread of the RPC induced charge on several adjacent inter-connected pads, allows the simultaneous detection of several particles without ambiguity.
In this scheme, pads are connected in rows through buried vias in rear layers in an original way so the charge induced by the passage of one particle is shared among pads belonging to different directions. The pads of one row are connected to one electronic channel.
The position of the particle is determined by the intersection of the rows associated to the fired pads and the ambiguity is eliminated by the fact that more than two crossing rows with two different directions are concerned.

The new scheme allows to instrument large detectors with a reduced number of electronics channels without reducing the spatial resolution obtained with pads read out individually.
We will present the results obtained on a cosmic ray bench built with 60 cm x 70 cm RPC read out with the new readout scheme and we will discuss our plan to use the new scheme to instrument large gaseous detectors.

New detector applications / 62

Use of pads-based readout RPC for home security applications

Author: Imad Laktineh[1]

[1] *Centre National de la Recherche Scientifique (FR)*

Corresponding Author: imad.baptiste.laktineh@cern.ch

RPC is a gaseous detector that associates high efficiency, fast timing and good spatial resolution to a cost effectiveness. Large RPC made either of HPL or glass are easily built and successfully operated in several HEP experiments. We propose the use of RPC to perform 3D scans of containers with the help of cosmic rays. In order to have an affordable large scanning system to cover large containers, a
To instrument very large detection areas similar to those needed in container inspection a new and genuine readout system that has the granularity and thus the spatial resolution provided with tiny pads read out individually but with a number of electronics channels of long strips readout system.
A cosmic ray bench built with 2 stacks each made of 4 RPC of 60 cm x 70 cm each separated by 20 cm, was used to detect successfully dense objects placed between the two stacks using the scattering technique.
Hidden material in concrete wrapping structure were also scanned and clearly identified. Work to extend the size of the instrumented area is on going as well as the optimization of the time exposure.

Detector R&D / 63

Study of Ionic signal properties with different readout methods.

Author: Alessandro Paoloni[1]

[1] *INFN e Laboratori Nazionali di Frascati (IT)*

Corresponding Author: alessandro.paoloni@cern.ch

The simultaneous measurement of the ionic and the fast prompt signals is fundamental for the understanding of the working principles of the RPC detector.
Typical RPC electrodes are made of resistive material with the voltage applied on a thin graphite layer, whose resistivity change the ionic pulse shape depending on the discharge position.
We have therefore realized a small RPC detector with a metallic grid deployed in one of the resistive electrodes, specifically designed for the precision measurement of ionic pulse shape and charge.
Typical copper strips pick-up allows reading the signal by capacitive coupling on the opposite electrode.
The purpose of the study described in this presentation is to test different ion signal read-out systems and the comparison with the prompt signal read out with traditional techniques, to improve the detector knowledge and for possible future applications.

Poster session / 64

Timing RPC for thermal neutron detection with 3D position sensitivity

Author: Luís Margato[1]

Co-authors: Alberto Blanco [2]; Andrey Morozov [3]; João Saraiva [3]; Luis Lopes [3]; Paulo Fonte

[1] *LIP-Coimbra, Departamento de Física, Universidade de Coimbra*

[2] *LIP Coimbra*

[3] *LIP-Coimbra*

Corresponding Author: margato@coimbra.lip.pt

Modern instruments for neutron science applications, such as, e.g., small-angle neutron scattering (SANS), reflectometry and macromolecular crystallography, require thermal neutron detectors with high detection efficiency, low sensitivity to gamma rays, high counting rates and high spatial resolution. At neutron spallation sources, due the pulsed nature of the beam, in most applications the capability of the detector to measure the neutron time of flight (TOF) is also required. This is particularly important to perform neutron wavelength-resolved measurements, and can easily be met with resistive plate chambers (RPCs), well known for their sub-ns time resolution. Moreover, it was also recently been shown that an RPC based thermal neutron detector can provide a high detection efficiency (> 50%) combined with sub-millimeter spatial resolution.
Here we will present a concept of a timing neutron detector aiming at four-dimensional readout capability (XYZ and time) and intended for TOF neutron diffraction and reflectometry, as well as other applications requiring readout of position and time, such as, e.g., wavelength resolved neutron imaging. The detector consists of a stack of neutron-sensitive double gap ¹⁰B-RPCs (RPCs lined with ¹⁰B₄C), oriented normally to the direction of the incident neutrons. Stacking RPCs is needed to achieve the detection efficiency of about 50%, and will also improve the counting rate capability nearly linearly with the number of RPCs. The neutrons TOF and the position of the neutron capture along of the stack (Z-coordinate) is obtained from the fast electronic component of the induced signal on the RPCs cathode. To determine the XY coordinate (plane parallel to the plates of the RPCs) of neutron events, two arrays of parallel metallic strips, orthogonal to each other and held by a thin film of polyamide, are placed between each neighbouring RPC. In this arrangement, gas gaps of adjacent RPCs share the same arrays of strips allowing to significantly reduce the number of readout channels. We will also report results of Geant 4 simulations targeting optimization of the detector design and providing the best trade-off between the detection efficiency, maximum count rate and the level of elastic neutron scattering on the detector components.

Detector R&D / 65

Outdoor systems performance and upgrade

Author: Luis Alberto Vieira Lopes[1]

[1] *LIP - Laboratorio de Instrumentação e Física Experimental de Partículas (PT)*

Corresponding Author: luis.alberto.vieira.lopes@cern.ch

In the last two decades, the possibility of using RPCs in systems that work outdoors has increased considerably. Our group has been involved in this effort having several systems in operation, continuing to work on their optimization, studying and developing new approaches that can contribute for the use of RPCs in outdoor applications.

A few detectors were deployed in the field at the Pierre Auger Observatory in 2019 but were idle, pending commissioning of support systems. The pandemic force us to leave the RPC modules without any gas flow during more than 2 years. The commissioning of these detectors restarted recently. The monitoring of those detectors will be presented.

The LouMu project combines particle physics and geophysics in order to map large geologic structures, using the Muon Tomography. The development of the RPC system and the data of the last two years will be presented.

Due to pandemic our R&D efforts in the last two years were not concentrated in this important objective. Nevertheless recent advances in large area (1 m2) double gap sealed RPC will be presented.

Eco-friendly mixtures for RPC detectors / 66

RPC performance with an alternative eco-friendly gas mixture

Author: Subhendu Das[1]

Co-authors: Jaydeep Datta [2]; Nayana Majumdar [1]; Supratik Mukhopadhyay [1]

[1] *Saha Institute of Nuclear Physics (SINP), India*

[2] *Université Libre de Bruxelles, Belgium*

Corresponding Author: subhendudas456038@gmail.com

The use of R134a-based gas mixture containing SF_6 for operating RPC is not recommended owing to its high global warming potential (GWP). The effective GWP of the standard gas mixture of R134a (95.2%), i-C_4H_{10} (4.5%) and SF_6 (0.3%) is about 1300 which is well beyond the permissible limit (less than 150) set in order to reduce the greenhouse gas (GHG) emissions. This work presents experimental qualification of an eco-friendly, non-flammable, inexpensive gas mixture of Ar (5%), CO_2 (60%), and N_2 (35%) for operating Resistive Plate Chamber (RPC) in avalanche mode, proposed on the basis of a numerical work [1]. The performance of RPC using the proposed gas mixture has been investigated and compared to the available experimental data for the standard gas mixture to study its efficacy and limitation.

[1] J. Datta, S. Tripathy, N. Majumdar, and S. Mukhopadhyay, Journal of Instrumentation 16 (2021) P07012.

Poster session / 67

An effective method for measuring the stiffness of a sealed vessel that can be applied to RPC gas volumes.

Authors: Barbara Liberti[1]; Enrico Pastori[1]

Co-authors: Alessandro Rocchi [2]; Anna Di Ciaccio [1]; Giorgia Proto [1]; Giulio Aielli [1]; Luca Pizzimento [2]; Luigi Di Stante [3]; Paolo Camarri [3]; Rinaldo Santonico [1]; Roberto Cardarelli [1]

[1] *INFN e Universita Roma Tor Vergata (IT)*

[2] *INFN*

[3] *Università degli Studi di Roma Tor Vergata*

Corresponding Authors: barbara.liberti@roma2.infn.it, enrico.pastori@cern.ch

A known volume of air is injected into or aspirated from a sealed vessel. In the ideal gas approximation, the corresponding vessel deformation is measurable. The liner correlation between pressure and deformation in the measurements carried out demonstrate the vessel elastic response. Measurements of several RPC gas volumes are reported. Different expansion and compression slopes of pressure vs volume plots, highlight a structure problem, as for example unglued spacers. Defective stiffness values of the electrode materials are also highlighted by anomalous slope values.

Eco-friendly mixtures for RPC detectors / 69

Performance studies of RPC operated with alternatives to R-134a in the presence of LHC-like background radiation

Authors: Beatrice Mandelli[1]; Gianluca Rigoletti[2]; Mattia Verzeroli[3]; Roberto Guida[1]

[1] *CERN*

[2] *Universita & INFN, Milano-Bicocca (IT)*

[3] *Pavia University and INFN (IT)*

Corresponding Author: gianluca.rigoletti@cern.ch

Resistive Plate Chamber (RPC) detectors are widely used at the CERN LHC experiments as muon trigger thanks to their excellent time resolution. They are operated with a gas mixture containing R-134a and SF6, both greenhouse gases (GHG) with a very high global warming potential (GWP). The search of new environmentally friendly gas mixtures is necessary to reduce GHG emissions and costs as well as to optimize RPC performance. Several recently available gases with low GWP have been identified as possible replacements for R-134a and SF6. The addition of CO2 to the gas mixture was studied as possible mid-term solution to mitigate R-134a usage, while R-1234ze was studied as a possible replacement for R-134a. The RPC detectors were tested in laboratory conditions and a set of selected mixture was then tested at the CERN Gamma Irradiation Facility (GIF++), which provides a high energy muon beam combined with an intense gamma source allowing to simulate the background expected at HL-LHC. The performance of RPCs were studied at different gamma rates in a presence of muon beam by measuring efficiency, streamer probability, induced charge, cluster size and time resolution.

Eco-friendly mixtures for RPC detectors / 70

Possible alternatives to SF6 for Resistive Place Chambers

Authors: Beatrice Mandelli[1]; Gianluca Rigoletti[2]; Roberto Guida[1]

[1] *CERN*

[2] *Universita & INFN, Milano-Bicocca (IT)*

Corresponding Author: beatrice.mandelli@cern.ch

Resistive Plate Chambers (RPCs) are widely employed in Particle Physics and at CERN LHC Experiments thanks to their excellent time resolution and low cost. In most of the applications, RPCs are operated with a humidified gas mixture made of C2H2F4, SF6 and iC4H10. Unfortunately, C2H2F4 and SF6 are greenhouse gases (GHGs) with a global warming potential (GWP) of 1430 and 22800 respectively. The SF6 is the world's most potent greenhouse gas and, even if it is used in low concentrations (about 0.3% for bakelite RPCs and 7% in glass RPCs), it contributes considerably to the GWP of the RPC gas mixture. A search for alternatives to SF6 it is therefore advisable.
In the recent years, industry research has also focused on alternatives to SF6, which is mainly used as insulator for high-voltage plants. The 3M Company has developed two new alternatives to SF6 with a high dielectric strength and low GWP: 3M Novec 5110 (CF3C(O)CF(CF3)2) and 3M Novec 4710 ((CF3)2CFCN). Two other gases have been studied in this work: the CF3I, which has a GWP of 0.4 and is very electronegative but it is toxic, and the C4F8O, which has a high GWP (~8700) but has good electronegative properties. Furthermore, in the family of HydroFluoroOlefyn (HFO), the Amolea 1224yd (C3HF4Cl), which has a GWP less than 1 and it contains a Cl atom, was tested.
The studies on alternatives to SF6 have been performed by using the standard gas mixture as reference and replacing the SF6 with the new candidates. For each candidate, different concentrations were tested to better characterise its properties. Afterwards SF6 was also replaced in new

eco-friendly gas mixtures. Detector performance were studied in terms of efficiency, streamer probability, rate capability, induced charge, cluster size and time resolution. Studies were done firstly in a laboratory set-up and afterwards, for some selected eco-friendly gas mixtures, at the CERN Gamma Irradiation Facility (GIF++), which provides a muon beam combined with a gamma source, allowing to simulate the background expected at HL-LHC.

Poster session / 71

Measurements of fluoride production in Resistive Plate Chambers

Authors: Beatrice Mandelli[1]; Gianluca Rigoletti[2]; Mattia Verzeroli[3]; Roberto Guida[1]

[1] *CERN*

[2] *Universita & INFN, Milano-Bicocca (IT)*

[3] *Pavia University and INFN (IT)*

Corresponding Author: gianluca.rigoletti@cern.ch

Resistive Plate Chambers (RPCs) are operated with a humidified gas mixture made of C2H2F4, SF6 and iC4H10. It is well known that under the effect of high electric field and radiation, the C2H2F4 molecule breaks into several compounds and free fluoride ions, which can accumulate under gas recirculation and could be harmful for the long-term detector operation. Furthermore in presence of water, the free fluoride ions become hydrofluoric acid (HF), a very reactive compound. The HF production depends on several factors as radiation rate, gas flow, detector current and gas mixture. In this study we developed and tested two different set-ups for the HF concentration measurements by using an Ion Selective Electrode (ISE) station. The measurement on the HF production were performed on 2 mm gas gap bakelite RPC detector irradiated at the CERN Gamma Irradiation Facility (GIF++) with different absorption factors. Several gas mixtures were tested to understand how the formation of HF is affected. The HF production of the standard gas mixture was compared with the one of the standard gas mixture with the addition of 30% CO2 at several gamma rates. Different concentrations of SF6 were also investigated to understand if and how the SF6 could affect the HF production. Finally, two gas mixtures containing HFO1234ze, C2H2F4 and He or CO2 were used to study the RPC HF production in presence of the HFO1234ze, which is less stable in atmopshere with respect to the C2H2F4.

Poster session / 72

Study of industrial epoxy resins with graphene nanotubes for the realization of low resistivity electrodes of RPC detectors

Authors: Alessandro Rocchi[1]; Barbara Liberti[1]; Roberto Cardarelli[1]

[1] *INFN e Universita Roma Tor Vergata (IT)*

Corresponding Author: alessandro.rocchi@cern.ch

The study of new materials for the construction of electrodes with low resistivity and high resistance to aging and radiation damage is a central theme in development of future RPC detectors. We investigated the properties of a new low-cost epoxy resin doped with graphene nanotubes, through the material voltammeter characterization and building a small demonstration prototype. The qualification of such a material would allow to produce detectors with very high-rate capability by exploiting conventional industrial processes. Furthermore, the epoxy resins properties would allow building electrodes of any shape and size, extending their application to detectors with non-planar geometry.

New detector ideas / 73

SI-GaAs wafers as resistive electrode for high rate RPC with very low dark count rate

Author: Alessandro Rocchi[1]

Co-authors: Anna Di Ciaccio [1]; Barbara Liberti [1]; Enrico Pastori [1]; Giorgia Proto [1]; Giulio Aielli [1]; Giuseppe Iacobucci [2]; Hubert Kroha [3]; Lorenzo Paolozzi [4]; Luca Pizzimento [5]; Luigi Di Stante [6]; Oliver Kortner [3]; Paolo Camarri [6]; Roberto Cardarelli [1]; Daniel Soyk [3]

[1] *INFN e Universita Roma Tor Vergata (IT)*

[2] *Universite de Geneve (CH)*

[3] *Max Planck Society (DE)*

[4] *CERN*

[5] *INFN*

[6] *Università degli Studi di Roma Tor Vergata*

Corresponding Authors: roberto.cardarelli@roma2.infn.it, barbara.liberti@roma2.infn.it, alessandro.rocchi@cern.ch

The characterization of new materials for electrodes plate design is one of the central themes in the development of high rate RPC detectors.
Semiconductive crystals have been characterized since the 90s, showing an excellent response to high irradiation with the limitation to fall into destructive discharges.
The development of new front-ends with high signal to noise ratio allowed us to reduce the gas gain, operating the detector before destructive discharges occour.
In this way we can study RPC with electrodes made of semi-conductive materials, which have a crystalline structure with very high carrier mobility and high resistivity.
Semiconductor wafers are also characterized by a surface roughness of less than 5 nm, which is reflected in a negligible number of dark counts without the aid of surface coatings.
We believe that the study of this type of materials deserves to be deepened for the application to high rate RPC.
For this purpose a detector with undoped Gallium Arsenide electrodes was exposed to different values of uniform photon irradiation and characterized with $180 GeV/c$ muons. Stable operation without loss of efficiency was observed up to the maximum source irradiation, equivalent to a counting rate of $40\ khz/cm^2$. It was also observed a dark count rate lower than $0.01\ Hz/cm^2$ due to the very low surface roughness of the polished semiconductive wafers.

New detector ideas / 74

The Surface Resistive Plate Counter

Authors: Gianfranco Morello[1]; Giovanni Bencivenni[1]; Giulietto Felici[1]; Giuseppe Papalino[2]; Matteo Giovannetti[1]; Maurizio Gatta[1]; Rui De Oliveira[3]; Marco Poli Lener[1]

[1] *INFN e Laboratori Nazionali di Frascati (IT)*

[2] *Laboratori Nazionali di Frascati*

[3] *CERN*

Corresponding Author: giovanni.bencivenni@lnf.infn.it

The surface Resistive Plate Counter (sRPC) is a new RPC based on surface resistive electrodes realized with Diamond-Like-Carbon sputtered on Apical® foil. Exploiting high granularity current evacuation schemes developed for resistive MPGD and using electrodes with surface resistivity from 1 GΩ/□ down to 100MΩ/□, sRPCs standing particle fluxes up to 1 - 100 kHz/cm2 should be easily developed.
At the moment prototypes with electrode resistivity > 1GΩ/□ have been tested, exhibiting high stability and good performance in terms of efficiency (~ 95%) and time resolution (~ 1ns). A high-rate

layout with ρ ~ 7GΩ/□ and 1 cm current evacuation pitch showed a rate capability with m.i.p. of ~ 3kHz/cm2.
The scalability of the technology allows the construction of detectors for large area applications at future high luminosity colliders.

Poster session / **75**

Design and performance study of a sealed mosaic high-rate MRPC

Author: Qiunan Zhang[None]

Corresponding Author: zhangqn17@mails.tsinghua.edu.cn

TOF (Time Of Flight) detector is an important detector for PID (Particle Identification) in high-energy physics experiments. This kind of detector is requested to have excellent time resolution for measuring the timing information of the arriving particles. It is often built with float glass MRPCs, whose efficiency is typically higher than 95%, the time resolution could be better than 100ps and the rate capability is a few hundred Hz/cm2 at a reasonable cost. Currently, the high-energy physics experiments are heading for high-rate or high-luminosity experiments to explore new physics phenomena. The corresponding high-rate experimental environment brings a new challenge to the rate capability of MRPC. One kind of low resistive glass had been proven to be able to increase the rate capability of MRPC to about 30kHz/cm2. However, the maximum dimension of the low resistive glass is 30 · 33 cm2 due to the craftsmanship, which limits the maximum dimension of the MRPC. Breaking the dimension limit of the low resistive glass MRPC will expand its usage, but a larger MRPC needs a bigger gas box, which indicates increased gas consumption. To break the dimension limit and limit the gas usage in the meanwhile, a sealed mosaic high-rate MRPC based on the low resistive glass has been developed. The test results show it has an global efficiency of about 95% and the time resolution could reach 70ps. The design has been proven to be feasible.

New experiments / **76**

The RPC in the cosmic ray physics of the next future

Author: Rinaldo Santonico[1]

[1] *INFN e Universita Roma Tor Vergata (IT)*

Corresponding Author: rinaldo.santonico@roma2.infn.it

The RPCs are widely employed in accelerator particle physics. Conversely, concerning cosmic ray physics, Argo was the only ground-based experiment which used this detector in a very extensive way. The brilliant results published by this experiment encourage to propose RPCs for further experiments. Indeed, they have the advantage of efficiently detecting very low energy secondaries and of imaging the front of an extensive air shower with an unprecedented detail. This makes them particularly attractive for the detection of very low energy showers. Moreover, the RPCs can be easily hybridized with water Cherenkov detectors, thus combining the advantages of both detectors.
Optimizing RPCs for cosmic ray physics requires however to substantially reconsider their optimal characteristics with respect to the case of accelerator experiments. The required parameters indeed are the construction simplicity, the working reliability in hostile environment and the low cost, rather than a very high time resolution and rate capability.
This talk will show an example of RPC based detector conceived for gamma ray astronomy and cosmic ray physics together with a chamber set up particularly suitable for this detector

Poster session / **77**

Gas recirculation systems for RPC detectors: from LHC experiments to laboratory set-ups

Authors: Beatrice Mandelli[1]; Gianluca Rigoletti[1]; Roberto Guida[1]

[1] *CERN*

Corresponding Author: beatrice.mandelli@cern.ch

The Resistive Plate Chamber (RPC) detectors are extensively used worldwide and at CERN LHC experiments thanks to their excellent time resolution and low cost. RPCs are often operated with a humidified gas mixture made of C2H2F4, SF6 and iC4H10. Unfortunately, C2H2F4 and SF6 are greenhouse gases (GHGs) with a global warming potential (GWP) of 1430 and 22800 respectively and they are subject to a phase-down policy in Europe (EU F-gas regulation). It is therefore foreseeable that F-gases availability would be uncertain for the future and their price could raise possibly making gas detectors operation very costly.
The reduction of GHG emissions is an objective of paramount importance for CERN and four different strategies have been identified to achieve it. One of these strategies is based on the use of gas recirculation systems. This solution is already implemented in all gas systems suppling gaseous mixtures to the CERN LHC detectors. These recirculation systems are complex and sophisticated apparatus for big detector volumes (tens to hundreds m3) that extend from surface to underground cavern and they are controlled through an industrial Programmable Logic Controller (PLC). Their cost is considerable and therefore they are used for large detector apparatus.
In order to cope with the increase of small experiments and detector facilities, the CERN gas team has developed two new portable gas recirculation systems at affordable cost. The first gas recirculation unit can be used for several detectors connected in series or parallel flushed with hundreds of liters per hour. It is controlled though a small PLC and it can regulate detector pressure at the level of the mbar. Some of these gas recirculation systems are already in use since several years at CERN GIF++ facility for CSC, GEM and RPC detectors.
A second gas recirculation unit has been developed for laboratory purpose where one or two detectors are flushed with few liters per hour. In this case, the unit has to be very cheap and user-friendly in order to allow an easy operation from the final user. A first prototype has been designed, assembled and tested on a RPC chamber of the EEE experiment.
Both portable gas recirculation systems can be easily adapted for the different types of detector systems and set-ups thanks to their low price, flexibility and user-friendly operation. An overview of the LHC, medium and small gas recirculation systems will be given in this contribution.

New experiments / 78

RPC detectors to search for long-lived particles with the ANUBIS detector

Authors: Jon Burr[1]; Oleg Brandt[1]; Toby Satterthwaite[1]

Co-authors: Giulio Aielli [2]; Luca Pizzimento [2]

[1] *University of Cambridge (GB)*

[2] *INFN e Universita Roma Tor Vergata (IT)*

Corresponding Author: jon.burr@cern.ch

RPC detectors combine several crucial advantages of excellent timing precision, high detection efficiency, and good spacial resolution, all at a moderate cost. This makes RPC detectors a prime choice for instrumenting large detector volumes for tracking applications where timing plays a crucial role. This talk reviews the ANUBIS detector concept using RPC detectors to search for long-lived particles at the high-luminosity LHC in a hitherto inaccessible lifetime regime. A small-scale demonstrator called pro-ANUBIS is introduced, which will take data on-surface above the ATLAS detector in autumn 2022, and inside the ATLAS cavern in 2023. Finally, first commissioning results of pro-ANUBIS are presented.

New experiments / **79**

Resistive Plate Chambers for Precise Measurement of High-Momentum Protons in Short Range Correlations

Author: Manuel Xarepe[None]

Co-authors: Alberto Blanco [1]; Anna Corsi [2]; Bastian Löher [3]; Daniel Galaviz Redondo [4]; Dominic Rossi [5]; Hans Toshihide Tornqvist [6]; Håkan Johansson [7]; Jan Michel [8]; João Saraiva [9]; Luís Lopes [1]; Michael Traxler [10]; Thomas Aumann [11]

[1] *LIP Coimbra*

[2] *CEA Saclay*

[3] *GSI*

[4] *LIP - Laboratorio de Instrumentação e Física Experimental de Partículas (PT)*

[5] *TU Darmstadt, GSI*

[6] *Chalmers University of Technology (SE)*

[7] *Chalmers*

[8] *Goethe University Frankfurt*

[9] *LIP-Coimbra*

[10] *GSI Helmholtzzentrum für Schwerionenforschung GmbH*

[11] *T*

Corresponding Author: mxarepe@lip.pt

The Reactions with Relativistic Radioactive Beams (R3B) collaboration of the FAIR facility in Darmstadt, Germany, has constructed an experimental setup to perform fundamental studies at the extremes of nuclear matter, using as a probe reactions with exotic nuclei at relativistic energies.
Among the various detection systems, one of the most recent upgrades consisted on the installation of a large area (~2 m²) multi-gap RPC (mRPC), equipped with twelve 0.3 mm gaps and readout by 30 mm pitch strips, exhibiting a timing precision down to 50 ps and efficiencies above 98 % for MIPs [1].
The mRPC was part of the setup of the FAIR Phase-0 experiment focusing on the measurement, for the first time, of nucleon-nucleon short-range correlations (SRC) inside an exotic nucleus (16C) that occurred in Spring 2022.
The excellent timing precision of this detector will allow the measurement of the forward emitted proton momentum with a resolution of around 1%.
In this work, the RPC detector will be introduced, the integration of the detector in the R3B setup will be presented, and some preliminary results will be shown.

References

[1] Blanco, Alberto, et al. "The SHiP timing detector based on MRPC." Journal of Instrumentation 15.10 (2020): C10017.

RPC@LHC / **80**

Commissioning and first measurements with LHC collisions of BIS78 RPCs, an innovative detector for ATLAS HL-LHC upgrades

Corresponding Author: sinem.sahin@cern.ch

The BIS78 project, BI pilot project, consists of 16 sMDT + RPC chambers installed in the barrel-endcap transition region with the function of helping in the reduction of the fake muons produced upstream of the cryostats. The BIS78 RPCs represents a new generation of RPCs, basing their largely

improved performance on a novel and highly performing front-end (FE) electronics, which is able to detect 1-2 fC of induced signals increasing rate capability by a factor of 10 with respect to the present ATLAS RPCs.
BIS78 are equipped with a gas gap of 1 mm thick, granting a time resolution of 350ps and less weight and space occupancy. Additionally, the new electronics could make the BIS78 apparatus more easily compatible with the new eco-gas mixtures. The entire BIS78 apparatus has been installed successfully within the ATLAS experimental cavern and its commissioning will be illustrated along with its performance at the beginning of LHC Run 3

Detector electronics and simulation / **81**

Design of the new RPCs and Front End electronics for the ATLAS High Luminosity LHC program

Corresponding Authors: luca.pizzimento@roma2.infn.it, luca.pizzimento@cern.ch

The present ATLAS RPC system is a 3D+time tracking detector providing the first level trigger in the ATLAS barrel. It is constituted by 6 concentric cylindrical layers providing independent space-time measurements along the track, with 1ns x 1cm resolution. This system will undergo a major upgrade for the HL-LHC program, consisting in inserting in the Inner Barrel region, three additional full coverage layers of new generation RPCs.
The new system will extend from about 70% to about 96% the trigger acceptance; add redundancy to the legacy RPC; increase the trigger selectivity and bring the resolution on the particle velocity to up 0.5%, thanks to the increased time resolution and lever arm.
The most innovative feature of this project, inheriting most of the other features from the BIS78 pilot, is a novel Front-End electronics (FE), and its integration in the RPC Farady cage. This FE features 1 fC sensitivity of preamplifier and fast discriminator and 70 ps resolution Time-To-Digital converter in SiGe BiCMOS technology, enabling the readout of the azimuthal coordinate from the time difference at opposite edges of the detector. A new RPC gas gap 1 mm thick, coupled with this novel front-end electronics represents a new generation of large area timing detectors, granting all the features above and a record time resolution of 350ps as well.
In this presentation, we will report the design progress, reaching the final prototype maturity, with a particular focus on the FE, our main challenge.

Detector R&D / **82**

Exploring the performance limits of the new generation of ATLAS RPCs

Corresponding Authors: giulio.aielli@roma2.infn.it, giulio.aielli@cern.ch

The new generation RPCs designed for the ATLAS upgrade, feature a gas gap of just 1 mm challenging the statistical detection limits of its gaseous target with MIPS, and a Front End (FE) electronics with 1-2 fC sensitivity challenging the grounding robustness on such large dimensions with respect to the signal frequency spectrum. This is necessary in order to respond to the performance request coming from the ATLAS upgrade needs, in terms of very limited space available and accessibility, longevity in the HL-LHC environment, requirement of maximum acceptance and efficiency, stand-alone muon selection capability, low power consumption.
The BIS78 Module zero chamber has been extensively tested with a muon beam and photons at the GIF++ facility of CERN, in order to establish the limits of this new technology, on a real case detector and in real working conditions, letting the RPC self triggering muon tracks on its whole surface, and comparing the results with an external trigger. The aim is to provide a realistic prediction for future experiments adopting this technology.

We will focus in particular on how the efficiency, time resolution and charge per count, depends on electric field in the gas and on FE threshold, with different background intensities and with R134A and HFO based gas mixtures.

RPC@LHC / 83

The ATLAS RPC system for the LHC Run-3

Corresponding Author: davide.boscherini@cern.ch

Resistive Plate Chambers provide the barrel region of the ATLAS detector with an independent muon trigger and a two-coordinate measurement. The chambers, more than 3700 gas volumes in total covering a surface area of about 4000m2, are arranged in three concentric double layers and operated in a strong magnetic toroidal field.

The system was originally designed to operate for 10 years with a luminosity up to the LHC nominal value of 10 ^ 34 cm-2s-1. After a successful data taking period in Run-2, when the luminosity reached more than twice the nominal value, the detector has undergone an intense maintenance aimed at ensuring efficient data taking during the just started Run-3.

Several interventions have been carried out on the detector mainly concerning the gas distribution with the aim of keeping the system under control and reducing the amount of gas released into the atmosphere.
Several interventions have been carried out on the detector mainly concerning the gas distribution with the aim of keeping the system under control and reducing the amount of gas released into the atmosphere.
The interventions can be summarised as follows:
- new gas distribution racks have been added in order to increase the vertical segmentation and in view of the installation of the new chambers for the phase-2 upgrade
- no-return valves have been installed on the chamber outputs to avoid reverse flows with large leaks
- a massive repair campaign have been done for fixing the continuously developing leaks
- a new repair technique aimed to fix and prevent new leaks has been tested
- the segmentation of the HV channels has been doubled in a third of the spectrometer.

The different aspects of the activity carried out in LS2 are described, from motivation to implementation. The expected system performance is also presented.

New detector ideas / 84

Picosecond Avalanche Detector - working principle and gain measurement with a proof-of-concept prototype

Author: Lorenzo Paolozzi[1]

[1] *CERN*

Corresponding Author: lorenzo.paolozzi@cern.ch

The Picosecond Avalanche Detector is a multi-junction silicon pixel detector based on a (NP)drift(NP)gain structure, devised to enable charged-particle tracking with high spatial resolution and picosecond time-stamp capability. It uses a continuous junction deep inside the sensor volume to amplify the primary charge produced by ionizing radiation in a thin absorption layer. The signal is then induced by the secondary charges moving inside a thicker drift region, using a “parallel plate” readout to deliver picosecond time resolution. A proof-of-concept monolithic prototype, consisting of a matrix of hexagonal pixels with 100 μm pitch, has been produced using the 130 nm SiGe BiCMOS process by IHP microelectronics. Measurements on probe station and with a 55Fe X-ray source show that

the prototype is functional and displays
avalanche gain up to a maximum electron gain of 23. A study of the avalanche characteristics, corroborated by TCAD simulations, indicates that space-charge effects due to the large primary charge produced by the conversion of X-rays from the 55Fe source limits the effective gain. The results of the first test beam with minimum ionizing particles will be presented.

91

Registration and welcome

92

INVITED TALK 1: Overview on future Astro-particle Physics

Corresponding Author: andreas.haungs@kit.edu

93

INVITED TALK 2

Eco-friendly mixtures for RPC detectors / 94

Coffee break

New experiments / 95

Status of the CBM Time-of-Flight (TOF) project

Author: Ingo-Martin Deppner[1]

[1] *Physikalisches Institut der Universität Heidelberg*

Corresponding Author: deppner@physi.uni-heidelberg.de

The Compressed Baryonic Matter (CBM) experiment is a future heavy ion (HI) experiment planed to
be installed at the Facility for Anti-proton and Ion Research (FAIR) which is currently under construction close to Darmstadt/Germany. The uniqueness of CBM is the operation at, for HI experiments, unprecedented interaction rates of up to 10 MHz for Au+Au collisions at beam energies between 2 and 12 AGeV imposing enormous rate capability requirements for all subsystem detectors. The main subsystem for charged hadron identification is a 120 m2 large TOF wall composed of Multigap
Resistive Plate Chambers (MRPC) with different granularities and electrode materials depending on their experimental demands. An effect which comes along with operation of gaseous detectors at
high particle fluxes (up to 30 Hz/cm2) is an increased gas-aging and -pollution.
An status overview on the CBM TOF project and our strategy how to mitigate counter aging will be discussed during this conference.

Poster session / **96**

Development of Hybrid Resistive Plate Chambers

Author: Burak Bilki[1]

Co-authors: Kutlu Kagan Sahbaz [2]; Mehmet Tosun [2]

[1] *Beykent University (TR), The University of Iowa (US)*

[2] *Beykent University (TR)*

Corresponding Author: burak.bilki@cern.ch

Among the several outstanding issues associated with the RPCs, the loss of efficiency for the detection of particles when subjected to high particle fluxes, and the limitations associated with the common RPC gases can be listed. In order to address the latter issue, we developed novel RPC designs with special anode planes coated with high secondary electron emission yield material such as Al2O3 and TiO2. The proof of principle was obtained for various designs and is in progress for the rest. The idea was initiated following the achievements on the development of the novel 1-glass RPCs.

Here we report on the construction of various different RPC designs, and their performance measurements in laboratory tests and with particle beams; and discuss the future test plans which include the long term performance tests of the newly developed RPCs, investigation of minimal gas flow chambers, and the feasibility study for the large size chambers.

RPC@LHC / **97**

Coffee break

New experiments / **98**

Coffee break

New detector ideas / **99**

Coffee break

Poster session / **100**

MONTE CARLO STUDIES OF ECO-FRIENDLY GAS MIXTURES FOR RPC DETECTORS USING GEANT4+GARFIELD++

Author: Marco Antonio Dıaz Maldonado[1]

[1] *Instituto de Ciencias Nucleares, UNAM*

Corresponding Author: marco_diaz@ciencias.unam.mx

In this work, we investigate the performance of Resistive Plate Chambers (RPC) using Geant 4 and Garfield++.
RPCs detectors are commonly operated with a freon-based gas mixture containing C2H2F4 and SF6, both with
a very high global warming potential. The present work aims at contributing to the search for eco-friendly gas
mixtures for RPCs detectors. Based on the studies presented by Verzeroli (2022), some alternatives to C2H2F4
are tested in simulations, such as CO2, He and iC4H10. Moreover, Novec 4710 was studied as a substitution of
SF6. The RPC performance is evaluated by calculating the efficiency of the detector and the cluster size. Finally,
in preparation for the implementation of these gas mixtures in the detector's lab of UNAM, the performance of
the detector with atmospheric muons using C2H2F4 and SF6 is reported.
References
Verzeroli M. (2022). Studies of eco-friendly gas mixtures for rpc detectors at cern lhc experiments. CERN-THESIS-2022-040.

Detector electronics and simulation / **101**

Check-Sort-Push protocol in CMS iRPC/RPC data compression/decompressi and transmission and its application in Backend electronics system (BY ZOOM))

Corresponding Author: z.liu@cern.ch

To provide better cluster position resolution a new iRPC with two-ends readout and upgraded LinkSystem in CMS RPC detector will be used to provide timing information together with hit information. Different from present CMS RPC system where a partition has been used in data compression and decompression before data transmission and after reception respectively [1], so a new compression/decompression has to be used and a so-called Check-Sort-Push protocol was proposed as in reference [2]. This talk will describe the principle of the Check-Sort-Push mechanism and some simulation, presents data analysis and results from joint test and cosmic-ray data taking with iRPC detector/FEE complex demonstrating a successful working backend system for the new iRPC detector. Some results showing the necessity and importance of the application of this Check-Sort-Push protocol in the final system will also be presented.

[1] M. Gorski et al./Nucl. Instr. and Meth. in Phys. Res. A 419 (1998) 701—706
[2]https://indico.cern.ch/event/967463/contributions/4071622/attachments/2126016/3579438/RPC_electronic_meeting

Detector R&D / **102**

RPC background studies at CMS experiment

Corresponding Author: francesco.carnevali@cern.ch

The Compact Muon Solenoid (CMS) is a general purpose experiment to explore the physics of the TeV scale in pp-collisions provided by the CERN LHC. Muons constitute an important signature of new physics and their detection, triggering, reconstruction and identification is guaranteed by various sub-detectors using different detection systems: Drift Tubes (DT) and Resistive Plate Chambers (RPC) in the central region and Cathode Strip Chambers (CSC) and RPC in the endcap. During Run

2 the higher instantaneous luminosity lead to a substantial background in the muon system. In this contribution we will describe the method used to measure these backgrounds in the RPC detectors. The analysis is based on data collected in 2018 pp collisions at 13 TeV with instantaneous luminosities up to 2.2 E34 cm-2s-1. Thorough understanding of the background rates provides the base for the upgrade of the muon detectors for the High-Luminosity LHC, where the instantaneous luminosity will reach 5-7.5 E34 cm-2s-1, resulting in 140-200 simultaneous pp-collisions. We will discuss in detail the origin and characteristics of the background introduced by the pp-collisions, we will analyze the response of the RPC detectors and illustrate the dependence of the background on the instantaneous luminosity and the LHC fill scheme. We will show it is possible to estimate the contribution from long-lived background rates separately from the promptly induced background.

Poster session / 103

A new scheme and first results for the implementation of a low-cost Gas recirculation system for the RPCs chamber.

Authors: Barbara Liberti[1]; Enrico Pastori[1]

Co-authors: Alessandro Rocchi [2]; Anna Di Ciaccio [1]; Giorgia Proto [1]; Giulio Aielli [1]; Luca Pizzimento [2]; Luigi Di Stante [3]; Paolo Camarri [4]; Rinaldo Santonico [1]; Roberto Cardarelli [1]

[1] *INFN e Universita Roma Tor Vergata (IT)*

[2] *INFN*

[3] *Università degli Studi di Roma Tor Vergata*

[4] *University of Roma "Tor Vergata"*

Corresponding Authors: enrico.pastori@cern.ch, barbara.liberti@roma2.infn.it

An efficient and safe Recirculation System for the gas target inside RPCs detector is a crucial item for planning any future application.
The system is based on a special valve that decouples a suction pump from the RPCs, with the aim to keep the pressure inside the chamber in the range of 1-3 mbar, regardless of variations in atmospheric pressure, recirculated flow, and temperature. The circulating gas is flushed in pure water where the impurities developed inside the detector are expected to be soluble and trapped.
A small prototype capable to flush few liters per hour was built and first result are reported.

Poster session / 104

Development of a sealed MRPC with high time resolution

Authors: Kai Sun[1]; Botan Wang[1]; Xiaolong Chen[2]; daming liu[1]; jianing Liu[3]; Yi Wang[1]; Dong Han[1]; Baohong Guo[1]

[1] *Tsinghua University*

[2] *Tsinghua University (CN)*

[3] *Tsinghua university*

Corresponding Author: sun-k21@mails.tsinghua.edu.cn

The Solenoidal Large Intensity Device (SoLID) at Jefferson Lab (JLab) uses Multi-gap Resistive Plate Chambers (MRPC) to identify kaons. SoLID requires 20ps for the total time resolution. In this paper, a sealed MRPC (sMRPC) prototype with 4 stack and 7 uniform gas gaps is designed to reach a good time resolution. At the same time sMRPC can lower the airflow through the chamber to reduce the greenhouse pollution. Both TDC and waveform sampling are used for the readout of the signal. In

cosmic tests we compared the time resolution of these electronic readout method and researched how readout method affects the time resolution.

Poster session / 105

Signal Integrality Analysis of Sealed MRPC for Muongraphy

Authors: Botan Wang[1]; Kai Sun[1]; Yi Wang[1]; daming liu[1]

[1] *Tsinghua University*

Corresponding Author: 1048553880@qq.com

As a novel imaging technology, Muongraphy has great potential in nuclear matter detection. MRPC has a significant advantage in the application of muongraphy. The signal quality is a crucial index to measure the performance of MRPC detector. This paper has analyzed the signal integrality of the sealed MRPC structure in detail with CST simulation. Including the reflection of high frequency signal in signal line, the reflection of signal through via hole, the cross talk of signals under multiplexing. The characteristics of the reflected signal are given. The via hole will bring a strong reflection for 2GHz signal. The saltation of signal line width will also affect signal integrity.The experiment result verify the simulation results to a certain extent. The optimization scheme is proposed ,which includes changing via hole's size, setting the discrete capacitor,ect.

106

Summary talk

New experiments / 107

Sensitivity of MATHUSLA to high-energy cosmic rays

Author: Juan Carlos Arteaga-Velazquez[None]

Corresponding Author: juan.arteaga@umich.mx

In order to complement the searches of neutral Long Live Particles (LLPs) at the next HL-LHC at CERN a new experiment has been proposed, which is called MATHUSLA, to be located at ground level near the interaction point of CMS. The proposal aims to build a massive scintillator tracking detector system to monitor a large volume of air (100 m x 100m x 30 m) in search of decays from LLPs that are expected to be produced at the CMS interaction point during the HL-LHC runs. One of the backgrounds in this experiment would be the extensive air showers induced by cosmic rays of high energy in the atmosphere. However, such events are interesting from the astrophysical point of view. The addition of a layer of RPCs will make possible a detailed study of air showers from cosmic rays. In this talk, we will explore the performance of the MATHUSLA detector with the addition of an RPC layer for the investigation of these high-energy cosmic rays using the results of CORSIKA for air showers and a ROOT toy model of the experiment.

New experiments / 108

Development of the TOF-RPC for the pi20 beamline at J-PARC

Author: Natsuki Tomida[None]

Corresponding Author: tomida.natsuki.5z@kyoto-u.ac.jp

In the hadron hall of J-PARC, the construction of a high-momentum secondary beamline, the $\pi 20$ beamline, is planned. By using the secondary beam up to 20 GeV/c, a variety of hadron experiments, such as charmed and Ξ baryon spectroscopy, high isospin dibaryon search, cross section measurement of hyperon scattering and study of the generalized parton distribution function will be carried out. A multi-purpose spectrometer for those experiments is now under construction. In the spectrometer, TOF-RPCs will be used for low momentum particle identification. The required time resolution is 60 ps with 1.6 m-long readout strip. We have developed a prototype TOF-RPC with an area of 1.8 m $\times$ 0.23 m. We have also developed a pre-amplifier customized for our RPC. We will report the performance of the prototype RPC.

New R&D schema: through ECFA proposal / 109

ECFA R&D proposal

New R&D schema: through ECFA proposal / 110

Discussion

111

CAEN presentation

112

Ditta 2

113

International Advisory Committee meeting

114

group picture of partecipants