XVII Conference on Resistive Plate Chambers and Related Detectors

9 Sept 2024, 08:00 → 13 Sept 2024, 20:00 Europe/Madrid

Diego Gonzalez Diaz (Universidade de Santiago de Compostela (ES)) , Enrique Casarejos (Universidade de Vigo)

Description Dear Colleagues:

It is our pleasure to invite you to the XVII international Conference on Resistive Plate Chambers and Related Detectors (RPC2024), which will take place from 9th to 13th of September 2024 in Santiago de Compostela, hosted by the Galician Institute of High Energy Physics (IGFAE). Registration is now open until July 15th, 2024 (extended till July 21st!), at this link.

IGFAE Instituto Galego de Física de Altas Enerxías · USC Universidade de Santiago de Compostela · XUNTA DE GALICIA

The meeting will be a continuation of the last 16 series, originated in Lecce (Italy) in 1991, with the aim to discuss the latest developments on the resistive plate chamber technology and related detectors. Following the very successful 2022 meeting at CERN, it is the first time that the event will take place in Spain, and we will try to live up to expectations with a rich scientific and social program, and of course excellent food and great old-town ambience (and hopefully weather, too), at Santiago de Compostela!

Best Regards
Diego González-Díaz (conference chair)
Enrique Casarejos Ruiz (conference chair)

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Monday 9 September

08:30 → 09:15 **Registration**

09:15 → 09:30 **Welcome**

Vice-chancellor of Research (10')
Chair of the Local organizing committee (5')

09:30 → 11:20 **HEP performance (part I)**

09:30 **Status and perspectives of the «Standard RPCs»** 30m

The purpose of this talk is to describe the evolution of the standard RPC concept as it was formulated at the very beginning. In spite of its conceptual simplicity, the RPC can be adapted to fulfill very different tasks ranging from muon triggering-tracking at collider experiments, to the detection of Extensive Air Showers for ground based cosmic ray experiments. This talk tries to focus on all free parameters characterizing an RPC and to study how they can be optimized for each application of this detector. The problem of finding environment-friendly gases replacing the present “standard mixture” is quite extensively studied. A look at different possible applications concludes the talk.

Speaker: Rinaldo Santonico (INFN e Universita Roma Tor Vergata (IT))

Status and perspect... Status and perspect...

10:00 **Performance of ATLAS RPC detectors and L1 Muon Barrel Trigger with a new CO2-based gas mixture** 20m

Resistive Plate Chambers are used in the ATLAS experiment for triggering muons in the barrel region. These detectors use a Freon-based gas mixture containing C2H2F4 and SF6, high global warming potential greenhouse gases. To reduce the greenhouse gas emissions and cost, it is crucial to search for new environmentally friendly gas mixtures. In August 2023, at the end of the proton-proton data-taking campaign, ATLAS collaboration decided to replace the standard gas mixture (94.7% C2H2F4, 5.0% i-C4H10, 0.3% SF6) with a new CO2-based gas mixture: 64% C2H2F4,30% CO2, 5.0% i-C4H10, 1% SF6. The performance of the RPC detectors with the new gas mixture will be presented with a particular emphasis on detector efficiency, cluster size and timing performance, as well as the efficiency of the L1 Muon Barrel trigger system.

Speaker: Shixiang Su (University of Science and Technology of China (CN))

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10:20 **CMS RPC performance and operation in LHC Run 3** 20m

The CMS experiment has collected more than 74 fb^-1 of proton-proton collision data at a 13.6 TeV center-of-mass energy in Run 3 data taking (2022, 2023 and early 2024). The CMS RPC system faces the challenge of the LHC expected delivered instantaneous luminosity of up to 7.5 x 10^34 cm^-2s^-1, providing redundant information for robust muon triggering, reconstruction and identification. To ensure stable data taking, the CMS RPC collaboration has performed a series of detector operation, calibration and performance studies, including the development and maintenance of various software monitoring tools. The detector operation and overall performance at 13.6 TeV, as well as the encountered problems and their corresponding solutions will be presented.

Speaker: Mariana Shopova (Bulgarian Academy of Sciences (BG))

CMS RPC performa...

10:40 **Operation and performance of the ALICE Muon IDentifier RPCs during LHC Run 3** 20m

ALICE stands for "A Large Ion Collider Experiment", and it is designed to study proton–proton and heavy-ion collisions at ultra-relativistic energies at the LHC. The main goal of ALICE is to assess the properties of quark gluon plasma (QGP), 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 quarks in Pb-Pb collisions. In order to detect heavy quarks via their muonic decays, ALICE is equipped with a forward muon spectrometer (MS).
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 (2019-2021) of LHC, ALICE achieved a major upgrade of its apparatus. The upgrade enables a new ambitious program of high-precision measurements. Moreover, in order to fully profit from the increased interaction rate to 50 kHz in Pb–Pb collisions (was 10 kHz in Run 2) the ALICE experiment is running in continuous readout (triggerless) mode, hence the muon trigger became the Muon IDentifier (MID).
In order to prevent ageing effects and to improve the RPC rate capability, it was chosen to operate the detector with a lower gain, keeping the same gas mixture and decreasing significantly the working voltage. The front-end and readout electronics of the Muon Identification

System have been upgraded in order to support low-gain operation and triggerless readout.
The stability and performance of the MID RPCs during the first two and a half years of Run 3, at the unprecedented center-of-mass energies of 13.6 TeV for pp collisions and 5.36 TeV/nucleon pair for Pb–Pb collisions, will be discussed in this talk.

Speaker: Livia Terlizzi (Universita e INFN Torino (IT))

Operation and perfo...

11:00 **15 Years Young: the ALICE TOF detector in LHC RUN 3** 20m

The ALICE Time Of Flight (TOF) detector, composed of 1593 Multigap Resistive Plate Chambers (RPCs) with a gas mixture of Freon (93%) and SF6 (7%), covers an active area of approximately 140 m² and includes over 150000 readout channels. During the LHC long shutdown in 2018-2022, the detector underwent a major upgrade of its readout, allowing for continuous data taking and, therefore, to handle the current increase in interaction rate provided by the LHC.

After 15 years of operation, the detector's stability remains excellent, with no observable degradation in the driven current, the global rate and uniformity, or in particle detection efficiency. In this contribution, the detector performance achieved so far in LHC Run3 will be presented.

The continuous readout of the MRPC signal wouldn't be possible without the low and stable background rate of the single MRPC pad, which can now be monitored continuously, differently from the selected trigger matching window approach used in LHC Run 1 and Run 2. The calibration procedure for the detector in the continuous readout scheme will be discussed, with an overall time resolution better than the target design of 80 ps, along with the implications for particle identification performance. A few examples of PID applications in physics analysis will also be described.

Speaker: Sofia Strazzi (University and INFN, Bologna)

SofiaStrazziRPC202...

11:20 → 11:50 **Coffee break** 30m

coffee break

11:50 → 13:30 **HEP performance (part II)**

11:50 **The ATLAS RPC Phase II upgrade for High Luminosity LHC era** 20m

RPC detectors play a crucial role in triggering events containing muons in the central region of ATLAS. In view of the HL-LHC program, the existing RPC system, consisting of six independent concentric cylindrical detector layers each providing a full space time localization of hits, is currently facing a significant upgrade. In the next few years, 306 triplets of new generation RPCs will be installed in the innermost region of the ATLAS Muon Barrel Spectrometer, increasing from 6 to 9 the number of tracking layers, doubling the trigger lever arm. This allows a substantial enhancement of the present trigger redundancy, increasing the coverage from 76% to 96% approximately. The new chamber design is based on a very efficient integration of an innovative front-end electronics within the detector Faraday cage, allowing to operate the RPCs with an order
of magnitude less of average charge per count, correspondingly increasing rate capability and longevity. Fitting new chambers in the narrow space left in ATLAS inner barrel was a challenge,achieved by optimizing RPC materials and thickness, featuring a 1 mm gas gap (instead of 2 mm),
and 1.4 mm resistive electrodes (instead of 1.8 mm). Both sides of RPCs are readout by strip panels oriented to measure the bending coordinate of the muon spectrometer, while the second coordinate is reconstructed from the time difference of signal drift at opposite detector's ends. To achieve such
results, a 100 ps precise TDC has been integrated in the front-end electronics ASIC. The expected time resolution of a single 1 mm RPC gas gap is approximately 300 ps, and the possibility of a stand-alone Time of Flight measurement will have a huge impact on ATLAS searches for massive long-lived particles. An overview and the present status of the ATLAS RPC Phase II project will be presented.

Speaker: Paolo Camarri (INFN e Universita Roma Tor Vergata (IT))

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12:10 **Novel ideas for CMS L1 trigger in HL-LHC using RPC ultimate timing performance** 20m

The CMS RPC system has been upgraded for Phase-2 with two major projects. First is the comprehensive redesign of the Link System connecting the Front-End Boards (FEBs) of existing CMS RPC chambers to the trigger processors, which leads to fully exploit the intrinsic time resolution of 1.6 ns. Second is the extension of the pseudorapidity coverage by adding new chambers from $|\eta| = 1.9$ to 2.4. The newly assembled chambers utilize Improved Resistive Plate Chambers (iRPC) technology, enabling signal readout from both ends of the strip for 2-dimensional hit reconstruction. Equipped with advanced electronics, iRPCs deliver hit timing with a 500ps resolution, facilitating the development of precise Time of Flight triggers.
Given the vital role of RPC in CMS experiment, specifically upgraded to cope with high
luminosity and high event pile up expected in the upcoming High-Luminosity Large Hadron Collider (HL-LHC) phase, we will discuss novel trigger algorithms and advanced offline analysis techniques. We aim at improving the detection efficiency of Long-lived particles (LLPs) offering a tantalizing glimpse into new physics, potentially providing clues about dark matter, supersymmetry, and other beyond-the-Standard-Model theories. The focus will be on particles that either decay into Standard Model muons in the detector's outer layers or are inherently muon-like heavy stable charged particles. The ultimate time resolution performance of existing RPCs and iRPCs will enhance the discovery potential of our searches in CMS for new physics.

Speaker: Andres Leonardo Cabrera Mora (Universidad de los Andes (CO))

Novel ideas for CM... Novel ideas for CM...

12:30 **CMS RPC non-physics event data automation** 20m

This paper introduces a novel framework designed to process and analyze raw condition data retrieved from the non-physics event bus of the CERN Compact Muon Solenoid (CMS) experiment in real time. Utilizing advanced data streaming techniques, the framework aims to explore correlations between key operational parameters of the Resistive Plate Chamber (RPC) detector at the CMS experiment, including currents and rates, with CERN Large Hadron Collider (LHC) instantaneous luminosity and environmental conditions. Additionally, the framework seeks to study the evolution of the main parameters over time and to further predict future detector behavior by modeling performance based on these correlations. The CMS RPC automation framework, developed in Java, comprises over 30 automates categorized into main, auxiliary, and study groups, each performing distinct tasks. The four main automates process asynchronous data from the CMS RPC PVSS condition schema into synchronized tables within the CMS_RPC_COND schema on the OMDS instance of the CMSONR production database. These automates handle raw data for RPC currents, LHC modes, and environmental conditions. The fourth main automate processes raw RPC link board histograms from ROOT files for further analysis of RPC rates data. The auxiliary automates segment the LHC filling cycle into four blocks, standardizing condition data. The study automates are the integrated and accumulated integrated charge, current evolution, HV Conditioning, HV Conditioning Fit, and analyses of current and rate dependencies on LHC instantaneous luminosity and RPC charge per hit. All studies concerning currents and rates are extended to newly created virtual objects representing larger granularity objects of the CMS detector, such as regions, wheels, disks, stations, and sectors. The RPC automation, operating on a 4-hour cycle, has effectively processed and analyzed extensive datasets from the CMS experiment. This routine automation enables continuous monitoring and analysis of RPC currents and rates, with data stored across multiple database tables designed for rapid visualization. The capability to produce predictive models and granular analyses through virtual detector objects has significantly enhanced our understanding and forecasting of detector behavior.

Speaker: Anton Dimitrov (University of Sofia - St. Kliment Ohridski (BG))

20240909 CMS RP... 20240909 CMS RP...

12:50 **On the performance of the novel front-end electronics for the ATLAS BI RPC upgrade at HL-LHC developed in SiGe BiCMOS technology** 20m

The High Luminosity phase of LHC will require a vast improvement of the ATLAS detector in terms of performance, since the entire apparatus will be operated in much harsher conditions. The BI project is one of the ATLAS Phase-2 upgrades, ensuring the demands coming from the physics for the next 20 years. In this framework, a novel dedicated Front-End electronics has been developed, which exploits a BJT-based preamplifier, a fast discriminator (minimum threshold achievable 1-2 fC) and a high resolution (<100ps) Time-To-Digital converter in SiGe BiCMOS technology, to vastly enhance the detector rate capability (1 order of magnitude with respect to the RPC currently installed in ATLAS). This front-end electronics is integrated for the first time within the detector faraday cage, largely reducing the effects of induced and self-induced noise, allowing a minimum effective charge threshold on the induced signal of 1-2 fC. The integration of the front-end electronics directly within the detector Faraday cage is also permitted by the low power consumption of 15 mW/ch. The RPC coupled with this novel front-end electronics represents a new generation of large area timing detectors, granting a record time resolution of 350 ps on a single gas gap of 1 mm and operated with the ATLAS standard gas mixture. The effect of the extremely low threshold has also an impact on the gas mixture, enabling the usage of eco-friendly gas mixtures which would not be usable elsewise.
The latest performance of this newly developed front-end electronics along with the results achieved with RPC detector coupled with it will be shown.

Speaker: Luca Pizzimento (University of Hong Kong (HK))

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13:10 **iRPC front-end board readout electronics** 20m

Advanced front-end electronics are designed for the new improved RPCs of CMS experiment to cope with the HL-LHC era challenges. The front-end electronics (FEB) are equipped with a new ASIC, iRPCROC, which reads the strips and digitises incoming signals, triggering the Cyclone V FPGA to stamp the time of each signal accurately. This electronics was developed to read out the RPC detectors from both ends of a signal strip, using timing information to identify the position along it. The challenges and successful performance of the FEB in nominal conditions, as well as the mass production details will be presented.

Speaker: Maxime Gouzevitch (Centre National de la Recherche Scientifique (FR))

Maxime_Gouzevitch...

13:40 → 15:30 **Finger-food lunch**

15:30 → 17:50 **Production and QA**

15:30 **Innovative Resistive Plate Chambers for the CMS Phase 2 Upgrade: Project Summary, Construction, and Quality Assurance** 20m

In view of the Phase-2 of the LHC physics program, called High Luminosity LHC (HL-LHC), the CMS muon system will be upgraded to maintain a robust muon triggering and reconstruction performance. Therefore RE3/1 and RE4/1 stations of the forward muon system will be equipped with new improved Resistive Plate Chambers (iRPC) as dedicated detectors for muon triggering in CMS. The new iRPC detectors have a different design and geometry w.r.t the present RPC system to improve the rate capability and survive the harsh background condition during HL-LHC. This talk summarizes the iRPC project including the iRPC design and production process, details of the ongoing detector production, quality control procedures at the production sites and results of performance studies with high energy muon beam under intense gamma radiation at the CERN Gamma Irradiation Facility (GIF++) facility.

Speakers: Jules Vandenbroeck (Ghent University (BE)), Mehar Ali Shah (Universidad Iberoamericana (MX))

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15:50 **New Facilities for the Production of 1 mm gap Resistive Plate Chambers for the Upgrade of the ATLAS Muon**

Spectrometer 20m

The ATLAS Muon Spectrometer is set for a significant upgrade as part of the High-Luminosity LHC (HL- LHC) program, which includes the installation of three additional full coverage layers of new generation thin-gap Resistive Plate Chambers (RPCs) in the inner barrel region. These RPCs feature a reduced gas gap thickness of 1 mm between high-pressure phenolic laminate (HPL) electrodes, enhancing their background rate capability and longevity. This upgrade aims to maximize the muon trigger acceptance and efficiency. To achieve this, nearly 1000 RPC gas gaps need to be produced. To mitigate reliance on a single supplier and expedite production, the ATLAS muon community has partnered with two new companies in Germany and the Max Planck Institute for Physics in Munich. The gas gap assembly procedure was adapted to the infrastructure and tools available at the industrial manufacturers, facilitating the transfer of technology to industry after the prototyping phase. The certification of the manufacturers was achieved by constructing several small- and full-size RPC gas gap prototypes at each facility. The prototypes underwent rigorous testing at CERN's Gamma Irradiation Facility (GIF++), where their efficiency and time resolution were measured under different gamma background levels. The performance of these prototypes met the requirements for ATLAS at the HL-LHC. Additionally, the prototypes successfully passed an accelerated aging test at the GIF++, where they were exposed to the maximum photon dose expected during HL-LHC operations. This contribution will present the gas gap manufacturing procedures, the results of the certification tests, and the comparative analysis of the production methods investigated to ensure the reliability and efficiency of RPC production at external companies. The outcomes demonstrate that the new facilities are capable of producing high-quality RPCs according to the industrial standards.

Speaker: Dr Francesco Fallavollita (Max Planck Society (DE))

RPC2024_Gas_Gap...

16:10 **A new generation of RPCs for the ALICE Muon IDentifier** 20m

A Large Ion Collider Experiment (ALICE) is one of the four large experiments at the CERN Large Hadron Collider (LHC) and it is designed to study the physics of Quark Gluon Plasma (QGP) using ultra-relativistic Pb-Pb collisions. To study the muonic decays of heavy quarks, ALICE is equipped with a Muon Spectrometer located at forward rapidity, which includes the Muon IDentifier (MID), a system of 72 Resistive Plate Chambers (RPCs) arranged in four detection planes, covering a total area of about
140 m2.

The peak interaction rate of Pb-Pb collisions increased from < 10 kHz to ~ 50 kHz between Run 2 and Run 3. To cope with the new running conditions, the front-end and readout electronics were upgraded.
However, the RPCs currently operating are still, by a large fraction, the ones installed before the LHC Run 1, in 2006. Some of these RPCs have integrated a non-negligible charge, compared to their certified life-time (50 mC/cm2). To prevent any degradation of the system performance, a new generation of RPCs is needed to replace the ones currently operating if needed.

In 2021, after several interactions with the manufacturing company, a new production of spare RPCs was launched, using a new type of bakelite laminates. These new RPCs are now undergoing full characterization in the INFN Torino laboratory and a few of them have been already installed in the ALICE cavern.

In this talk the first results of tests on a significant number of spare RPCs will be presented, along with the performance of those that are already operating in the experiment.

Speaker: Sara Garetti (Universita e INFN Torino (IT))

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16:30 **Mass production and quality control of CEE iTOF-MRPC** 20m

Multi-gap resistive plate chamber (MRPC) has been adopted to construct the inner Time-of-Flight (TOF) detector for the CEE experiment at HLEF. Its mass production started in May 2024. The production procedure and related quality control (QC) are described. A preliminary status of the MRPC production and the test results with cosmic rays is given. The inner TOF covers a total area of approximately 3.4 m^2 and uses 24 high time resolution MRPC modules. With strict QC throughout the production process, the cosmic ray test results indicate that the time resolution is better than 40 ps and the efficiency exceeds 95%.

Speaker: Yingjie Zhou (University of Science and Technology of China)

Mass production an...

16:50 **Production and test of the RPC detectors for the large sectors of the ATLAS Inner Barrel (BIL) Phase II upgrade** 20m

The current RPC system is undergoing a major upgrade, consisting in the installation of approximately 1000 RPC detector units of new generation in the innermost barrel layer of the ATLAS Muon Spectrometer. The goal of the project is to increase the detector coverage, currently limited to approximately 80%, and improve the trigger robustness and efficiency. The production of the gas volumes takes place in a factory in Italy, in MPI and USTC, while the readout panels in Cosenza and USTC. The Italian collaboration is taking care of the construction and test of the chambers located in the large sectors of the ATLAS barrel (BIL).
Here we present the state of the art of the production, certification and logistics related to all the components produced at the Italian sites, as well as the assembly line and characterization of the BIL chambers at CERN. In particular, we describe the protocols defined and the instrumentation created for the certification of gas volumes at the Italian production factory, for the construction and certification of the read-out panels in Cosenza and for the assembly and certification with cosmic rays of the detectors at CERN. The certification results of the components produced are analyzed and discussed.

Speaker: Paolo Camarri (INFN e Universita Roma Tor Vergata (IT))

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17:10 **Mass production of RPC readout panels for ATLAS Phase-II upgrade and R&D on thin gas gap production at USTC** 20m

In order to cope with the High-Luminosity Large Hadron Collider, the current ATLAS Muon system foresees a significant upgrade during the Long Shutdown-3.
For the muon trigger, three layers of thin-gap Resistive Plate Chambers (RPC) will be added to the BI (Barrel Inner) region.
This new generation of RPC benefits from the thin-gap structure to achieve the required higher rate capability.
At the same time, it is also very challenging for detector production, quality assurance, and quality control.

Our Chinese ATLAS group undertook the construction of 912 readout panels, the fabrication of 72 BI gas gaps, and the assembly of 360 singlets for the upgrade.
To fulfill the BI-RPC project in China, we have established and optimized the vacuum-bag-based method for honeycomb readout panel production in our laboratory at USTC.
The same method is also applied to the production of readout panels in the industry. The speed and quality of readout panel production have been significantly accelerated.
The production procedures of the gas gap prototypes at USTC are presented. The gas gaps are oiled at a room temperature of 40Â°C and flushed with heptane before applying the Linseed oil.
This process can significantly enhance the quality of linseed oiling on the inner surfaces of the Bakelite RPC.
The quality of those gas gap prototypes are checked and the results are very promising.

Speaker: Dongshuo Du (University of Science and Technology of China (CN))

USTC_RPCPhase2U...

17:30 **Triplet assembly and certification of the new generation of RPC for the ATLAS phase-2 upgrade at Max Planck Institute**
20m

A new generation of Resistive Plate Chambers have been developed for the ATLAS phase-2 upgrade in sight of the High-Luminosity phase of the Large Hadron Collider. These RPCs consist in three independent 1 mm gas gaps(singlets) equipped with a newly low-threshold Front-End electronics, assembled in the same mechanical structure(triplet). During 2024 the production of the phase-2 RPCs started and the detectors will undergo (2024-2025) a certification test before the installation in the ATLAS cavern. The triplet assembly and the certification with cosmic rays of the BIS-type detectors is performed at the Max-Planck-Institute for Physics (MPI) in Munich. The architecture of the cosmic rays test stand has been built at MPI and has been studied in order to provide an efficient and robust structure to ensure an excellent quality control and study precisely the whole RPC performance needed to certify the detectors for the ATLAS experiment. In this presentation the assembly procedure, the architecture of the test stand and the certification protocols will be presented along with the validation tests to characterize the RPC performance.

Speaker: Giorgia Proto (Max Planck Society (DE))

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19:00 → 21:00 **Welcome cocktail** 2h

Colexio Maior Fonseca

Tuesday 10 September

09:00 → 11:10 **HEP & BHEP applications (part I)**

09:00 **Planning for the future of particle physics** 30m

The field of particle physics is currently in unknown territory, facing the question of how to further explore the frontier represented by the standard model of particle physics. With several questions left unanswered and a plethora of models for physics beyond the standard model, a very broad program of exploration for new phenomena and particles, with masses ranging over several tens of orders of magnitude is being pursued or planned. A key element of this future exploration will be the next big collider that will operate at the energy frontier. With the major players in the global high energy physics scene having completed their corresponding strategy processes either several years ago (Japan with the ILC and China with the CEPC) or recently (US with the P5 process), all eyes are now turned to Europe. The talk will provide an overview of current options and plans for formulating a strategy for the future of European, and thus also global, particle physics.

Speaker: Paris Sphicas (CERN/Athens)

2024-09-10-RPC-Wo...

09:30 **Status of the CBM Time-Of-Flight project** 20m

In order to provide an excellent particle identification (PID) of charged hadrons at the future high-rate Compressed Baryonic Matter (CBM) experiment the CBM-TOF group has developed a concept of a 120 m^2 large Time-of-Flight (ToF) wall (about 90000 channels) with a system time resolution below 80 ps based on Multi-gap Resistive Plate Chambers (MRPC). Prior to its destined operation at the Facility for Antiproton and Ion Research (FAIR), a preproduction series of MRPCs is being used for physics research at two scientific pillars of the FAIR Phase0 program. At STAR, the fixed-target program of the Beam Energy Scan II (BES-II) relies on 108 CBM MRPC detectors enabling forward PID for center of mass energies in the range of 3 to 7.7 AGeV Au+Au collisions. At miniCBM, high-performance benchmark runs of Λ production at top SIS18 energies (1.5/1.9 AGeV for Au/Ni beams) and CBM design interaction rates of 10 MHz became feasible. Apart from the physics perspectives, these FAIR Phase-0 involvements allowed for high rate detector tests including aging studies and long term stability tests. The MRPC detectors of different granularities were extensively tested in several beam campaigns at particle fluxes of up to a 30 kHz/cm^2 and reached by now the final design so that for some MRPC types the mass production could be started recently.
Latest detector performance results and the status of the CBM TOF project including counter mass production, the infrastructure and time line will be discussed.

Speaker: Ingo-Martin Deppner (Physikalisches Institut der Universität Heidelberg)

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09:50

Radiation hard Multi-Strip Multi-Gap Resistive Plate Chamber architecture for low polar angles of the CBM-TOF wall

20m

The Multi-Strip, Multi-Gap Resistive Plate Chambers (MSMGRPCs) developed to fulfill the high counting rate and granularity requirements of the low polar angle region of the CBM-TOF wall showed very good performances in time resolution (50 ps) and efficiency (>90%), up to 30 kHz/ cm^2 counting rate, exposed on the whole active area. Considering that CBM will run in the average 2 months/year for about 10 years, comprehensive studies of the behavior of such detectors at high irradiation dose are mandatory.
Detailed studies of the aging effects induced in a MSMGRPC by high γ irradiation dose showed a gas pollution effect. Higher deposition of radicals of different types on the whole surface, on both sides of the floating glass electrodes and noise rates around the spacers were evidenced with impact on the detector performance and artificial increase of the data volume in a free-running data acquisition mode. The solutions for the mitigation of such effects have been the design of MSMGRPC prototypes with a direct flow of the gas mixture, (100% gas transmission through the gas gaps) and replacement of the fishing line by discrete spacers. The exposure to high X-ray flux of a prototype with the new design demonstrated negligible aging effects even for rather low gas flow. We report in this contribution the construction details of the new architecture, results of extensive aging tests using high X-ray flux as well as the performance of the prototypes in terms of efficiency and time resolution obtained in the in-beam tests performed at SIS18, GSI-Darmstadt in the mCBM experimental setup. Details on the implementation of direct flow MSMGRPCs in the first CBM-TOF inner wall module – module M0- whose configuration is the most complex among the twelve CBM-TOF inner wall modules, will be presented.

Speaker: Mariana Petris (Horia Hulubei National Institute of Physics and Nuclear Engineering (RO))

MarianaPetris_RPC...

10:10

T-SDHCAL Hadronic Calorimeter for future Higgs factory

20m

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 and FCCee) has started with the conception and the realization of new prototypes.
The new prototype proposes to exploit the excellent time resolution provided by (M)RPC detectors in order to better build the hadronic showers with the aim to separate close-by ones and also to single out the contribution of delayed neutrons with the purpose to improve on the Particle Flow Algorithm (PFA) performances and better reconstruct the showers energy.
A new technique to build MRPC has been developed and first results confirm the excellent efficiency of the ne detectors. Timing performance is under study using the PETIROC ASIC developed by OMEGA group. The new activities are part of the new collaborations DRD1 and DRD6.
The progress realized on the different aspects of the new concept will be presented and the future steps will be discussed.

Speakers: Imad Laktineh (Centre National de la Recherche Scientifique (FR)), Michael Tytgat (Vrije Universiteit Brussel (BE))

RPC2024_SDHCAL....

10:30

Use and application of the CMS RPC in future experiments

20m

The RPC chambers are the only detector in the muon system of the CMS experiment that covers the barrel and the endcap. During the entire time of operation in CMS, they have demonstrated their robustness, exceeding the ten-year limit for which they were originally designed. Moreover, for the high luminosity LHC period, an upgrade of the electronic boards will be performed to exploit the full potential of their time resolution (in the order of 1-2 ns), increasing even more their importance in the trigger system of the CMS experiment. RPC is a low cost and low maintenance detector (compared to other gaseous detectors) and the experience accumulated in the CMS experiment shows that it is a great alternative to be used in new physics experiments that require a large amount of detection area with high temporal resolution. During this talk we will explore some alternatives for the use of RPC chambers in new experiments, and some examples of physics analysis in which they can be used.

Speaker: Ece Asilar (Hanyang University)

RPC2024_otherExp...

10:50

COmpact DEtector for EXotics at LHCb: CODEX-b

20m

The COmpact DEtector for EXotics at LHCb (CODEX-b) is a particle physics detector dedicated to displaced decays of exotic long-lived particles (LLPs), compelling signatures of dark sectors Beyond the Standard Model, which arise in theories containing a hierarchy of scales and small parameters. The CODEX-b detector is a cube with 10m per side with two internal sections, planned to be installed near the LHCb interaction point. It is built of a new generation of high performance RPCs triplet chambers, derived from the ATLAS upgrade RPC technology, providing a space x time resolution of a few mm x 300 ps per individual detector layer. It will have a zero background environment, hence complementing the new-searches program of other detectors like ATLAS or CMS. A demonstrator detector, CODEX-β, is being assembled now to take data beginning in 2025. It will validate the design and physics case for the future CODEX-b. CODEX-β will be responsible for validating the background estimations for CODEX-b, demonstrating integration in the LHCb readout system, and showing the suitability of the baseline tracking and its mechanical support. This talk will present the latest developments and will focus on the status and plans for CODEX-β.

Speaker: Michael Jacob Peters (University of Cincinnati (US))

Michael Peters.pdf

11:10 → 11:30 **Coffee** 20m

11:30 → 13:30 **HEP & BHEP applications (part II)**

11:30 **ANUBIS: future large-scale application of RPC detectors** 20m

An important potential large-scale application of RPC detectors in the near future is the ANUBIS detector at the HL-LHC, with a total gas gap area of about 8,000 m^2. The primary physics goal for the ANUBIS detector is searching for new long-lived particles (LLP) that are predicted in many extensions of the Standard Model with Dark Matter candidates. The ANUBIS detector will provide unprecedented sensitivity to LLPs with decay lengths of O(10m) and above produced at the electroweak scale. After a brief review of the ANUBIS physics case, the performance benchmarks that are dictated by the physics case will be discussed, and a proposed design of the ANUBIS detector will be outlined. This year, a first complete prototype detector module called proANUBIS has been taking data in the ATLAS cavern. The physics case for proANUBIS and its relevance to ANUBIS physics case will be outlined.

Speaker: Oleg Brandt (University of Cambridge (GB))

2024_09_10_RPC20...

11:50 **Insights from the proANUBIS demonstrator using Run 3 LHC collision data** 20m

The proposed AN Underground Belayed In-Shaft (ANUBIS) experiment aims to search for long-lived particles (LLPs) within CERN's ATLAS underground cavern. Recent efforts to realise this experiment include the installation and commissioning of a prototype detector, proANUBIS, which has been collecting LHC collision data since in 2024. The key point physics programme of the proANUBIS demonstrator is the study of expected backgrounds for the ANUBIS experiment. The demonstrator employs the ATLAS BIS78 RPCs, which feature a 1mm gas gap, in contrast to the 2mm used in the legacy ATLAS RPCs. In this presentation, we will discuss the quality control and performance studies of these RPCs using cosmic ray flux. Additionally, we will report on the performance of proANUBIS, including hit multiplicity, cluster size, and reconstruction efficiency of these RPCs, based on recent data collected by the demonstrator during Run 3 LHC collisions.

Speakers: Aashaq Shah (University of Cambridge (GB)), Oleg Brandt (University of Cambridge (GB))

proANUBIS_update....

12:10 **New RPC readout for EAS mapping in ground based cosmic ray detectors** 20m

Besides High Energy Physics experiments, RPCs have been successfully employed also in cosmic ray physics, as demonstrated by ARGO experiment.
The detector readout is however very different from that used for particle tracking in collider experiments, based on strips behaving as transmission lines with non-negligible signal propagation time.
Cosmic ray detection with ground-based apparatuses requires mapping extensive air showers with good accuracy. The detector requirements, based on simulations as well as on past experiments, are a modest rate capability (the cosmic rays one) coupled to good capability of measuring high hit densities (up to 10^6/m^2 around the core region); a time resolution of the order of the ns is also required for the incident direction reconstruction. A space resolution of the order of 10 cm is sufficient, due to intrinsic fluctuations of the shower front. Given the large area to be covered, the detector must be simple, robust, reliable and economic.
To fulfill these requirements we will present a new readout, based on squared pads of area around 40x40 cm^2, which compared to Argo, can reduce the number of read-out channels down to about an order of magnitude without losing space and time resolutions. Another innovative aspect of the new readout is the signal pick-up point that is localized not at the pad edge but at its center.
Preliminar studies about signal pick-up will also be presented.

Speaker: Dr Alessandro Paoloni (INFN - LNF)

Paoloni_EAS.pdf

12:30 **Outdoor MARTA RPCs performance update** 20m

Over the last two decades, the possibility of using RPCs in outdoors systems has increased considerably. Our group has participated in this effort having installed several systems and continues to work on their optimization, while simultaneously studying and developing new approaches that can to use of RPCs in outdoor applications.

In particular, some detectors were deployed in the field at the Pierre Auger Observatory in 2019 remained inactive, awaiting the commissioning of support systems. During the pandemic the detectors were left without gas flow for more than two years, until 2022 when the were fill with gas and turn HV on,
The behavior of 5 large area RPCs deployed under one of the AUGER water Cherenkov tanks will be presented.

Speaker: Luis Alberto Vieira Lopes (Laboratory of Instrumentation and Experimental Particle Physics (PT))

Luis_Lopes_RPC20...

12:50 **The miniTrasgo International Research Network** 20m

The Trasgo detectors were proposed a few years ago for the measurement of cosmic rays at ground level with a very high angular resolution, with the ability to measure bundles of particles and with an electron/muon PID carried out by software. Now a new generation of detectors, the miniTrasgos, of only 0.1m2 of surface, has been launched and several of them have already been built and distributed in different universities in Madrid (Spain), Warsaw (Poland) and Puebla (Mexico). Other detectors are still under construction. All detectors share layout and both reconstruction and analysis software. In this poster we show details of the network, the characteristics of each node and some preliminary results of the detectors already active.

Speaker: Prof. Juan A. Garzon (Univ. Santiago de Compostela)

jag24_09_Trasgos_...

13:40 → 16:00 **Finger-food lunch & poster session (I)**

13:40

CMS RPC L1 Trigger primitives in HL-LHC
20m

This talk delves into the crucial enhancements of the RPC system as part of the comprehensive upgrades to the CMS Level-1 Trigger, tailored to address the increased luminosity challenges at the HL-LHC. The revised Level-1 architecture maximizes the integration and utility of the muon subsystems—CSC, DT, and particularly the RPC—to ensure superior performance and reliability under extreme operational conditions. The presentation will focus on the specific advancements and strategic role of the RPC upgrades in enhancing muon trigger efficiency and robustness. It will present a newly developed clustering algorithm, detailing the first results from cosmic and test beam evaluations of the new Trigger Primitives with upgraded backend boards.

Speaker: Qingfeng Hou (Chinese Academy of Sciences (CN))

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14:00

iRPC clustering algorithm and hit reconstruction
20m

One of the upgrades of CMS RPC system is the installation of new chambers - the improved RPC - with a new readout technology, achieving a space resolution along the strip of about ~2cm, enabling the inclusion of the RPC hit in the CMS muon reconstruction. The main characteristic of the iRPC is the two side strip readout which makes a new clusterization algorithm necessary. The algorithm was developed during the test beams at GIF++ and its implementation at CMS Software is under development. In this poster we present the main idea of the algorithm, the final hit reconstruction in the chamber, and the results obtained in the test beams.

Speaker: Mauricio Thiel (Universidade do Estado do Rio de Janeiro (BR))

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14:20

An extension to the Analytical Method clustering algorithm for BMTL1 benefitting from CMS RPC timing
20m

This poster introduces an extension to the Analytical Method clustering algorithm designed for the Barrel Muon Track Finder Layer 1 (BMTL1) for HL-LHC. The new extension leverages the enhanced timing capabilities of the CMS RPC system. The new algorithm significantly reduces the prefiring of muons. This method addresses challenges associated with high particle flux environments, ensuring robust and reliable muon track reconstruction. The presentation will cover the algorithm's development, its integration with existing CMS infrastructure, and comparative results demonstrating its performance improvements over traditional clustering methods. Data from MC simulations, which showcase the algorithm's effectiveness, will also be shared.

Speaker: Raphael Gomes De Souza (DFNAE - UERJ)

CMS_muon_poster_...

14:40

CMS RPC L1 Trigger clustering at CMSSW
20m

This poster presents the development of RPC L1 Trigger clustering within the CMS software framework, CMSSW, incorporating the improved timing capabilities of RPC chambers. The integration of these upgrades significantly enhances the resolution and reliability of the L1 Trigger emulator, enabling more precise trigger responses. The presentation will detail the technical advancements in digitisation, the integration with CMSSW, and the benefits observed in preliminary tests, demonstrating the system's improved performance in particle tracking and data handling using MC simulations.

Speaker: Cristina Giordano (Austrian Academy of Sciences (AT))

RPCPoster_Cristina...

15:00

CMS RPC efficiency using tag-and-probe method in LHC Run 3
20m

The CMS experiment is collecting proton-proton collisions at the center-of-mass energy of 13.6TeV in LHC Run 3. RPC detector is one of the sub-detectors of the CMS muon system which is capable of triggering and reconstruction of muons. In this poster, efficiency of the CMS RPC detector during the Run 3 data taking period is presented. The Tag-and-Probe method with the decay of the Z boson to two muons was used in measuring the efficiency of the operating RPC detector. Efficiency is derived from the matching of RPC hits with probe muons extrapolated up to the RPC.

Speaker: Jongwon Shin (Kyung Hee University (KR))

RPC_Efficiency_Run...

15:20

Machine Learning approach to CMS RPC HV scan data analysis
20m

The HV scan is a crucial sequence of calibration runs typically conducted at the onset of each data-taking year with the initial collisions of the CERN Large Hadron Collider (LHC) at nominal luminosity. This procedure ensures the proper functioning of the Resistive Plate Chamber (RPC) detectors at the Compact Muon Solenoid (CMS) experiment at CERN by establishing correct working points. In the past, aspects of the HV scan analysis were performed manually, leading to time-consuming procedures. This study endeavors to revolutionize the analysis of RPC HV scan data by integrating machine learning (ML) algorithms. The primary objective is to automate and expedite manual steps in the analysis process, thereby enhancing the efficiency and speed of task deliverables. Through the application of ML techniques, this research seeks to optimize RPC detector performance analysis, facilitating quicker decision-making processes and ensuring timely adjustments to detector settings for optimal data collection during LHC operations. The HV scan measures efficiency and cluster size as functions of operating voltage for each RPC double gap, within the effective voltage range of [8600, 9800]V. Our methodology prioritizes parametrizing efficiency curves to enable the evaluation of RPC double gap efficiency at arbitrary voltage values. To achieve this, we employ an artificial neural network (ANN) capable of discarding outliers and approximating efficiency behavior, even in cases when data is missing within the efficiency plateau. We developed a dedicated autoencoder ANN that operates in Fourier space to approximate efficiency vs. HV curves per double gap. This autoencoder takes measured efficiency at various supply voltage values and estimates detector efficiency within the voltage interval of 8.0 to 10.5 kV. Subsequently, the refined curve undergoes sigmoidal function fitting, and resulting parameters are utilized in the working point definition procedure. Once the working HV point per double gap is established, a specialized optimization procedure is employed to evaluate working points per HV channel. Multiple double gaps share a single HV supply line, and voltage adjustments are made to fulfill efficiency and cluster size requirements, providing the necessary output for analysis. Thanks to novel technologies and the applied methodology, the time required to analyze the calibration data of the CMS RPC HV scan can be reduced from over 3 months to less than a week.

Speakers: Anton Dimitrov (University of Sofia - St. Kliment Ohridski (BG)), Mihaela Pencheva Pehlivanova (University of Sofia - St. Kliment Ohridski (BG))

ML_for_RPC_hvsca...

15:40 **CMS RPC Background studies in LHC Run 2 and Run 3** 20m

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 and Run 3 the higher instantaneous luminosity leads 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 pp collisions at 13 and 13.6 TeV in 2018 and 2022-2023, respectively, with instantaneous luminosities up to 2.2 10^34 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 10^34 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. The reported analysis allows to distinguish and showcase the contributions from long-lived background rates and the promptly induced background.

Speaker: Leonardo Favilla (Scuola Superiore Meridionale & INFN Naples Section (IT))

LFavilla_Poster_RP...

16:00 → 18:00 **Techniques**

16:00 **Performance studies of thin-gap RPC detectors with thin phenolic glass electrodes** 20m

The timing Resistive Plate Chambers (tRPCs) detectors are generally characterized by a multi-gap structure with multiples floating high resistivity glass electrodes. These features restrict their field of application to medium sized areas experiments. In this presentation we show the performance of two single thin-gap RPCs prototypes designed to work as an intermediate solution between tRPCs and RPCs. The detectors are characterized by a 0.2 mm gas gap, 0.4 mm thick phenolic glass electrodes and a Front-End electronics with 2 fC threshold. Phenolic glass, instead of bakelite, has been selected for its mechanical strength even in thin sheets despite the high bulk resistivity. The combination of this parameters allows to gain significant factors both in terms of rate capability and temporal resolution. Test with 180 GeV/c muons beam with and without gamma radiation background have been performed showing the possibility of achieving a time resolution better than 150 ps, operating up to 4 kHz/cm2 at 80% of efficiency. This solution has been studied in two configurations: two detectors with independent pick-up electrodes and gas volumes, and one detector with one read-out electrode picking up the signal from two shared gas volumes. The characterization of all the detector figures of merit is described and compared to the traditional solutions.

Speaker: Alessandro Rocchi (INFN e Universita Roma Tor Vergata (IT))

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16:20 **Novel tunable materials for resistive protection of gaseous detectors from room temperature to 90 K** 20m

The resistive well (R-WELL) and the resistive plate well (RP-WELL) are resistive-protected gaseous detectors, capable of operation in a harsh accelerator environment in discharge-free mode. Among current room-temperature applications are digital hadron calorimetry and muon tomography. These detectors also present a potential solution for operation in cryogenic conditions, with adequate resistive materials. We hereby present the characterization results of two resistivity-tunable materials, namely DLC (diamond-like carbon) film coatings and Fe2O3/YSZ (iron oxide + Yttria-stabilized zirconia) plates, suitable for operation at LXe and LAr temperatures. Operation at LXe temperature (163 K) demonstrated stable operation at gains well above 10^5, with soft x-rays. Measurements in Ar vapor near LAr temperature (90 K) provided stable avalanche gain with the protected structures, up to 5-fold larger than with thick GEM (THGEM) - opening potential prospects for operation of dual-phase time projection chambers at lower energy thresholds.
In this work we will discuss in detail the characteristics of this first-generation of cryogenic resistive materials, capable of discharge quenching in gaseous detectors down to LAr temperature. Additionally, it will be shown how they can be tailored to room-temperature operation, yet with resistivities in the range of 10-10^4 MΩ /sq (resistive coatings) and 10^9 - 10^12 Ω·cm (resistive plates), compatible a priori with RPC-based detectors.

Speaker: Sara Leardini (Universidade de Santiago de Compostela (ES))

Sara_Leardini_RPC....

16:40 **Noise and Performance Study of Sealed MRPC Detectors with Different Spacers Based on Simulation and Cosmic Ray Test** 20m

MRPC detectors, known for their excellent time resolution, are widely used in Time of Flight (TOF) systems for high-energy physics experiments. The CBM experiment requires detectors that can handle an intensity greater than 20 kHz/cm². MRPCs with low-resistance glass and pad spacers meet these requirements. Tsinghua University undertook the development and production of the CBM-TOF MRPC2. This paper primarily investigates three main aspects.

Firstly, this paper presents a theoretical study on the noise performance of sealed MRPCs based on simulations, discussing the noise performance of pad spacer sealed and fishline spacer sealed MRPCs.
Secondly, cosmic ray tests with the self-trigger method were conducted on pad spacer and fishline spacer MRPCs. High voltage scans were performed to test the dark currents and noise signal frequency as a function of voltage. The noise count rate of both types of MRPC follows an exponential increase with operating voltage. For pad-sealed MRPCs, under the same high voltage, the noise rate per unit area is approximately one percent of the fishline-sealed MRPCs. Additionally, the study obtains hit position maps of the self-trigger cosmic ray tests, Which noise signals occupy the majority. The position maps clearly show higher noise rates at the spacer locations, and a statistical analysis of the noise rate differences between the spacer locations and other parts of the detector is also conducted. This research systematically studies the noise principles and performance of pad spacer and fishline spacer sealed MRPC detectors.
Finally, an external-trigger cosmic test scans the efficiency and time resolution performances of both MRPC2 types, Both sealed MRPC2 with different spacers reached a time resolution of better than 90 ps and an efficiency of better than 95% at a high voltage of 5700V. Additionally, a coincidence self-trigger cosmic test is also held, providing a faster testing method for the performance of MRPC2 in mass production.

Speaker: Mr Kai Sun (Tsinghua University)

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17:00 **Carbonless and self-sealed MRPC for MARQ experiment in Japan** 20m

The MARQ (Multi-Purpose Analyzer for Resonance and Quark dynamics Spectrometer) experiment, a future experiment in Japan, involves the construction of two types of Multigap Resistive Plate Chambers (RPCs): Time-Of-Flight RPCs and tracking RPCs. The former will be utilized for π/K/p separation below 1.7 GeV/c, while the latter will serve for muon identification downstream. However, the development of these detectors has encountered various challenges. Notably, the supplier of carbon tape is no longer available. To solve this problem, we built a carbonless RPC in configuration of 1 stack, 5 gaps, a 0.26mm gap, and a 20cm x 20cm active area. The carbonless electrode consists of an array of 1cm x 1cm copper pads interconnected with several MOhm resistors to simulate the function of the carbon electrode and reduce the chamber's current draw during operation. The side advantage of carbonless is the relatively easier production since the electrode and readout strip are integrated into the same PCB. Additionally, we have encountered constant issues with gas leaks in the glue-sealed Acrylic cases, attributed to transportation damage. To address this, we designed an O-ring gas-sealed chamber with the electrode-readout PCBs as the top and bottom covers, named self-sealed chamber. The material budget is reduced and the production is also simplified with this design. A recent interest of replacing fishline with Mylar spacer is also tested with this chamber. The beam tests were performed at SPring-8 to evaluate the performance. We will present the development and share the test results.

Speaker: Chia-Yu Hsieh (Academia Sinica (TW))

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17:20 **Sealed Resistive Plate Chambers: A Case Study from the SND@LHC Experiment** 20m

The phase-out of Hydro-fluorocarbons, due to their high Global Warming Power, affecting the main gas used in Resistive Plate Chambers (RPCs), tetrafluorethane $C_2H_2F_4$, has increased pressure on existing systems and imposes strong restrictions on its use in new systems. A possible solution to the problem is the substitution of this gas by others with a much lower Global Warming Potential.

But there could be another possibility, which is the construction of sealed chambers, i.e. chambers that do not need a continuous gas flow to operate (in a similar way to Geiger-Muller counters). This possibility would allow continuing to use HFCs or eventually other types of gases that are already banned. It would also greatly simplify the detector, not requiring the complex and expensive gas systems normally used. This simplification could be very relevant for the use of this type of technology outdoor.

After an initial development in the laboratory, the first practical use of this technology in the Scatter Neutrino Detector (SND@LHC) is described in this work. A telescope composed of four planes of sealed RPCs has been installed in front of the SND detector to measure the muon flux, the main background source of the experiment. The most relevant parameters in the continuous operation of the detector will be presented, showing no evident differences with RPCs operating in continuous gas flow, demonstrating the possibility of using this technology, over several months and exposed to a low particle rate of around a few Hz/cm².

Speaker: Alberto Blanco Castro (Laboratory of Instrumentation and Experimental Particle Physics (PT))

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17:40 **Upgraded simulation of the CERN Gamma Irradiation Facility (GIF++)** 20m

GIF++ irradiation facility at CERN is a unique infrastructure for performance test and long term characterization of gaseous detectors under severe gamma background conditions. Also, a muon beam line is available to ensure precise detector studies. The gamma flux is originated by a 14 TBq 137 Cs source and can be modulated in a wide range by means of various absorption filters which can be controlled remotely.
To understand the detector response, an evaluation of the dose and the gamma flux at the detector position is needed. To this aim we have performed a detailed GEANT 4 simulation of the area, and the ambient equivalent dose rate has been computed. The results are validated by comparison with some measurement campaigns which have been taken using fixed and portable gamma dosimeters at various distance from the source and different attenuation filter combinations
Once calibrated with experimental measurements, the simulation offer the possibility to compute the gamma flux on a given detector and therefore estimated the expected hit rate.

Speaker: Nicola Ferrara (Universita e INFN, Bari (IT))

GIF_++_ferrara_RPC... GIF_++_ferrara_RPC...

Wednesday 11 September

09:00 → 11:10 **Ecogases and longevity (part I)**

09:00

Gaseous Detectors R&D, where do we stand / where do we go 30m

Rather than focusing on any specific research or technology, this contribution will emphasize the importance of collaborative efforts in advancing R&D in gaseous detector instrumentation.

It begins by contextualizing the setting up of several new R&D collaborations on instrumentation, specifically the newly established DRDs, following the recommendations from the latest European Strategy Update for Particle Physics. The focus will then shift to the DRD1 Collaboration, which encompasses a range of gaseous detector technologies, including Micro Pattern Gas Detectors (MPGD), Resistive Plate Chambers (RPC), and wire-based detectors. The formation of DRD1 has benefited from the experience and heritage of the RD51 Collaboration, an international R&D initiative based at CERN that was dedicated to advancing MPGD technologies. A brief overview of RD51's modus operandi and a series of concrete examples of its impact on the field of R&D in gaseous detectors will be provided. This will be used to highlight the potential benefits of the new DRD1 collaboration in supporting innovation, improving understanding, developing tools, and facilitating the R&D activities of the involved groups. The talk will conclude by outlining current strategies common to all newly established DRD collaborations for securing long-term funding to support ongoing innovation in instrumentation.

Speaker: Eraldo Oliveri (CERN)

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09:30

New RPC Gas Mixtures for Sustainable Operation in the CMS Experiment 20m

The current operation of the Resistive Plate Chamber (RPC) system within the CMS experiment involves approximately 95% tetrafluoroethane (C2H2F4, TFE). However, in response to climate change concerns, the European Union has instituted a ban on TFE owing to its elevated Global Warming Potential (GWP), resulting in an associated increase in market prices. In this framework, shared endeavors within the RPC EcoGas@GIF++ Collaboration, have been dedicated to investigating novel ecological gas mixtures based on tetrafluoropropene (C3H2F4, HFO-1234ze) to ensure the sustainable functionality of RPCs. This presentation will delve into the performance outcomes derived from improved RPC gas gaps operating on HFO/CO2-based mixtures as ecologically viable alternatives, particularly in anticipation of the High Luminosity LHC phase. Additionally, the utilization of TFE/CO2 mixtures will be explored as a pragmatic strategy to swiftly alleviate gas-related operational costs.

Speaker: Dayron Ramos Lopez (Universita e INFN, Bari (IT))

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09:50

Signal shape studies and rate dependence of HFO-based gas mixtures in RPC detectors 20m

The RPCs employed at the LHC experiments are currently operated in avalanche mode, with a mixture containing a large fraction of C2H2F4 (> 90%) with the addition of i-C4H10 and SF6 in slightly different concentrations (depending on the experiments). However, C2H2F4 and SF6 are fluorinated greenhouse gases (F-gases) with GWP of ~1400 and ~22800 respectively. EU regulations imposed a progressive phase-down of C2H2F4 production and consumption, aiming at strongly reducing its emission. This is already resulting in an increase of its price and reduction in availability.

The most desirable long-term solution to this problem is to find an alternative, F-gases free gas mixture, able to maintain similar detector performance. To address this challenge, the RPC ECOgas@GIF++ collaboration (including RPC experts of ALICE, ATLAS, CMS SHiP/LHCb and the CERN EP-DT group) was created in 2019. The collaboration is currently studying a gas from the olefine family, the C3H2F4 (or simply HFO, with GWP~6), to be used, in combination with CO2, a substitute for C2H2F4.

This contribution will focus on the signal shape studies that have been carried out by the collaboration during dedicated beam test periods. The methodology used in the data analysis will be presented, together with the results obtained with several HFO-based gas mixtures, compared to the currently employed one. Furthermore, results on the counting-rate dependence of the RPC performance, obtained by combining the muon beam with the GIF++ 137Cs source with different attenuation factors, will also be presented.

Speaker: Luca Quaglia (Universita e INFN Torino (IT))

LucaQuaglia_RPC20...

10:10

Characterization of Glass Multigap RPC Detector with alternative gas to R134a and SF6 20m

Glass Multigap Resistive Plate Chamber (MRPC) detectors are primarily used for their excellent time resolution properties in High Energy Physics and Tomography application. Typically, they are operated with a freon-based gas mixture containing C2H2F4 (R134a) and SF6, both greenhouse gases (GHG) with high global warming potential.

This study focuses on the construction and characterization of new prototypes of 4-gap glass MRPC detectors, along with their performance evaluation. The construction employs an alternative method for spacer placement, using one-side glued circular spacers, making the construction process easier.

The detector's performances with alternative gas mixtures will be presented. Initially, a partial substitution of the R134a with CO2 and HFO will be considered, followed using NOVEC 4710 as an SF6 alternative. The detectors are characterized with cosmic muons to evaluate efficiency, current, streamer probability, prompt charge, and cluster size.

Finally, the time resolution of the different gas mixture will be analyzed, using the combination of two MRPC and the PETIROC 2A front-end ASIC.

Speaker: Mattia Verzeroli (Universite Claude Bernard Lyon I (FR))

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10:30

Study of environment-friendly SF6 substitute for the Resistive Plate Chambers 20m

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 current and the comfortable avalanche-streamer separation guarantee high detection efficiency, rate capability and slow detector ageing. This gas mixture has a high Global

Warming Potential (GWP$\sim$1430) due to the presence of $C_2H_2F_4$(GWP$\sim$1450) and SF_6 (GWP$\sim$22400).
The $C_2H_2F_4$ and SF_6 are not recommended for industrial uses anymore, thus their availability will be increasingly difficult over time and the search for an alternative gas mixture is then of absolute priority within the RPC community.
Moreover, CERN is pursuing a campaign toward the reduction of these gases, because they represent most of the LHC particle detectors greenhouse gas emission.
There are several studies on going aimed at replacing the $C_2H_2F_4$. All these studies require the increase of the SF_6 concentration from 0.3$\%$ (standard gas mixture) to 1$\%$ to achieve an avalanche-streamer separation of 300 V. This means that the GWP of the alternative gas mixtures can not be below $\sim$200 and the increase of SF_6 should be avoided to maintain the GWP at low level. A very promising alternative to the SF_6, the $C_3H_2ClF_3$, has been found and is presented in this work. This gas has a GWP$\leq$1, paving the way to the possibility to operate the RPC detector with a completely environment friendly gas mixture. The tests of the performance and longevity operating the RPC with this gas are reported. The tests have been performed at the Gamma Irradiation Facility (GIF++) at CERN using a 1 mm gas gap RPC.

Speaker: Giorgia Proto (Max Planck Society (DE))

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10:50 **R134a recuperation and SF6 recuperation plants: status and plan** 20m

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 first R134a recuperation plant is connected to the CMS-RPC system and operational since July 2023. 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.
R&D studies to design a SF6 recuperation plant are also ongoing.
Results (gas quality, efficiency, plant reliability, ..) from the first operational experience with the R134a recuperation plant and status of the R&D for the SF6 recuperation plant will be presented.

Speaker: Roberto Guida (CERN)

RPC2024_RGuida_v... RPC2024_RGuida_v...

11:10 → 11:30 **Coffee break** 20m

11:30 → 13:30 **Ecogases and longevity (II)**

11:30 **Operation of 1 mm HPL RPCs with low-GWP gas mixtures** 20m

RPCs have traditionally used a gas mixture with a high Global Warming Potential (GWP). To reduce the environmental impact, promising low-GWP gases and the addition of CO2 to the standard mixture have been explored on small 50 x 50 cm^2 RPC prototypes using a 1 mm single-gap HPL-based technology. Preliminary measurements of key performance metrics like efficiency, streamer probability, induced charge, cluster size, and time resolution are presented, highlighting their impact on detector performance and potential broader applications.

Speakers: Aashaq Shah (University of Cambridge (GB)), Oleg Brandt (University of Cambridge (GB))

rpc_operation.pdf

11:50 **Performance and long-term ageing studies on Eco-Friendly Resistive Plate Chamber detectors** 20m

In High Energy Physics Resistive Plate Chamber (RPC) detectors are typically operated in avalanche mode, making use of a high-performance gas mixture which main component, Tetrafluoroethane (C2H2F4), is classified as a fluorinated high Global Warming Potential greenhouse gas.

The RPC EcoGas@GIF++ Collaboration is pursuing an intensive R&D on new gas mixtures for RPC detectors to explore environmentally friendly alternatives complying with recent European regulations. During the last few years, the performance of RPCs characterized by different layouts and read-out electronics have been studied with Tetrafluoropropene (C3H2F4)-CO2 based gas mixtures at the CERN Gamma Irradiation Facility. A long-term ageing test campaign was launched in 2022 and is still on-going. In 2023 and 2024 all detector systems underwent evaluation by means of dedicated beam tests.

Preliminary results on these studies will be presented in this talk together with their future perspectives.

Speaker: Marcello Abbrescia (Universita e INFN, Bari (IT))

Abbrescia@Santiag... Abbrescia@Santiag...

12:10 **Evaluating the Performance and Long-Term Stability with LHC-like Background Irradiation of RPC Detectors with a CO2-based Gas Mixtures** 20m

Resistive Plate Chamber (RPC) detectors at CERN's LHC experiments traditionally use a Freon-based gas mixture containing C2H2F4 (R-134a) and SF6, both of which are high global warming potential (GWP) gases. To reduce greenhouse gas emissions, operational costs, and optimize RPC performance, the best compromise is the gas mixture with a substitution of 30% of R-134a with CO2 in the standard gas mixture. This gas mixture that we proposed it is in use in the ATLAS RPC system since Summer 2023.

This study investigates the detector's performance when CO2 is introduced into the standard gas mixture as a medium-term solution to minimize emissions while maintaining compatibility with current CERN RPC systems.
Conducted at the CERN Gamma Irradiation Facility, this research uses a 12 TBq ^137Cs source and a muon beam to simulate the LHC experiment's background radiation. The setup includes five 2 mm single-gap High Pressure Laminate (HPL) RPCs placed at different distances (outside the irradiation bunker, 5m, and 12m from the gamma source).
Since March 2023, the detectors inside the bunker have been continuously irradiated to study long-term performance, aiming to achieve the integrated charge expected for ATLAS RPC detectors during LHC Run 3 and the High Luminosity LHC phase. Monitoring is performed with various metrics such as gas analysis, oxygen, humidity, dose, environmental parameters, and flow measurements to ensure the gas system operates correctly.
Several periodic test beam periods are conducted to assess muon performance parameters, including efficiency, current, streamer probability, mean prompt charge, cluster size, and time resolution. Results for the ageing studies, using our proposed 30% CO2 gas mixture, will be presented.

Speaker: Stefania-Alexandra Juks (Université Paris-Saclay (FR))

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12:30

Performance and longevity of CO2 based mixtures in CMS Improved Resistive Plate Chambers in the HL-LHC environment

20m

Resistive Plate Chamber (RPC) detectors in the Compact Muon Solenoid (CMS) experiment operate with a gas mixture comprised of 95.2% of C2H2F4, that provides a high number of ion-electron pairs, 4.5% of iC4H10, that ensures the suppression of photon-feedback effects and 0.3% of SF6, used as an electron quencher to further operate the detector in streamer-free mode. C2H2F4 is known to be a Greenhouse gas with a global warming potential (GWP) of 1430. Several ECO-friendly alternatives to C2H2F4 have been studied in the last few years. In this context, one short-mid term approach for the next years of the Large Hadron Collider (LHC) operation could be to focus on reducing the GWP of the RPC gas mixture by adding CO2 in the place of C2H2F4. The studies are done at CERN Gamma Irradiation Facility (GIF++) in the North Area of SPS, where a 13.6TBq radiation source and a muon beam from SPS are used to mimic the conditions of Phase-II of LHC. This work will present the performance and aging of a 1.4mm gap RPC chamber with three different CO2 based mixtures under a high gamma background, as well as the first results after 80 mC/cm2 integrated charge in the longevity campaign.

Speaker: Joao Pinheiro (Universidade do Estado do Rio de Janeiro (BR))

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12:50

Studies of F- Impurities Formation in ALICE MID RPC detectors: A Comparison between RUN2 and RUN3

20m

ALICE MID system consists of 72 single-gap Resistive Plate Chamber (RPC) detectors, operated with a gas mixture composed of C2H2F4 (R134a)/iC4H10/SF6 - 89.7%/10%/0.3%, along with about 40% of relative humidity. The combined effects of background irradiation and the electric field within the detector's gas result in the production of F- ions and F-based impurities, also due to the high concentration of fluorinated gases used to operate the detector.

During RUN2, a preliminary setup was installed to monitor the formation of these impurities, which could lead to the formation of hydrofluoric acid, potentially damaging the detectors and the gas system irreparably. This setup successfully demonstrated the production of HF and other impurities, and the purifier's capability to trap them, ensuring the feasibility of operating the gas system in recirculation mode.

During LS2, the set up was improved and was commissioned for the restart of RUN3. It consists of a gas chromatograph to monitor the correct composition of the gas mixture and F-based impurities and an Ion Selective Electrode (ISE) setup for detecting the F- concentration.

This study provides a comprehensive overview of the creation of impurities in the RPC detectors under irradiation. Furthermore, it presents a comparative analysis between the results obtained during RUN2 and those ongoing in RUN3.

Speaker: Mattia Verzeroli (Universite Claude Bernard Lyon I (FR))

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13:10

A Novel Anti-Aging TBS MRPC For CBM-TOF

20m

The Compressed Baryonic Matter (CBM) experiment is an ongoing high-rate fixed-target experiment at the Facility for Antiproton and Ion Research (FAIR) in Germany. The Time-of-Flight (TOF) system in the CBM experiment subjects Multi-gap Resistive Plate Chambers (MRPCs) to flux ranging from several hundred Hz/cm² to 25 kHz/cm². In such high-rate environments, traditional MRPCs with fishline spacers experience aging effects due to the extremely strong electric field and insufficient gas exchange near the fishlines, leading to ionization of the working gas and the formation of deposits, thereby affecting the performance of MRPCs.
To address this issue, we propose a novel solution by replacing traditional fishline spacers with cylindrical thermal bonding spacers (TBS) as support structures, based on MRPC3, one of the CBM-TOF components, developing a new type of TBS MRPC detector. We tested the detector's performance under cosmic rays. And particularly, we conducted comparative testing with traditional MRPCs, focusing on the performance of the TBS MRPC in high flux environments under X-ray irradiation. Furthermore, we performed a microscopic study using scanning electron microscopy (SEM) to inspect the glass electrodes before and after irradiation. The research results suggest that, under high irradiation flux environments, the TBS MRPC detector shows better anti-aging performance compared to traditional MRPCs with fishline spacers. Based on the research, the TBS MRPC is expected to be used in the future CBM experiment.

Speaker: Mr Ming Yao (USTC)

RPC meeting-Ming ...

13:40 → 15:45 **Finger-food lunch & poster session (II)**

at venue

13:40

Investigating RPC Gas Flow and Ion Transport Using Computational Models

20m

The CMS Experiment utilizes advanced muon detection systems comprising various gas-based technologies, such as Drift Tubes, Cathode Strip Chambers, and Resistive Plate Chambers (RPCs). RPCs are notable for their rapid response, which is crucial for the system's triggering mechanism. The CMS RPC system features a 2 mm gas gap filled with a mixture of 95.2% C2H2F4, 4.5% iC4H10, and 0.3% SF6. This mixture reacts under high radiation levels and intense high voltage (approximately 10 kV), producing fluorine ions that contribute to the aging of the chambers. Recent studies indicate that increasing gas flux can help disperse these ions, thereby delaying the aging process. With the LHC Phase-2 upgrade, the CMS will introduce 72 new RPCs with a reduced gas gap of 1.4 mm in areas expected to experience significantly higher radiation levels. Understanding the relationship between gas flux and aging is crucial for this upgrade. This study builds on initial research to enhance RPC longevity by developing mathematical and computational models for gas flow and fluorine ion transport. Using the Navier-Stokes equations for fluid dynamics and incorporating ion diffusion, migration under electric fields, and convection, these models are discretized using finite element methods via the Gridap library. This research underscores the importance of optimizing RPC design by carefully considering geometry and flow dynamics to minimize aging effects. Such advancements not only enhance the performance and durability of RPCs but also contribute to more cost-effective and reliable detection technologies in high-energy physics.

Speaker: Mauricio Thiel (Universidade do Estado do Rio de Janeiro (BR))

POSTER_RPC24_Ga...

14:00

Quality assurance tests and techniques to investigate and increase hermetic sealing of ATLAS Phase II RPC detectors

20m

The Phase II upgrade of the ATLAS Muon Spectrometer plans to install approximately 1000 new-generation Resistive Plate Chambers (RPCs). This upgrade will enhance detector coverage, increase hit efficiency and timing precision, improving the trigger precision and robustness.
The chamber production is ongoing and gas volumes are commercially produced in Italy. To investigate and improve the integrity of the gas volumes, their mechanical property and the gas tightness, several techniques have been proposed and applied.
This talk describes experiences on ATLAS gas gaps with thermal cycling (TC) performed between -30°C and +30°C, and the subsequent impact in the context of gas leaks, as well as techniques to investigate and improve gas tightness.
The goal is to produce leak-tight detectors preventing the emission of gases having impact on global warming.

Speaker: Aashaq Shah (University of Cambridge (GB))

14:20

Preliminary aging studies of improved RPC gaps operated with HFO based mixtures

20m

Resistive Plate Chambers (RPC) at the CMS experiment are operated with a gas mixture containing around 95% Tetrafluoroethane (C2H2F4), commonly known as R-134a, which has a global warming potential (GWP) of 1430. In the framework of the CMS Upgrade project for the High Luminosity phase, new improved RPC detectors (iRPC) have been developed to enhance the legacy performances in the most RPC forward region of the experiment. To comply with European regulations and explore environmentally friendly gaseous mixture alternatives for long-term RPC operation, CMS RPC within the RPC EcoGas@GIF++ collaboration has launched a longevity study operating the chambers with HFO/CO2-based eco-friendly candidate mixture. Through this poster can be found the preliminary aging analysis of the gaps resulting after around one year of irradiation at the Gamma Irradiation Facility at CERN.

Speaker: Zubayda Eve Kofi (University of Dundee (GB))

Preliminary_aging_s...

14:40

Gas gaps and chambers quality control of improved resistive plate chambers (iRPC)

20m

In preparation for the Phase II Upgrade for the HL-LHC program, 72 improved Resistive Plate Chambers (iRPCs) will be installed in the third and fourth endcap disks of the Compact Muon Solenoid (CMS) during the next year-end technical stop (YETS). These new generation RPC detectors will operate in a low-angle momentum (extending RPC coverage from $|\eta|$ = 1.9 to 2.4), in a high radiation environment, and will bring a better space and time resolution for this challenging region. Assembly of the new detectors is taking place at CERN 904 laboratory and Ghent University. To ensure proper performance, iRPC chambers undergo a series of quality control (QC) tests at each stage of the assembly chain. These tests include QC1 for the basic components, QC2 for chamber elements such as gaps and cooling, QC3 for evaluating the full chamber performance after production, which includes noise, efficiency, and current, and lastly and QC4 for the final validation test. In this poster, we present the summary results of the QC tests for the newly built iRPC chambers in the assembly sites.

Speaker: Mohammad Ahammad Ali (University of Dundee (GB))

irpc quality control....

15:00

iRPC FEB cooling system

20m

In view of the High Luminosity upgrade of CERN LHC, the forward CMS Muon spectrometer will be extended with two new stations of improved Resistive Plate Chambers (iRPC), covering the pseudorapidity range from 1.8 to 2.4. A new Front-End-Board (FEB) is designed to readout iRPC signals with a very low threshold and a Time Digital Converter (TDC) embedded into a Cyclone V INTEL FPGA. In contrast to the previous RPC boards, this one produces 22 W of heat in a rather confined space that needs to be carefully evacuated. A cheap and robust cooling system was designed based on a copper plate and water cooling. This system was first simulated with a CFD package, Ansys Fluent and then optimized with thermal measurements. In this poster the system and its prominents features are described. A quantitative comparison between the experimental measurements in the laboratory with the simulation is provided proving the robustness of the former.

Speaker: Otari Kemularia (Georgian Technical University (GE))

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15:20 **CMS RPC Link System fiber planning and qualification** 20m

During LHC Long Shutdown 3, the new RPC Link System will be installed. The new Link System will allow us to exploit the high time resolution of the detector from the current 25 ns, due to a limitation in the electronics of the existing system, to the order of 1 to 2 ns with the upgrade. Utilizing the performance of the new electronics will require a low attenuation loss fiber optic infrastructure for high-speed data transmission at the rate of 10 Gbps, which will be replaced with current optical links. It is worth mentioning that the new electronics include, by default, two redundant channels for data transmission on the master link board and two redundant channels on the control boards. Profiting from redundancy requires detailed planning to define the number of fiber optic lines needed, the choice of the number and location of patch panels, the available optical power budget due to different connectors and transmission distances, the fiber type, etc. This poster will show how all these factors led to the current design for the fiber optic infrastructure and how this can serve as an experience for detectors with similar needs.

Speaker: Andres Leonardo Cabrera Mora (Universidad de los Andes (CO))

Poster fibers_v3.pdf

15:45 → 23:00 **Social event (visit to Finisterra, Ézaro falls and nearby rias)**

Thursday 12 September

09:00 → 11:10 **Physics and simulations (part I)**

09:00 **Discharges in Gaseous Detectors: a view from MPGD experience** 30m

The history of gas discharge physics dates back to the early 1800s when V.V. Petrov discovered arc discharge. Since then, the physics of gas discharges is presumably one of the best-studied fields in modern science. Yet, after more than two hundred years of experience, the fundamental questions about discharge phenomena are still vivid, especially within the gaseous particle detector community.
A brief summary of gas discharge physics and its relevance for MPGDs will be given and various discharge phenomena occurring in MPGDs will be discussed. The latter can usually be explained with a streamer model. Various studies point to the conclusion that the primary charge density, arriving at the single amplification cell of an MPGD, is a key factor influencing the stability of the structure against a spark discharge. However, not all discharge events follow this reasoning. An interesting example of a secondary discharge occurring in between subsequent structures in an MPGD stack points to a mixed mechanism of a slow and fast discharge and is still a topic of debate. The overview of recent results will be complemented with the most common mitigation strategies, new ideas, and possible ways towards the development of a spark-less MPGD structure.

Speaker: Piotr Gasik (GSI - Helmholtzzentrum fur Schwerionenforschung GmbH (DE))

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09:30 **Studies on electron swarms and streamer discharges in environmentally friendly RPC gas mixtures under LHC-like conditions** 20m

One of the key challenges in R&D strategies for RPCs is the replacement of currently used $C_2H_2F_4$ and SF_6 with environmentally friendly alternatives. Usually, the $C_2H_2F_4$ is replaced by a proper mixture of $C_3H_2F_4$ and CO_2, while CF_3I, C_4F_7N and $C_5F_{10}O$ were considered as alternatives to SF_6. In the first part of this work, we propose complete and consistent sets of cross sections for electron scattering in $C_3H_2F_4$ and C_3HF_5. The cross sections are validated through a series of comparisons between swarm data calculated using a numerical solution of Boltzmann's equation and Monte Carlo simulation, and experimental data obtained under pulsed-Townsend conditions. Swarm analysis has also been performed for CF_3I, C_4F_7N, and $C_5F_{10}O$ and gases, which are considered as potential replacements of SF_6 in typical RPC mixtures. Other sets of cross sections for these gases that are available in the literature are also used as input in our numerical codes to test their completeness, consistency, and accuracy. In particular, we discuss the dependence of transport coefficients on the pressure, temperature, and composition of RPC gas mixtures made of these gases. We also study the explicit and implicit effects of non-conservative collisions on the transport of electrons and the induced kinetic phenomena such as negative differential conductivity.

In the second part of this work, we study the development of an electron avalanche and its transition into a streamer discharge in environmentally friendly RPC gas mixtures under LHC-like conditions. Recently, we have developed a 3D streamer model in the AMReX environment. AMReX is an open-source C++ library for massively parallel block structured adaptive mesh refinement applications. AMReX has in-built geometric multigrid solvers for solving elliptic differential equations, and it supports MPI and OpenMP parallelization on CPUs as well as parallelization on GPUs. The classical fluid model, which involves the drift-diffusion approximation and local field approximation, is implemented assuming a certain level of background ionization to simulate the inception and propagation of positive streamers. The time integration is performed by employing the second order Runge-Kutta method, while the spatial discretization is performed by using the finite volume method. We calculate the electron and ion densities, electric field, and velocity of streamers as a function of the applied electric field for various RPC mixtures. We also look at the development of electron avalanches in the presence of space charge effects. The results of these simulations, in association with the scattering and transport data for electrons in environmentally friendly RPC gas mixtures, should be considered in experimental measurements and modelling efforts to test the performance of RPCs.

Acknowledgment: This work is supported by the Science Fund of the Republic of Serbia, Grant No. 7749560, Exploring ultra-low global warming potential gases for insulation in high-voltage technology: Experiments and modelling EGWIn.

Speaker: Saša Dujko (Institute of Physics Belgrade)

Dujko_RPC_Final N...

09:50 **Improved streamer inception criterion to numerically estimate streamer probabilities of resistive plate chambers for environmentally friendly gas mixture alternatives** 20m

F-gas regulations foresee restrictions and bans of highly potent greenhouse gases such as R134a and SF6 used in RPCs. Current research is dedicated to finding an environmentally friendly gas mixture replacement for RPCs. Simulations of RPCs are crucial in supporting and extending the mostly experimental-based research of identifying suitable eco-friendly alternatives.
To date, there is no comprehensive quantitative description of the avalanche-to-streamer transition in uniform electric fields. Particularly in the context of RPCs, this is essential for estimating the streamer probability of a certain mixture, to accurately predict the avalanche-streamer separation. An improved form of the classical streamer criterion is introduced predicting the transition phase to overcome this problem. The criterion is entirely based on the space-charge field of the many superimposed avalanches due to primary ionization. A rigorous simulation of the single-gap high-pressure laminated RPC (HPL-RPC) is developed to integrate and test the improved streamer criterion along with the capability to estimate other performance parameters, for example, the detector's efficiency. The simulation is based on Garfield++ and is extended for this study to include the axis-symmetric space-charge model originally developed by Christian Lippmann. Additionally, a dedicated electrical signal transmission system is modeled to accurately replicate the experimental setup. Validation of the simulation is achieved through comparison with acquired performance data of the experimental HPL-RPC setup at the GIF++ muon beam experiment for several eco-friendly gas mixtures.
This contribution intends to present the detailed modeling of the RPC simulation and to show that for CO2-based standard mixtures (CO2/R134/i-C4H10/SF6) the experimentally measured avalanche-streamer separation is accurately modeled by the improved streamer criterion.

Speaker: Dario Stocco (ETH Zürich)

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10:10

Utilizing open-source toolkits for the simulation of avalanche formation and space-charge effects in Resistive Cylindrical Chambers 20m

An investigation of avalanche formation in Resistive Chambers with a cylindrical geometry is presented in this report. Resistive Cylindrical Chambers (RCC) were proposed in the last decade with the purpose of improving conventional Resistive Plate Chambers (RPC). The new geometry allows for the increase of gas pressure in the gas gap, leading to an increase in efficiency as well as a slightly inhomogeneous field which might lead to better containment of the electron avalanche. The development of RCC which will manifest these advantages, requires R&D studies, including an interplay between prototype testing and simulations.
In this report, we present a detailed numerical calculation of the field, a simulation of the interaction between the gas molecules in the working volume and a passing ionizing particle and the subsequent gas multiplication process. For considerable avalanche charges, local perturbations of the electric field arise, known as space-charge effects. The simulations have been performed using a collection of open-source software packages: gmsh for geometry and mesh generation, FEniCS for FEM numerical calculations and Garfield++ for modeling particle interactions, detection of a passing ionizing particle, and the probing of the resulting signal. Space-charge effects have been simulated by recursively adjusting the field in the gas gap during the formation of the avalanche. In addition, alternative gas mixtures are considered in view of the transition to eco-friendly gas mixtures for detectors used in modern-day high-energy experiments. The results are compared to conventional RPC detectors currently in use.

Speaker: Elton Shumka (University of Sofia - St. Kliment Ohridski (BG))

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10:30

Microscopic and fluid modelling of RPCs under LHC-like conditions 20m

We present a 2.5D Particle-in-Cell Monte Carlo collision (PIC/MCC) and a 2D fluid model of RPCs. The PIC/MCC model uses a Monte Carlo technique and a 2D numerical grid coupled with Poisson equation solver to track individual electrons and their collisions with the background gas in 3D. The fluid model is based on drift-diffusion-reaction equation and local field approximation. Both models rely on axis symmetry and are developed using the AMReX software framework. AMReX is an open-source C++ library for massively parallel block structured adaptive mesh refinement applications. The presented RPC models are employed to study the signal induction, space charge effects and avalanche to streamer transition in RPCs under LHC-like conditions. The conditions assume a 2 mm gas gap with a standard gas mixture based on C2H2F4, or eco-friendly alternatives based on C3H2F4 and CO2. In addition, we also employ a microscopic Monte Carlo model to calculate the efficiency and time response functions for these RPC configurations.

Acknowledgment: This work is supported by the Science Fund of the Republic of Serbia, Grant No. 7749560, Exploring ultra-low global warming potential gases for insulation in high-voltage technology: Experiments and modelling EGWIn.

Speaker: Dr Danko Bošnjaković (Institute of Physics Belgrade)

D Bosnjakovic RPC ...

10:50

Advancements in Simulating C3H2F4-Based Gas Mixtures for Resistive Plate Chambers 20m

One of the primary objectives of R&D strategies for Resistive Plate Chambers (RPCs) is to replace the currently used gases with more environmentally friendly alternatives. Current research is particularly focused on substituting C2H2F4, which is widely used in high concentrations in RPCs, with C3H2F4, a more environmentally friendly gas.
This contribution presents a comprehensive set of scattering cross sections for electrons in C3H2F4. These cross sections are validated through a systematic comparison of electron swarm parameters calculated using the Monte Carlo simulation MATOQ with experimental data obtained from a pulsed Townsend experiment. Furthermore, we demonstrate that simulation results for the effective Townsend coefficient and drift velocity are in good agreement with measurements obtained directly from an RPC using a laser beam to ionize C3H2F4-based mixtures. Finally, we discuss the dependence of the effective Townsend coefficient and drift velocity on the electric field for gas mixtures currently under study in the RPC community, especially those investigated by the RPC-ECOGAS@GIF++ collaboration.
The findings from this work can contribute to simulating the behavior of RPCs operating with gas mixtures containing C3H2F4. These results have the potential to

significantly advance experimental research aimed at identifying environmentally friendly gas mixtures for RPCs.

Speaker: Dr Antonio Bianchi

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11:10 → 11:30 **Coffee break** 20m

11:30 → 13:30 **Physics and simulations (part II)**

11:30 **Time Resolution in Resistive Plate Chambers from Statistical Considerations** 20m

The quest for optimal time resolution remains one of the most intense areas of current research on Resistive Plate Chambers (RPCs). Achieving superior time resolution is crucial for a wide range of applications, from high-energy physics experiments to medical imaging technologies. Various technological solutions are proposed, each aiming to enhance the performance of RPCs, whose actual effectivness must be experimentally verified.

However, beyond technological advancements, there are fundamental statistical considerations inherent to the process of signal formation in RPCs that set theoretical limits on the best time resolution achievable. These considerations stem from the stochastic nature of particle interactions and signal generation within the chamber. Understanding these statistical constraints is important for setting realistic expectations and guiding the development of new technologies.

This talk will delve into these statistical limitations, offering an overview of how they influence the time resolution of RPCs. We will explore the primary factors contributing to these limits. Furthermore, the discussion will extend to potential solutions and strategies for optimizing time resolution within these statistical bounds.

Speaker: Marcello Abbrescia (Universita e INFN, Bari (IT))

Abbrescia@Santiag... Abbrescia@Santiag...

12:10 **Simulating MRPCs with Garfield++ and time-dependent weighting potentials** 20m

Detailed Monte-Carlo simulations of the induction of signals in Resistive Plate Chambers (RPCs) remain a key tool for understanding their response, optimizing the detector geometry, and finding eco-friendly gas mixtures for applications in High Energy Physics (HEP) experiments. In this contribution, we will discuss recent developments in the Garfield++ toolkit that can be used for the simulation of Multi-gap RPCs (MRPCs); from avalanche modeling to signal induction in the presence of resistive elements or external impedance elements.

In Garfield++, the microscopic tracking of electrons follows particles from collision to collision, providing a detailed description of avalanche formation in the gas. Given the typically large number of charge carriers, a mixed method is used for a more efficient calculation of the detector's response. This method retains microscopic electron tracking for the initial phase of avalanche development to accurately capture its initial fluctuations. Once the avalanche has reached a sufficient size, the implemented Lipmann-Riegler 1D grid-based method describes its further development. As the charge carriers traverse their trajectories, the induced signal on the electrodes is calculated.

Currents induced on grounded electrodes by moving charges can be obtained using static prompt weighting potential with the Ramo-Shockley theorem. However, the presence of resistive elements requires an extension of this theorem to capture the delayed component of the signal from the time-dependent reaction of the detector materials. In this case, the weighting potential becomes dynamic. In Garfield++, both analytical and Finite Element Method (FEM) approaches are available for calculating the static and time-dependent weighting potential of rectangular electrodes in MRPCs. For MRPCs, the numerical FEM methodology can account for the finite conductivity of the resistive plates and high-voltage electrodes. The focus will be on applying this approach to the case of MRPCs and discuss topics such as the contribution of the HV electrode to signal formation. In addition, the FEM strategy is applicable to complex detector layouts across resistive gaseous detector technologies, from RPCs to resistive Micro-Pattern Gaseous Detectors (MPGDs), and can in addition be applied to solid-state detectors.

Speaker: Djunes Janssens (CERN)

DJanssens_RPC_20... DJanssens_RPC_20...

12:30 **Quantum chemical calculation of reactions in the plasma molecules important for the operation of the RPC system** 20m

The current operation of the Resistive Plate Chamber (RPC) system within the CMS experiment involves tetrafluoroethane (C2H2F4, TFE) and SF6. However, in response to climate change concerns, the European Union has instituted a ban on these molecules due to their high Global Warming Potential (GWP).

As a result, researchers have been dedicated to investigating novel ecological gas mixtures based on tetrafluoropropene (C3H2F4, HFO-1234ze) and NOVEC 4710 to ensure sustainable functionality of RPCs. This study focuses on ab initio and density functional theory (DFT) calculations of electron impact ionization, electron impact excitation, and electron attachment reactions in plasma for these molecules using Gaussian 16 and ORCA quantum chemical packages. We calculate vertical and adiabatic transition energies, the values of thermodynamic functions for these reactions, and investigate the stability of the produced species during these reactions. Based on this calculation, we can draw conclusions about the behavior of these new species, compare their behavior with the molecules in use, and assess their potential as replacements. This study will help us in the systematic search for new eco-friendly gaseous alternatives.

Speaker: Nebojsa Begovic (University of Belgrade (RS))

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12:50 **Theoretical Time Cost to Distinguish Special Nuclear Materials in Different Scenarios through MPRC-ToF based MST**

20m

Muon scattering tomography (MST), which has gained significant attention in recent years, is a novel radiation imaging technique evolving into two research directions: rapid inspection and detailed imaging. Increasing research shows that fully utilizing the momentum information of muons is essential to achieve satisfactory results for both two directions. MRPC (Multi-gap Resistive Plate Chamber) detectors are renowned for their excellent time resolution and high detection efficiency for charged particles and are widely used in Time-of-Flight (ToF) systems in high-energy physics experiments. Our resent research shows the time resolution of very narrow gaps MRPC can reach 16 ps. Therefore, MRPC holds great potential in muon imaging where momentum information needs to be considered.
In this study, using the GEANT4 toolkit and ROOT's TMVA toolkit, focusing on rapid inspection, we conducted detailed simulations under various background conditions, including different volumes, geometrical setups, materials and shielding methods. We evaluated the rapid response capability of the MST system for typical special nuclear materials using MRPC detectors as ToF to obtain muon momentum and true muon momentum, applying unsupervised classification methods like EM-GMM and supervised classification methods like BDT, CNN and DNN. The results show that using CNN for classification, the MRPC-ToF based MST system can achieve an accuracy of over 92.8% within 45 seconds with a geometrical acceptance of 45.2%. When the geometrical acceptance is 18.8%, the accuracy is then 81.26%, which demonstrates that using MRPC detectors as ToF to acquire muon momentum information for a fast-responsive MST system is highly feasible.

Speaker: Ziyang Chen (Tsinghua University)

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16:00 → 18:00 **IOC & IAC meetings**

18:30 → 23:59 **Guided tour and social dinner**

Friday 13 September

09:30 → 11:40 **Applied research and new ideas (part I)**

09:30 **Timing RPCs: 25 years** 30m

About 25 years ago, in the framework of the ALICE TOF R&D effort, the time resolution of the RPC detector technology was extended to sub-100 ps by decreasing the gap width by about one order of magnitude and adopting the multigap construction method. This resolution range is interesting for particle identification or tagging by time-of-flight and opened the way to practical very large time-of-flight detectors for HEP and nuclear physics.

In this communication we will describe the preceding related detectors and the discovery process, the applications that have meanwhile emerged and the status of the theoretical understanding of these detectors.

Speaker: Paulo Fonte

P.Fonte tRPC RPC2...

10:00 **Developmental Studies on the Performance Enhancement of Gas-Tight Resistive Plate Chambers (RPCs) for Muography Applications** 20m

Muon-based radiography, also known as "muography", is an application of particle physics based on muons naturally produced from cosmic rays in the upper atmosphere. Muography determines the average density of an object by measuring the muon flux passing through it and comparing it with a reference flux through the unobstructed sky.
In this talk, we report on the status of our development of a portable muon hodoscope built using glass-RPC detectors with an active area of 16 cm × 16 cm, featuring a readout strip with a pitch of 1.0 cm and a strip width of 0.9 cm. The goal of this project is to use this detector for muography applications in confined locations (e.g. underground tunnels or crammed rooms), with complex logistics that are common for field work in archaeology, cultural heritage studies and geophysics. Therefore, some of the most important design considerations are portability, compactness, low weight, low cost, autonomy and versatility.
As RPCs are gas detectors, leaks are a concern in confined spaces; moreover, we need to minimize refills. This leads to emphasis on assessing and minimizing the dependence on time of the detector performance metrics on timescales of hours, days, weeks or months. Thus, in this talk, we present our studies on the long-term stability of these detectors, covering aspects such as efficiency, time response, and gas stability, in addition to some preliminary results from an absorption muography study conducted with various objects to assess the feasibility and performance of the current version of the detector.

Speaker: Samip Basnet (UCL - CP3)

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10:20 **A modular muon telescope for tomography and radiography applications** 20m

Muography is a non-invasive technique that exploits the absorption and scattering features of cosmic-ray muons and produces projectional image of a target volume. We are studying different muon telescope configurations for use in tomography applications such as imaging the spent nuclear fuel dry cask, border controls of transport, and radiography applications such as to investigate cavities/shafts present in railway tunnels, archaeological cultural heritage sites.
A portable muon telescope is being developed in a modular form with four layers. Each module houses a glass Resistive Plate Chamber (RPC) of 16 × 16 cm2 active area. The RPC is sandwiched between two Printed Circuit Board (PCB) strip readout panels, with strip pitch of 1 cm, placed orthogonally to each other to trace the X and Y position of the muon hit.
The muon telescope has been simulated in Geant4 [1] and with EcoMug [2] as the cosmic-ray muon generator. The spacing between

different layers in the telescope has been optimized to achieve the best possible position and intrinsic angular resolutions of 7.3 mm and 4 mrad, respectively. Using the Point of Closest Approach (PoCA) algorithm [3], the image of a Lead block of size 100 × 100 × 100 mm3 is reconstructed and the scattering angle distributions are used to distinguish the high and medium Z materials. The image reconstruction is further improved by implementing the Binned Clustering Algorithm (BCA) [4].
For building the proposed muon telescope, glass RPCs are constructed and characterized using PCB based readout panels. The RPCs are operated in avalanche mode and showed a muon detection efficiency > 95 %. The charge collection and time resolutions of the RPCs are measured. An acrylic chamber has been developed to house the RPC and the air-tightness studies have been carried out. The results and the future plans will be discussed in the workshop.

[1] https://geant4.web.cern.ch/
[2] D. Pagano et al., Nucl. Inst. and Meth. in Phys. Res. A 1014 (2021) 165732.
[3] L.J. Schultz et al., Nucl. Inst. and Meth. in Phys. Res. A 519 (2004) 687–694.
[4] C. Thomay et al., JINST 8 (2013) P10013.

Speaker: Dr Raveendrababu Karnam (National Institute of Science Education and Research (NISER) (IN))

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10:40 **New Readout Codification in Large-Area Multi-Gap Timing RPCs for Muon Scattering Tomography** 20m

A novel readout technique was designed for applications covering large surfaces, such as the muon scattering tomography. Knowing that the FEE is often the driving cost of RPCs, the new codification was developed with the initial intention of significantly reducing the dependence of the number of electronic channels on the detector area, without substantial decrease of its performance.
The technique was first tested with a multi-gap timing RPC, composed of a double stack of 6 gaps of 300 um and sensitive area of 30 cm x 30 cm, using 24+24 preamps to read out 120+120 strips. A new setup is currently being prepared with a detector area tenfold larger: 120 cm x 90 cm, while the same 24+24 preamps will be used to read out a much higher number of strips.
The new readout scheme used with the 30 cm x 30 cm RPC resulted in a spatial resolution better than 1 mm and time resolution below 100 ps. Details about the new readout codification and preliminary results obtained with the larger RPC will be presented in this communication.
FLUKA simulations were preformed in order to demonstrate the relevance for the scattering tomography technique of having not only a submillimetric spatial resolution, but also a very good time resolution. These calculations will be presented too.

Speaker: Joao Pedro De Carvalho Saraiva (Laboratory of Instrumentation and Experimental Particle Physics (PT))

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11:00 **The first miniTRASGO Cosmic Ray telescope** 20m

Since their discovery in 1912, cosmic rays have been an invaluable source of information about the distant universe, constituting one of the pillars of the so-called multi-messenger astronomy. Also, they act as a penetrating radiation providing information about near-Earth space and the solar activity. In order to deepen our knowledge in cosmic rays, a new family of detectors called Trasgos has been proposed. These high granularity tracking devices employ Resistive Plate Chambers (RPCs) to detect ionizing secondary cosmic rays in a plug&play philosophy. The 0.1 m2 small size Trasgo here presented includes pressure, temperature and humidity sensors as well as built-in rate monitoring software and hit maps. The detector performance and calibration procedures are outlined, along with results from measurements and preliminary analyses. This study not only proves the scientific potential of the miniTRASGO concept, including the observation of a Forbush Decrease, but also sets the stage for its future integration into a international muon telescope network, which aims to enhance global cosmic ray research.

Speaker: Cayetano Soneira-Landín (GFN - Complutense University of Madrid)

miniTRASGO - RPC2... Soneira_Talk_RPC2...

11:20 **A TOF-tracker MRPC for simultaneous measurements of timing and position at the pi20 beamline of J-PARC** 20m

In the Hadron Hall of J-PARC, we plan to measure the cross sections for exclusive Drell-Yan reaction ($\pi^- p \to \mu^+\mu^- n$) aiming to determine the generalized parton distribution functions (GPDs) of nucleons. The experiment will be conducted in the π20 beamline and MRPCs will be utilized for muon identification. An area of 1.8 m × 2.4 m will be covered by a MRPC that is designed to identify a muon pair from the Drell-Yan reaction. It is important to distinguish the desired muon pair from random combinatorial muons. For that purpose, we designed a MRPC that can measure timing and position simultaneously, which we call a TOF-tracker MRPC. We have designed 2-dimensional read-out strips for both zero-degree and 90-degree configurations. In the zero-degree read-out (X-direction), we utilize positive signals, while in the 90-degree configuration (Y-direction), we employ negative signals. The configuration is 1 stack, 0.26 mm $\times$ 5gaps, 500 mm $\times$ 1000 mm active area, and a 5 mm of strip pitch. We conducted a beam test at the LEPS2 beamline in the SPring-8 facility. We achieved more than 99 % efficiency, 65 ps time resolution, and 0.8 mm position resolution. The results satisfy the performance requirements, which are 99 % efficiency, 100 ps time resolution, and 1 mm position resolution. However, we are facing a shortage of carbon sheets that we have been using for the HV electrodes. As an alternative, we are exploring the possibility of utilizing several kinds of polymer-based conductive coatings. The performance of the prototype TOF-tracker and the test results of alternative electrodes will be presented in this report.

Speaker: Ryotaro Koike (Kyoto Universuty)

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11:40 → 12:00 **Coffee** 20m

12:00 → 13:40 **Applied research and new ideas (part II)**

12:00 **Picosecond timing performances of the FERS-5200 readout system** 20m

Next generation high energy physics experiments will feature high-granularity detectors with thousands of readout channels, thus requiring ASICs (low power and dimension).
CAEN FrontEnd Readout System (FERS) integrates ASICs on small, synchronizable and distributable systems with Front and Back Ends. The A5203 FERS houses the recently released CERN picoTDC ASIC and provides high-resolution time measurements of ToA and ToT.
In this talk we will analyze the performances of the A5203 unit: 3.125 ps LSB, ToA measurements down to ~7 ps RMS over a single board, and ~20 ps RMS for input signals of variable amplitude. The walk effect introduced by different amplitudes is corrected using ToT. Besides walk correction, the ToT is used for signal amplitude reconstruction and background reduction.
The A5203 has been used in various applications, both experimental and industrial. These will be quickly illustrated as well as the upcoming units where picoTDC will be combined with new Weeroc ASICs.

Speaker: Mr Massimo Venaruzzo (CAEN)

PicosecondTiming...

12:20

Efficiency and time resolution of a thin gap Resistive Cylindrical Chamber

20m

The Resistive Cylinrical Chamber (RCC) is a new gaseous detector designed to overcome some limitations of Resistive Plate Chambers (RPC), broadening their application range and performance. The RCC consists of two concentric cylinders made of resistive material which define a gas gap whose thickness is almost negligible with respect to the cylinder radii. The cylinder surfaces not facing the gas volume are coated with high resistivity graphite layers, which distribute the High Voltage on the whole electrode. The signals can be read out by AC coupled pick-up strip or pads which can be positioned both in the internal cavity of the smaller cylinder and/or on the external surface of the larger cylinder. This kind of structure introduces an intrinsic two-gap configuration with independent pick-up electrodes usable to implement particles tracking and improve efficiency and time resolution. Furthermore, the cylinder structure allows to pressurize the gas inside the detector up to the elastic deformation strength of the electrodes material without mechanical efforts. The gas pressurization increases the target density with a consequent intrinsic efficiency improvement, also for very thin gas-gaps. Despite of the gas gap thickness, the detector could be always designed to produce a not uniform electric field whose gradient depends on the ratio between the gas gap thickness and the cylinder radius. In this configuration the internal electric field accelerates or dumps the avalanche discharge growth according to the electrons drift direction fixed by the high voltage polarity, extending the operability respectively to very high saturated charge distributions or to low quenched eco-friendly gas mixtures for high rate capability. With this features the RCC is a detector with very high time resolution (order of 100 ps), high efficiency (about 90% for 0.3 mm gas gap filled with 95% R134a based gas mixtures), low material budget and flexible to various applications.
In this presentation we will discuss the characterization of an RCC detector with 0.3 mm gas gap, operated with standard gas mixture (95% TFE - 4.7% iC_4H_{10} - 0.3% SF_6), performed with high energy muon beam. A reference scintillator was inserted in the cylinder cavity to optimize the acceptance of the trigger system and to highlight the potential for integrating the RCC with other detection devices. Preliminary test of operation with pressurized CO_2 have been also performed highlighting some weak points of the current configuration.

Speaker: Alessandro Rocchi (INFN e Universita Roma Tor Vergata (IT))

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12:40

A method to design a fast hybrid photodetector based on the RPC structure

20m

The idea of using gaseous detectors to amplify photo-electrons emitted by an embedded photocathode has been declined in may ways in the last decades, using different gaseous detector structures, including RPCs. Moreover, coupling such structures with a radiator element, enables these devices to detect charged particles, though the radiated photons.
There are at least two main challenges in building such structures: the combined yield of the radiator and the photocathode may be too low to gain high detection efficiency; high yield photocathode materials, also sensitive to a wider photon spectrum are very fragile and easy to oxidize, quickly degrading under the ionic flow typically generated in gaseous detectors.
In this paper we will present a method to exploit the most significant aspects of RPC physics to design an efficient hybrid detector, significantly enhancing most of the present gaseous detectors features and limitations.

Speaker: Giulio Aielli (INFN e Universita Roma Tor Vergata (IT))

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13:00

A high rate and high timing gaseous photodetector prototype with RPC structure

20m

In order to meet the requirements of high-rate and high time resolution in future high energy physics experiments, a prototype of gaseous photodetector with RPC structure was developed in this paper. The performance of the detector was simulated in Garfield++, and the single-photoelectron performance in different gases was tested using ultraviolet laser. The detector useed a low resistivity (~ 1.4e10 Ω ·cm) float glass, so that it has high-rate capability, the laser test results show that in MRPC gas, the single-photoelectron time resolution is best to reach ~20 ps at a gain of ~7e6 Qe. This detector can quantitatively test the single-photoelectron performance of different gases, and will be used to find eco-friendly MRPC gases.

Speaker: Mr Yiding Zhao (USTC(University of Science and Technology of China))

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13:20

Progress with the nRPC-4D detector concept for neutron scattering applications: assessment of XYZ-position and nTOF readout capability in beam tests 20m

Building upon our prior work on the development of the neutron RPC detection technology [1, 2], we have recently introduced the nRPC-4D detector concept. It provides high cold/ thermal neutron detection efficiency and the capability to simultaneously readout the XYZ-position of each detected neutron and its time-of-flight (nToF). For the simplicity of construction and maintenance, the detector architecture is based on stand-alone neutron detection modules. Each module features a double gap timing RPC with $^{10}B_4C$-coated cathodes, faced on both sides with arrays of signal pickup strips for X- and Y-position readout. We are conducting the development of this type of detector for neutron scattering applications, such as time-of-flight neutron diffraction and time resolved neutron imaging. The concept also shows good potential for other applications benefiting from simultaneous readout of the neutron events position and time. We will report on the recent progress related to this detector concept along with the implementation details of a prototype. It will be shown that the new arrangement of the signal pickup strips allows one to identify the $^{10}B_4C$ layer along the stack where a neutron is captured. This enables the determination of the nToF with an unprecedented precision and allows to correct misalignment between the planes of signal pickup strip arrays, which can spoil the spatial resolution. Finally, in-beam experimental results on the XYZ-position resolution, nToF measurements and counting rate capability will also be presented.

Acknowledgements
This work was funded by the Portuguese national funds OE and FCT-Portugal (http://doi.org/10.54499/EXPL/FIS-NUC/0538/2021). L. Margato acknowledges FCT-Portugal support through contract CEECINST/00106/2018/CP1494/CT0001.

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[1] L.M.S. Margato and A. Morozov 2018 JINST 13 P08007, DOI: 10.1088/1748-0221/13/08/P08007
[2] L.M.S. Margato et al 2020 JINST 15 P06007, DOI: 10.1088/1748-0221/15/06/P06007

Speaker: Luís Margato (Laboratory of Instrumentation and Experimental Particles Physics, Dep. of Physics, University of Coimbra)

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13:40 → 14:20 **Summary talk and conference closing**

13:40

summary talk 30m

Speaker: Alberto Blanco Castro (Laboratory of Instrumentation and Experimental Particle Physics (PT))

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