3rd International Conference on Detector Stability and Aging Phenomena in Gaseous Detectors

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Book of Abstracts

Contents

Ageing phenomena / 3

HV stability and aging phenomena observed in the drift chamber system of the MEG experiment

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The MEG experiment (phase 1) at the Paul Scherrer Institute, searching for the charged lepton flavor violating decay mu -> e + gamma, took physics data from 2009 until 2013. The analysis of the combined data sample resulted in an upper limit of 4.2·10E{-13} (90%CL) on the branching ratio that is still the most stringent limit on this decay to date.

The drift chamber system was designed to ensure the precision measurement of 52.8 MeV/c positrons. The system consisted of 16 drift chamber modules and was part of the innovative spectrometer of the MEG experiment. The drift chambers were supplied with a gas mixture of helium:ethane (50:50) and were placed inside a helium atmosphere to reduce multiple scattering of the decay positrons. The drift chambers were operated at a gain of 5·10E5 and in the central part, they had to cope with a particle rate of ˜30 kHz/cmˆ2. This resulted in an accumulated charge of ˜1C / 8 months of operation on the anode wires. The cathodes of the drift chamber consisted of an aluminized polyimide foil with an etched Vernier pattern.

The operation with a helium-based gas mixture and inside a helium atmosphere initially led to a gradual degradation of the HV stability, but this was recovered by a proper potting and an improved design to avoid a hidden "helium pocket"that increasingly filled with helium, resulting in a reduced breakdown voltage.

The operation at high gain and high rate lead to polymerization of the hydrocarbon component in the counting gas and resulted in a growing layer on the anodes wires that could be analysed using scanning electron microscope (SEM) technique. Energy-dispersed x-ray spectroscopy (EDX) confirmed carbon as the main component of the anode wire coating.

Some drift chamber modules suffered from Malter effect, showing remaining and fluctuating currents during beam off periods, most likely caused by remaining photo resist on the cathode foils. An improved cleaning procedure by the manufacturer resulted in a better performance of new and replaced drift chamber modules.

Poster session / 4

yttrium oxide

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Yttrium oxide thin films are deposited using indigenously developed metal organic precursor (2,2,6,6-tetra methyl-3,5-hepitane dionate) yttrium, commonly known as Y(thd)3 (synthesized by ultrasound method). Microwave electron cyclotron resonance plasma assisted metal organic chemical vapor deposition process was used for these depositions. Depositions were carried out at a substrate temperature of 350 ℃ with argon to oxygen gas flow rates fixed to 1 sccm and 10 sccm respectively throughout the experiments. The precursor evaporation temperature (precursor temperature) was varied over a range of 170–275 ℃ keeping all other parameters constant. The deposited coatings are characterized by X-ray photoelectron spectroscopy, glancing angle X-ray diffraction and infrared

spectroscopy. Thickness and refractive index of the coatings are measured by the spectroscopic ellipsometry. Hardness and elastic modulus of the films are measured by load depth sensing nanoindentation technique.
C-Y2O3 phase is deposited at lower precursor temperature (170 ℃). At higher temperature (220 ℃) cubic yttrium oxide is deposited with yttrium hydroxide carbonate as a minor phase. When the temperature of the precursor increased (275 ℃) further, hexagonal Y2O3 with some multiphase structure including body centered cubic yttria and yttrium silicate is observed in the deposited film. The properties of the films drastically change with these
structural transitions. These changes in the film properties are correlated here with the precursor evaporation characteristics obtained at low pressures

Ageing phenomena / 5

Detector aging effects at the FRIB's Advanced Rare Isotope Separator diagnostics detectors

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FRIB is one of the premier rare-isotope beam facilities, with the capability of producing a majority (approximately 80 percent) of the isotopes predicted to exist from oxygen to uranium, and beam energies of 200MeV/u. With the increase in beam power from the present 5kW to the planned 400kW, FRIB experiments are about to enter a new era which requires the operation of particle detectors at unprecedented high rates of low-mass proton-rich nuclei. Full functionality of such detectors over the long time required by experiments in a harsh radiation environment is of prime concern. A summary of aging phenomena in the Advanced Rare Isotope Separator (ARIS) detectors for beam diagnostics, including Parallel Plate Avalanche Counters (PPAC) and plastic scintillation detectors for time-of-flight measurements, are presented.

Poster session / 6

Studies of eco-friendly gas mixtures for RPC detectors

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In the context of climate change, one of the main contributors to global warming is the greenhouse effect. Regulations have been implemented in different areas of society to reduce or ban the use of greenhouse gases, such as freon. Despite the fact that large-scale experiments (such as the ones held at CERN) have been excluded from these restrictions, as a scientific community we have the duty to look for alternatives which are more eco-friendly to the environment. In this work we perform stability and aging studies for RPC detectors using eco-friendly gas mixtures in the context of the Phase II upgrade of the CMS detector, tested at the Gamma Irradiation Facility (GIF++) at CERN.

Poster session / 7

Investigation of the stability in the performance of triple GEM detectors for High Energy Physics experiments

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The advancement of accelerator technologies helps the High Energy Physics (HEP) community to reach higher collision rates to measure rare physical observables with unprecedented precessions. This imposes a great challenge to the rate handling capabilities of the detectors. In the HEP experiments, gas-filled detectors are commonly used for tracking, triggering, and timing measurements. Gas Electron Multiplier (GEM) is one of the most used gaseous detectors in the HEP experiments. GEMs are widely used as tracking devices due to their high-rate handling capability and good position resolution. Long term stability in performance is one of the main criteria for choosing detectors for the HEP experiments. Investigating the performance of the chambers with prolonged irradiation is one of the useful methods to understand the stability of the chambers. Thus, an initiative is taken to study the performance of the GEM chamber prototypes in the laboratory using external irradiation for different gas mixtures. In this work a Fe-55 X-ray source is used to irradiate the GEM chambers. The same source is also used to monitor the spectrum. The effect of temperature, pressure, relative humidity on the gain and energy resolution, the charging up effects are studied. The details of the experimental setup, methodology and results will be presented.

Discharge and spark studies / 8

Study of discharges observed in the CMS GE1/1 station during LHC Run-3

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Since July 2022, GE1/1, the first station using Gas Electron Multiplier (GEM) technology in the Compact Muon Solenoid (CMS) experiment, has been participating in the data-taking in proton-proton collisions. This station is the first of three (GE1/1, GE2/1 and ME0) planned to be installed in CMS, to cope with the challenging conditions given by the upgrade of luminosity of the Large Hadron Collider (High-Luminosity LHC program). This contribution will illustrate in detail the analysis developed to monitor the discharge rate per each LHC fill and the strategies developed to operate the detectors safely. An important intervention was the modification of the HV power system, to correctly power detectors affected by short circuits in the GEM foils. The contribution will also present the current status of operation for GE1/1 in Run-3 in 2023 and the next steps to be implemented to improve the detector's behavior.

Longevity studies / 9

Longevity studies for the CMS Drift Tubes towards HL-LHC

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The High Luminosity LHC (HL-LHC) program will pose a great challenge for the CMS Muon System. Existing subdetectors, which consist of Drift Tubes (DT), Resistive Plate Chambers (RPC) and Cathode Strip Chambers (CSC), will have to operate at 5 times larger instantaneous luminosity than the designed for, and, consequently, will have to sustain about 10 times the original LHC integrated luminosity. Longevity of DT system will be crucial to ensure a good performance in the CMS barrel region. Assessing DT performance is part of the upgrade program. In this talk will be reported the outcome of the accelerated irradiation studies, carried on at the CERN Gamma Irradiation Facility (GIF++) and recently concluded. These studies allowed to estimate performance of DT up to 3 times HL-LHC, and to plan a strategy to keep the longevity effects under control.

Longevity studies / 10

Longevity study of a triple-GEM chamber for the HL-LHC upgrade

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As part of the high-luminosity LHC (HL-LHC) upgrade, the CMS muon spectrometer will extend its coverage in the very forward region with triple-GEM detectors. These detectors will cope with a harsh environment with expected background fluxes up to 150 kHz/cmˆ2. At the end of HL-LHC operation, the total accumulated charge at the hottest point is expected to reach 7.9 C/cmˆ2. This accumulated charge is unprecedented for a GEM detector.

A full-size triple-GEM chamber was built using the design planned for the most forward CMS muon station using GEM foils produced at CERN. Using a gas mixture of Ar/CO2 (70/30)%, the chamber was irradiated with photons from a silver-target X-ray source over 1.5 years to reach an accumulated charge of 8 C/cmˆ2. Before and after irradiation the chamber was validated using the standard quality control procedures; gas gain and energy resolution were measured. During irradiation the gain was monitored weekly. The irradiation was interrupted only for the certification measurements. A non-irradiated sector was monitored for comparison. Temperature and pressure in the lab were continuously measured to derive correction factors to calibrate the gas gain. No degradation in gas gain was observed when reaching 8 C/cmˆ2. Irradiated and non-irradiated chamber components were inspected for potential impacts from irradiation.

Longevity studies / 11

CMS CSC longevity studies at GIF++ setup

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Study of the gaseous detectors longevity is essentially important in view of the future LHC upgrade into the High Luminosity mode. Longevity and performance of two Cathode Strip Chamber types, different in design and experiencing the highest backround level at CMS, are being studied at the Gamma Irradiation Facility (CERN).

The irradiation started in 2016 and now the accumulated charge per unit length of anode wire exceeds 550 mC/cm for ME2/1 and 770 mC/cm for ME1/1, what is about factor three of the charge expected at HL-LHC. The charge accumulation rate is about 30 times higher than that of the HL-LHC conditions.

As for the CMS operation, the chambers are supplied with gas in a close gas loop with replenishment rate of 10%. The working gas mixtures used in the study are 40%Ar, CO2 and different fractions of 10%, 2% and 5% of CF4. Regular monitoring of various CSC characteristics, including the muon test beam measurements, does not show any degradation of the chamber detection performance up to now.

New gas mixtures and gas mixture degradation / 12

Studies toward reduction or replacement of CF4 in the CMS CSC working gas mixture

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Cathode Strip Chambers (CSC) are used for precise measurements of muon track coordinates in the CMS endcap region. CMS CSCs operate with 40%Ar+50%CO2+10%CF4 as a working gas mixture, where the CF4 component provides reliable protection against anode wire aging sufficient for operation during the HL-LHC period. However, CF4 has a Global Warming Potential (GWP) of 6630 over 100 years, and is subject to the European Union F-gas regulation which aims reduction of the F-gas emission by two-thirds by 2030 compared with 2014 levels. So, either lowering the fraction of CF4 or excluding it entirely from the CSC gas mixture is well-motivated.

Measurements of the performance and longevity capability of various gas mixtures are primarily done with small CSC prototypes constructed of the original CSC materials strictly following the production technology. Dedicated material analysis of irradiated electrodes provides additional information on possible aging processes during the prototype irradiation. The role of CF4 in preventing anode wire aging is clearly seen and searches for its safe reduction or replacement in the CSC working gas mixture are ongoing.

Detector operation and performance / 13

In-situ monitoring of the CSC longevity at CMS

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540 Cathode Strip Chambers (CSC), a type of multi-wire promotional chamber, provide precise measurements of muon track coordinates in the CMS endcap region (pseudorapidity: 0.9-2.4) In the HL-LHC lifespan the CSC performance might degrade, in a process often called "aging", due to the unprecedented high radiation dose. To this end, the CSC group has been conducting irradiation tests at the CERN Gamma Irradiation Facility (GIF++) with full-scale CSC chambers. In addition, accurate measurements and monitoring of the CSC gas gain in-situ is crucial to detect any possible early signs of aging. In this presentation, CSC gas gain studies using muon induced charges on cathodes in the 2017, 2018 and 2022 data (corresponding to 148 fb-1 integrated luminosity) are presented. Aging effects are assessed by monitoring gas gain as a function of the integrated luminosity. The impact of atmospheric pressure, instantaneous luminosity, and changes in detector settings (HV, gas mixture, etc.) is taken into account.

Ageing phenomena / 14

Comparative aging studies of GEM chambers in contaminated environment

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GEM-based detectors are widely used in High Energy Physics (HEP) environments due to their inherent resistance to classical aging. Their unique design, which spreads charge amplification across multiple GEM holes and layers, effectively reduces the local plasma energy responsible for polymer formation, a major cause of detector aging. Consequently, GEM detectors are particularly advantageous for high-rate environments.

However, with the ongoing upgrade of the Large Hadron Collider (LHC) and with anticipated future particle accelerators, the radiation environment in which gaseous detectors operate will experience a significant increase in particle rate and contribution from heavy ionizing particles. In this context, it is crucial to reassess aging study strategies and establish appropriate test conditions that realistically replicate long-term operation in the target environment.

This report presents the results of comparative aging tests conducted on small GEM prototypes and wire chambers, all operated in forced contaminated environments and subjected to different irradiation conditions. Specifically, we investigate the aging effects caused by low-energy X-rays and Alpha particles. The performance of the detectors after irradiation, as well as the microscopic effects, were measured.

Ageing phenomena / 15

Outgassing studies for the CMS GEM detectors

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Like other gaseous technologies, GEM detectors can experience premature aging when operating in high-rate environments. This occurs when gas molecules dissociate and recombine within the plasmas generated during electron amplification, leading to the formation of large and complex polymers. These polymers can be deposited on the amplification structure and significantly impact the performance and stability of the detector. Although gas mixtures can be optimized to reduce or suppress polymerization, the presence of unwanted pollutants in the gas volume can fuel plasma polymerization, thus triggering conventional aging.

The CMS GEM group has conducted extensive research on the long-term behavior of triple-GEM detectors for over 10 years. This research is part of the upgrade of the forward muon system, which involves the incorporation of three new detector stations based on GEM technology. In addition to studying aging in high-radiation environments, the group has performed a series of specific tests to evaluate the outgassing properties of the materials used in detector construction and the impact of potential contaminants on the operation of gaseous detectors.

In this report we present the rationale behind the design of the dedicated outgassing test stand used for CMS GEM detectors. Furthermore, we discuss the operational experience gained from the tests and potential upgrades for future applications. We also present the test conditions and final results for all the materials that were tested.

Detector operation and performance / 16

MicroBooNE's Detector Physics Program and Stability throughout its 7 Years of Data Collecting

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The MicroBooNE experiment is a Liquid Argon Time Projection Chamber (LArTPC) placed along Booster Neutrino Beam (BNB) at Fermilab. MicroBooNE ran its physics and R&D runs from 2015 through 2021. Its primary physics goal is to contribute to addressing the elusive short-baseline MiniBooNE low energy excess. MicroBooNE records and utilizes both the ionization charge and scintillation light produced inside the TPC to select and reconstruct its events. To properly address the physics goals, it is crucial to properly understand how the detector evolves over time and perform continuous calibrations. This means performing state of the art measurement of detector physics quantities such as electron lifetime, diffusion, as well as paying close attention to the light yield. It is also very important to look at the performance over time. This talk will go over what MicroBooNE has learned and measured throughout its nearly continuous 7 years of running regarding detector physics measurements. Analysis of MicroBooNE performance over time be beneficial to the next many years long running Short-Baseline Neutrino (SBN) and DUNE programs to properly understand the important detector physics measurements in LArTPCs and their stability and aging over long periods of running.

New gas mixtures and gas mixture degradation / 17

Towards Sustainable RPC Detectors: Exploring CO2-Based Gas Mixtures for CERN LHC Experiments

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Resistive Plate Chamber detectors at the CERN LHC experiments use a Freon-based gas mixture containing R-134a and SF6, high global warming potential greenhouse gases. To minimise greenhouse gas emissions and expenses and optimise RPC performance, it is crucial to research new environmentally friendly gas mixtures. Thus, according to CERN's environmental strategies and European regulations, this study aims to understand the properties of adding CO2 to the standard gas mixtures as a medium-term solution to reduce greenhouse gas emissions. The gas mixtures tested were chosen to be compatible with the current CERN RPC systems. Detector performance, operational costs, and emissions are key characteristics considered in this research, focused on the potential use of CO2-based gas mixtures in the ATLAS RPC system during LHC Run 3.
This research is conducted at the CERN Gamma Irradiation Facility, where a 12 TBq 137Cs source and a muon beam allow emulating the background radiation experienced in the LHC experiment. The setup consists of five, 2 mm single-gap HPL RPCs located on three different positions, placed respectively outside the irradiation bunker, at 5m and 12m from the gamma source.

The detectors inside the bunker are continuously irradiated for long-term performance studies, aiming to reach the integrated charge expected for ATLAS RPC detectors in LHC Run 3 and for the future High Luminosity LHC phase. Monitoring is performed with various metrics: gas analysis, oxygen, humidity, dose, environmental parameters, and flow measurements to ensure the correct operation of the gas system. Throughout the study, three test beam periods are used to evaluate the muon performance parameters for the targeted gas mixtures: efficiency, current, streamer probability, mean prompt charge, cluster size, and time resolution.
Preliminary results using 30% CO2 will be presented, showing performances closely aligned with the Standard Gas Mixture. In addition to long-term studies, muon beam performance with higher

amounts of CO2 in the mixture, aimed at further reducing the consumption of R-134a, will be presented. Furthermore, an investigation into SF6 reduction is conducted to further decrease the mixture's GWP.

Detector operation and performance / 18

Experience gained about Resistive Plate Chambers ageing from the ALICE Muon TRigger/IDentifier detector

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The ALICE Muon IDentifier is composed by 72 single gap bakelite Resistive Plate Chambers, which have been operational since 2009 in maxi-avalanche mode (discrimination threshold:7 mV without amplification) with a tetrafluoroethane/isobutane/sulfur hexafluoride gas mixture, undergoing counting rates of the order of tens of Hz/cmˆ2.

In this talk, the long-term performance and stability of this RPC system will be discussed, in terms of efficiency, dark current and dark rate. An assessment of potential signs of ageing observed on the detectors will be presented, together with a summary of the most common hardware problems experienced.

Poster session / 19

Performance of new CO2 based mixture in CMS Improved Resistive Plate Chambers in HL-LHC environment

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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 of a 1.4mm gap RPC chamber with two different CO2 based mixtures (30% and 40%) with a high gamma background, as well as the perspectives to start the aging campaign for the best mixture.

Ageing phenomena / 20

Material analysis of the MWPC electrodes irradiated in longevity tests

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CMS CSC is a particular kind of Multi-Wire Proportional Chambers, or MWPC. Operation principle of MWPC is based on avalanche amplification of the primary charge in vicinity of a thin anode wire. The regions of avalanche development are microscopic areas of plasma, and plasma chemical reactions may lead to formation of deposit on the electrode surfaces of the MWPC, causing degradation of its detection performance.

Careful choice of detector materials and the working gas mixture minimizes the possible chamber aging. Dedicated longevity tests of a considered MWPC type involve a long-term operation of a detector prototype or a production chamber under intense irradiation. Comprehensive analysis of MWPC electrodes can be done after irradiation. It provides additional information on possible chamber degradation processes and increases reliability of the chamber longevity prediction based on the irradiation test results. We present a set of complementary analytical techniques which gives detailed characterization of deposit accumulated on MWPC electrodes. Optical, scanning electron and atomic force microscopy (OM, SEM, AFM) are used to characterize the surface morphology. To define the chemical composition, a combination of energy dispersive X-ray and photoelectron spectroscopy (EDS and XPS) are performed, as well as vibrational techniques, such as Fourier-Transform Infrared (FTIR) and Raman spectroscopy and X-ray diffraction (XRD) method.

Discharge and spark studies / 21

Study and mitigation of discharges in CMS triple-GEM detectors

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The GEM project of CMS encompasses the development, construction, and operation of three new triple-GEM detector systems, GE1/1, GE2/1 and ME0, for the upgrade of the forward muon spectrometer. The development of these systems and the operation of multiple advance-design demonstrators installed in the experiment, allowed for thorough studies of the gas breakdown effect that typically leads to discharge of energy stored in the GEM foils. This so-called discharge process has been investigated in different detector configurations, from single GEM hole to full size triple-GEM modules, and the consequences of discharge events were measured.

We studied the internal processes that could lead to the formation of discharges and their propagation inside the detector volume. We established the probability for such events to happen depending on the electric field strength, the internal detector capacitance, and the type of coupling to the high voltage power system. We measured the impact of discharges on the detector performance and longevity, looking at both the microscopic damage of the GEM foil itself, and the probability to damage peripheral systems such as the front-end electronics.

In this report, we summarize the studies of discharges in CMS GEM detectors and the strategies developed to mitigate the short-term and long-term degradation of detector performance.

New gas mixtures and gas mixture degradation / 22

Studies of eco-friendly gas mixtures for RPC detectors

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In the context of climate change, one of the main contributors to global warming is the greenhouse effect. Regulations have been implemented in different areas of society to reduce or ban the use of greenhouse gases, such as freon. Despite the fact that large-scale experiments (such as the ones held at CERN) have been excluded from these restrictions, as a scientific community, we have the duty to look for alternatives more eco-friendly to the environment. In this work, we perform stability and aging studies for RPC detectors, tested at the Gamma Irradiation Facility (GIF++) at CERN, using eco-friendly gas mixtures in the context of the Phase II upgrade of the CMS detector.

Detector operation and performance / 23

Study of long term stability of a 50 liters TPC, based on TRIPLE-GEM with optical readout, for the CYGNO experiment

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The CYGNO project aims to study rare events, as of low-mass (few GeV) Dark Matter (DM) or solar neutrino, exploiting the optical readout approach of the scintillation light produced in the ionisation in a multiple Gas Electron Multiplier (GEM) structure in large volume Time Projection Chamber (TPCs).
The volume is filled with an He:CF_4 gas mixture at atmospheric pressure. The 3D topology, and therefore direction of the recoils, is reconstructed thanks to the combined use of high-granularity, high sensitivity sCMOS cameras, which perform a precise tracking of the projection of the recoils on the GEM plane, and of fast light in order to obtain the coordinate perpendicular to the camera plane.

To conclude the R&D phase, the 50 L prototype, called Long Imaging ModulE (LIME), was moved underground at the Laboratori Nazionali del Gran Sasso (LNGS) in order to study the performance of the CYGNO experimental approach in a low background environment and to assess the contributions to the background from different sources, also checking with Monte Carlo simulations.
Stability studies and the effects of environmental condition on the light yield will be presented, focusing on the effect of humidity on the detector response and stability amount and rate of self-sustaining micro-discarges.

This is a crucial step towards the development of a large demonstrator.

Ageing phenomena / 24

Aging phenomena in the BESIII drift chamber

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As the main tracking detector of Beijing Spectrometer (BESIII), the multilayer drift chamber (MDC) is used to accurately measure the position and the momentum of the charged particles produced in e+ e- collisions at Beijing Electron-Positron Collider (BEPCII), and meanwhile to test dE/dx information

for particle identification.
MDC has been taking data since 2008. During about 15 years of operation, the chamber has worked stably with good performance, but it is suffering from aging issues due to beam related background. The gains of the cells in the first ten layers show a significant decrease, reaching a maximum decrease of about 50% for the first layer, and correspondingly, the spatial resolution and hit efficiency also show a degradation. What's more, the inner chamber of the MDC encountered Malter effect in January 2012. After some tests, about 0.2% water vapor was added to the gas mixture to solve this cathode aging problem. No Malter discharge has been observed since then. These aging monitoring and study provide important references for stable operation of the MDC and the upgrade of the inner chamber.
The aging effect of the BESIII drift chamber will be presented in this talk. The phenomena of Malter effect and the solution of this issue will also be shown.

New gas mixtures and gas mixture degradation / **25**

Study of gas aging impact on detector performance for the development of a new gas circulation system for ACTAR-TPC at GANIL

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Recent advancements in active target detectors, enabling the detection gas to act as a target for nuclear reactions, have provided a significant boost to the exploration of nuclei near the drip lines and the exotic nuclear phenomena associated with them. ACTAR-TPC at GANIL is a novel detector of such kind that can construct a 3-D mapping of the decay or reaction products from two-dimensional projection of the tracks and electron drift time. In such kind of detection technique which is based on the gas-filled detection chamber, gas purity is a key factor in ensuring optimum detector performance and their lifetime. The recycling of detection gas becomes significantly important to minimize operational costs, in the case of using expensive gases like deuterium (2H), tritium (3H), helium-3 (3He), xenon (Xe), etc. Another significant concern is the use of greenhouse gases (GHG) like CF4 , SF6, C3F8, etc in certain experiments to achieve the physics interest of the study. This amplifies the importance of gas recycling considering the environmental consciousness. However, the quality of the recycled gas after cleaning must be satisfactory to achieve the defined optimum performance of the detector. Aiming to the development of an advanced gas regulation system, a comprehensive study is underway to investigate the impact of gas aging on detector performance. For the study, a detection chamber with Mayaito detector is coupled with a gas regulation system which can deliver different gases at desire pressure to the chamber. Characterization of gas filters was carried out to ensure their efficiency and determine their suitability for adoption in gas recycling. In this presentation, important methodologies employed in the studies will be discussed and the corresponding results will be presented.

Ageing phenomena / **26**

Recovery of HADES drift chambers suffering from Malter-like effects

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The central tracking system of the HADES detector, installed at the SIS-18 synchrotron at GSI/Darmstadt (Germany), employs large-area, low-mass drift chambers. They are located in six identical sectors in forward direction of the fixed-target setup, two chamber planes before and two behind the toroidal magnetic field, respectively. Each chamber comprises six stereo angel wire layers. To minimize multiple scattering the detectors employ aluminum potential wires and have originally been operated with a He-isobutane gas mixture (60:40) [1]. The chambers in front of the magnetic field have developed significant self-sustained currents and discharges during operation at the working point, not allowing for stable operation any longer. Only the combination of switching to Ar:CO2 (70:30) and adding 1000 to 3000 ppm of water into the gas, individually optimized for a given chamber, allowed to recover the chambers, enabling stable operation in several production runs, e.g. with high-intensity heavy-ion induced reactions.
This contribution will present the status quo, having observed the Malter-like effects, and will detail the steps towards re-establishing stable operation in-beam, including the mandatory conditioning phase in front of high-intensity beam experiments.

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Ageing phenomena / **27**

Radiation Tolerance of the LHCb Outer Tracker: in the Lab and in the Forward Region at the LHC

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The LHCb experiment is designed to study B-decays at the LHC, and as such is constructed as a forward spectrometer. The large particle density in the forward region poses extreme challenges to the subdetectors, in terms of hit occupancies and radiation tolerance.

To accurately and efficiently detect the charged decay particles in the high-density particle environment of the LHC the Outer Tracker (OT) has been constructed. The OT is a gaseous straw tube detector, consisting of 53,760 straw tubes, covering an area of 360 m2 of double layers.

A the time of detector construction in the years 2004-2006, worrying ageing effects were observed. The results of extensive studies performed between 2005 and 2012 regarding the ageing phenonemon, the underlying cause and the mitigation methods will be discussed.

A remarkable radiation resistance of this sensitive gas detector is reported. Unlike most other subdetectors in LHCb, constructed with various technologies, no sign of ageing was finally observed after having received a total dose corresponding to about 400 mC/cm in the hottest region.

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Detector operation and performance / 28

Performance of the LHCb Outer Tracker in Run-I and Run-II of the LHC

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The LHCb experiment is designed to study B-decays at the LHC, and as such is constructed as a forward spectrometer. The large particle density in the forward region poses extreme challenges to the subdetectors, in terms of hit occupancies and radiation tolerance.

To accurately and efficiently detect the charged decay particles in the high-density particle environment of the LHC the Outer Tracker (OT) has been constructed. The OT is a gaseous straw tube detector, consisting of 53,760 straw tubes, covering an area of 360 m2 of double layers.

The performance of the OT during run I and run II of the LHC from 2010 to 2018 will be presented. Two independent and complementary methods have been used to measure the radiation resistance of this gas detector in the forward region at the LHC. One method uses a dedicated setup in situ, with which a 90Sr source is scanned over the surface of part of the OT detector. The second method utilizes reconstructed tracks during LHC operation, with which the hit efficiency over the full detector surface is determined at increased amplifier threshold. In addition, the final performance in terms of hit resolution and hit efficiency will be presented.

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JINST 12 (2017) P11016 [arXiv:1708.00819 [hep-ex]]

Detector operation and performance / 29

Long-term Operation of the Multi-Wire-Proportional-Chambers

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The muon detector of LHCb, which comprises 1368 multi-wire-proportional-chambers (MWPC) for a total area of 435 m2, is the largest instrument of its kind exposed to such a high-radiation environment. In nine years of operation, from 2010 until 2018, we did not observe appreciable signs of ageing of the detector in terms of reduced performance. However, during such a long period, many

chamber gas gaps suffered from HV trips. Most of the trips were due to Malter-like effects, characterised by the appearance of local self-sustained high currents, presumably originating from impurities induced during chamber production. Very effective, though long, recovery procedures were implemented with a HV training of the gaps in situ while taking data. The training allowed most of the affected chambers to be returned to their full functionality and the muon detector efficiency to be kept close to 100%. The possibility of making the recovery faster and even more effective by adding a small percentage of oxygen in the gas mixture has been studied and successfully tested.

New gas mixtures and gas mixture degradation / 30

Exploring Eco-Friendly Gas Mixtures for Resistive Plate Chambers: A Comprehensive Study on Performance and Aging

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Resistive Plate Chambers (RPCs) are gaseous detectors widely used in high energy physics experiments, operating with a gas mixture primarily containing Tetrafluoroethane ($C_2H_2F_4$), commonly known as R-134a, which has a global warming potential (GWP) of 1430. To comply with European regulations and explore environmentally friendly alternatives, the RPC EcoGas@GIF++ collaboration, involving ALICE, ATLAS, CMS, LHCb/SHiP, and EP-DT communities, has undertaken intensive R&D efforts to explore new gas mixtures for RPC technology. A leading alternative under investigation is HFO1234ze, boasting a low GWP of 6 and demonstrating reasonable performance compared to R-134a. Over the past few years, RPC detectors with slightly different characteristics and electronics have been studied using HFO and CO_2-based gas mixtures at the CERN Gamma Irradiation Facility. An aging test campaign was launched in August 2022, and during the latest test beam in July 2023, all detector systems underwent evaluation. The presentation will showcase the results of the aging studies and the performance evaluations of the detectors with and without irradiation.

Ageing phenomena / 31

Irradiation effects on GEM detectors operated at RUN1 and RUN2 at the LHCb experiment

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The GEM detectors with pad readout have been installed in the Muon apparatus of the LHCb experiment, more precisely in the innermost region (R1) of the first muon station (M1) . The GEM detectors have been operated with $Ar/CO_2/CF_4$=45/15/40 gas mixture at a gain of about 4000 with an average particle flux of about 200 kHz/cm^2. During the RUN1 and RUN2, corresponding to about 440 days colliding beams, the triple-GEM have integrated a charge up to 0.6 C/cm^2.
In this work, we present and compare the different effects, on the GEM detectors, obtained in a previous global irradiation test at the Calliope facility of the ENEA-Casaccia (1.25 MeV γ rays flux from a ^{60}Co source) and after their operation in LHCb with the CF_4-based gas mixture.
In both cases, the detectors have been opened and the GEM foils have been investigated by the EN-MME-MM CERN group [1] with a Field Emission Gun Scanning Electron Microscope (FEG-SEM) for a magnified image analysis and an X-Max Energy Dispersive X-Ray Spectroscopy (EDS) for the chemical one.
After the accelerated test at Calliope, where a charge up to 2.2 C/cm^2 has been integrated in 30 days, is clearly observed an etching of the GEM foils due to fluorine: larger effect is visible on the hole diameter of the third GEM foil (from the standard 70 μm up to
80 μm), while minor effects are found on the first and second foils. Fluorine is mostly located on the copper around the holes edge, leading to the formation of a thin non-conductive layer (a fluorine-copper compound). This fluorine etching effect is due to the bad gas flow condition (350 cc/min) with respect to the very high particle irradiation (about 20 MHz/cm^2) used during the Calliope test [2].
On the contrary, the preliminary results on triple-GEM detectors after their operation in LHCb do not show clear evidence of fluorine etching: residues of Sulfur (S), Nitrogen (N) and Oxygen (O) have been found all over the GEM copper surface, the holes edges and on the exposed Kapton inside the amplification holes. The thickness of these depositions varies from few nanometers (first GEM) to about 2 μm (third GEM) and their origin is actually under investigation.

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Detector operation and performance / 32

The LHCb Triple-GEM Detectors: Operational Experience

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During LHC Run1 and Run2 the LHCb muon system consisted of over a thousand gas detectors spread across five distinct stations, mostly MWPCs but also triple-GEM detectors in the central part of the first station.

The muon detector provided the input to the first level muon trigger and was also used to identify muons in the reconstruction process.

The first station of the muon detector, located upstream of the calorimetric system, consisted of 274 separate chambers. The 12 chambers around the beam pipe were double triple-GEM detectors with pad readout.

These triple-GEM detectors, with an active area of 200x240 mm2, were operated at rates as high as 300 kHz/cm2. They used a gas mixture of Ar/CO2/CF4 in a 45/15/40 ratio and achieved the required efficiency (96% in a 20 ns time window for the logical OR of the two sensitive gaps) while operating at a gain of about 5000.

For over nine years, from 2010 to 2018, these triple-GEM detectors operated in the challenging LHCb conditions without major signs of performance degradation. However, we often observed increased leakage currents in the GEM foils and in some cases we experienced GEM foils shorts following repeated discharge phenomena.

In this presentation, we will report on the performance of these 24 triple-GEM detectors during Run1 and Run2, the main problems we encountered and the solutions we implemented to keep the muon detector efficiency close to 100%.

Poster session / 33

Paschen curves measurement made with real Micromegas electrodes using a specific new tool.

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Thanks to a tool specially developed for that, we measured Paschen curves with real resistive Micromegas electrodes, both real mesh and real resistive anode layer. The resistive Micromegas structure and geometry studied correspond to those of the New Small Wheel (NSW) detector upgrade project of the ATLAS experiment at CERN.
Also these Paschen curves have been obtained for different gas mixtures: Ar:CO2 93:7 or Ar:CO2:isobutane 93:5:2 and also pure Argon.
The measurements have been made on different resistive anode layers corresponding to different NSW resistive PCB, taken from the real production batch. In particular, we have done these measurements for different resistive PCB, i.e. with different local resistivity and also different global resistances, where the so called global resistance is the one measured from the tested position w.r.t. to the HV polarisation connexion of the resistive (strips) layer.
The tool we developed gives us the possibility to do these measurements for a distance of the Micromegas mesh to the resistive anode going from 50 to 250 microns or more.
With this new tool, we are also able to test other geometries or configurations of resistive Micromegas.

Discharge and spark studies / 34

Numerical simulation of charging up, accumulation of space charge and formation of discharges

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Aging and stability of gaseous ionization detectors are intricately related to charging up, accumulation of space charge and formation of discharges. All these phenomena, in their turn, depend on the dynamics of charged particles within the device. Because of the large number of particles involved and their complex interactions, the dynamic processes of generation and loss of charged particles, and their transport within the detector volume are extremely expensive to simulate numerically.
In this work, we propose and evaluate possible algorithms / approaches that show some promise in relation to the above-mentioned problems. Several important ionization detectors having parallel plate configurations, such as GEM, Micromegas, RPCs and THGEMs, are considered for this purpose. Information related to primary ionization is obtained from HEED, while all the transport properties are evaluated using MAGBOLTZ. The transport dynamics have been followed using two different approaches. In one, particle description using neBEM-Garfield++ combination has been used. For this purpose, the neBEM solver has been significantly improved such that perturbations due to the charged particles present within the device are considered while estimating electric field. In the other approach, the transport is simulated following hydrodynamic model using COMSOL during which the electric field is also provided by COMSOL where it is easy to set up space charge effects. A comparison between these possible approaches will be presented. Effect of different simulation parameters will also be demonstrated using simple examples.

Ageing phenomena / 35

Aging suppression timing Multi-Strip Multi-Gap Resistive Plate Counter for high counting rate experiments

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The high counting rate MSMGRPC (Multi –Strip, Multi-Gap Resistive Plate Chamber) prototypes developed for the CBM experiment at FAIR, operated with C_2H_2F_4 and SF_6 based gas mixtures, showed in laboratory cosmic -ray tests a very good performance. Later on, the obtained results were confirmed in the in-beam tests with reaction products, in the high counting rate test the efficiency being better than 90% with ˜50 ps single counter time resolution up to 30 kHz/cmˆ2 exposure on the whole active area. However, as it is well known, a long operation time of Multi-Gap RPCs with gas mixtures based on C_2H_2F_4 and SF_6 leads to aging effects reflected in an increase of the dark current and dark counting rate, with impact on the chamber performance and artificial increase of the data volume in a free-running data acquisition mode. The aging studies performed by us using a high activity ˆ{60}Co source evidenced a gas pollution effect by the deposition of different radicals on the anode surfaces and by ablation/etching processes on the cathode surfaces of the resistive electrodes. Enhanced depositions and higher dark rates were also evidenced around the nylon spacers used for defining the gas gaps between resistive electrodes. For the mitigation of the effects mentioned above, MSMGRPC prototypes designed with a direct gas flow through the gas gaps (instead of classical gas exchange via diffusion process), with 100% gas transmission through the active volume and minimization of the number of spacers in the electric field, were developed. Three prototypes with this new design, differentiated by their strip length of 56 mm, 96 mm and 196 mm, corresponding to different granularities of the polar angle regions of the inner zone of the CBM-TOF wall, were assembled and investigated. Construction details of the new developed architectures, results of the comprehensive aging tests using a high X-ray flux, as well as the efficiency, time and position resolutions obtained in the cosmic -rays tests will be reported .

New detector materials / 36

The ceramic GEM-based neutron detectors at China Spallation Neutron Source

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China Spallation Neutron Source (CSNS) is a large-scale scientific facility which is a source of high-flux pulsed neutrons. It contains a 80 MeV linear proton accelerator, a 1.6 GeV rapid cycling synchrotron, a target station, and a suite of modern neutron instruments mainly for application to neutron scattering, imaging, and other kinds of neutron science research to promote high-level material science and technological development in China. Until 2023, the 11 neutron instruments have been built with the 9 remaining to be planned. The facility has been in public operation at a power of 140 kW since 2021. Many new instruments require 3He-free neutron detectors with high counting rate capability to match the high neutron flux. At CSNS, a novel ceramic GEM was developed to meet the demand of high counting rate for the neutron detection and an alternative to 3He detector. Many types of ceramic GEM-based neutron detectors have been developed for neutron instruments. More than 20 beam monitors (Fig 1) were installed and used with 2D position sensitivity and wide neutron-flux measurement range. Two highly efficient GEM detectors (˜50%@4 Å, Fig 2) were used to detect the small angles scattered neutrons at Very Small Angle Neutron Scattering Instrument (VSANS). Two large area (200mm*200mm) GEM detectors were applied to carry out Bragg-edge imaging for Energy-resolved Neutron Imaging Instrument (ERNI). A fast neutron GEM detector (Fig 3) based on natU was developed for the beam measurement at the Atmospheric Neutron Irradiation Spectrometer (ANIS). And a sealed GEM detector (Fig 4) was developed to obtain the long-term stability. In

all the applications, the detector stability and aging phenomena were observed, which need to be optimized and resolved in the future.

Ageing phenomena / **37**

Evidence for polyimide redeposition and possible correlation with sparks in gas electron multipliers working in CF_4 mixtures

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The interest in using visible and near-infrared scintillation in Gas Electron Multipliers (GEMs) in experimental approaches based on optical readouts has grown recently. One gas mixture used for this purpose includes CF_4, which is known to cause etching in the interior walls of the GEM holes [1]. One question may arise: Where will this etched material be re-deposited? The question is essential for many reasons, but one of them concerns the longevity of the sensor, which is related to the formation of insulation layers on the electrodes with time and the occurrence of the Malter effect. In this work, we report our findings on GEM surface studies using Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) technique on severely damaged GEM foils used with CF_4 mixtures. We found solid evidence for with deposition of sub-products of polyimide etching in the vicinity of the roles and possible correlation of parks. Complex molecular fragments from polyimide fragmentation deposit on top of the electrode in an apparent chemical reaction with a fluorine content of the gas. Comparisons with polyimide fragmentation by other means show the same molecular signature, indicating the origin. Conversely, pristine GEM samples showed the absence of the same molecular fragment, indicating that the etching occurred during its use.

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Poster session / **39**

Capabilities of the ionization chamber in the VAMOS++ facility for isotopic identification of fission fragments.

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The study of nuclear fission is integral to the fundamental understanding of nuclear physics and it has significant implications in many sectors, such as energy generation, space research, and radioisotope synthesis for medical uses. With the VAriable MOde Spectrometer (VAMOS++) facility, at Grand Accélérateur National d'Ions Lourds (GANIL), we are exploring the nature of nuclear fission through the application of inverse kinematics, a method that allows for a kinematic boost that yields greater kinetic energies of fission fragments relative to standard kinematics. Through the upgraded, segmented Ionization Chamber (IC) in the VAMOS++ setup, we have effectively determined and detailed the highly resolved isotopic distributions of fission fragments produced from various fusion- and transfer-induced fission reactions. This study comprises data analysis of the measurements using this IC, assessing its performance in Z-measurement in the context of current and future high-intensity particle detection requirements. The conference presentation will offer insights into the performance evaluation of the IC, with key findings and strategies for achieving unprecedented Z-resolution.

New detector materials / 40

Discharge quenching mechanism and RPWELL performance with tunable 3D printed resistive plates

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Resistive electrodes are used in gaseous detectors to quench spark discharges. This helps to protect delicate electrodes and readout electronics and to improve the stability of the detector operation. An RPWELL is a THGEM-based WELL detector with a resistive plate coupled to a conductive anode. Till now, the choice of the resistive plate was limited to a few materials, like LRS Glass and Semitron. These materials have fixed resistivities and, sometimes, pre-defined thickness and area limitations. These shortages restrict the potential usage of the detector to a rather small range of applications, as well as the possibility of studying in depth the physics processes governing the discharge quenching mechanism.
In our present study, we used a new plastic material doped with carbon nanotubes (3DXSTAT^{TM} ESD ABS) to produce resistive plates by Fused Deposition Modelling (FDM) technique pouring the material layer after layer with a commercial 3D printer. This method has the flexibility to produce samples of different thicknesses and different resistivity values. We will describe in detail the sample production, RPWELL performance with different resistive plates and show the dependence of discharge quenching on the thickness and resistivity of the resistive plate. We will also discuss and provide a preliminary model relating the dynamics of the charge carriers within the material and the discharge quenching mechanism.

Poster session / 41

Development and test of the readout electronics for the new large area MicroMegas detector for the AMBER experiment at CERN

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The ongoing work on the development and testing of a prototype of a Micromegas (MM) detector and its front end electronics will be presented. Presently a revision of the front-end electronics with a new discharge protection circuit is being tested and results will be discussed. Moreover, a first insight on the development of a new ASIC for the MM readout will be provided.
For the AMBER (NA66) experiment several upgrades of the COMPASS (NA58) spectrometer are foreseen for the medium and long-term AMBER program. Among this R&D program the replacement of a part of the COMPASS Multi-Wire Proportional Chambers (MWPCs) is planned, to face
up the aging of some of the structural elements of the MWPC chambers. Our main candidate technology to substitute the most aged MWPCs is the presently well-established Micro-Pattern Gaseous Detectors (MPGD).
This R&D project started with testing our non-resistive floating mesh MM detector with the TIGER-based front-end initially designed for the Cylindrical GEM detector of BESIII experiment. Those tests comprised laboratory tests and test beam campaigns.
The main difficulty we had to face up was regarding the Electro-Static Discharge (ESD) protection circuit of the FE cards. For this reason, we designed a new revision of the front-end board with a new protection circuit which aims on a single channel discharge quenching, thus enhancing the detector stability and reducing aging.

Longevity studies / 42

Long Term Irradiation of an ATLAS NSW SM2 Micromegas Quadruplet Using an AmBe Neutron Source

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The NSW Micromegas chambers in the ATLAS forward muon
spectrometer are subject to background rates of 15-20 kHz/cm^2
under HL-LHC conditions.
Typical anode currents will be around 6 μA on an area of 1440 cm^2
in the innermost part closest to the beamline.
Due to the late change of the detectorgas from non-ageing Ar:CO2 93:7
to the more HV stable ternary mixture Ar:CO2:isobutane 93:5:2
and the known vulnerability of wire chambers to
hydrocarbon containing gas mixtures
a three year long ageing study has been performed.
At CERN an SM1 and LM2 chamber underwent
intense gamma irradiation of 662 keV gammas in GIF++
and an SM2 series module of the NSW Micromegas quadrupets
was irradiated at LMU in Munich using a 10 GBq strong AmBe neutron source
emitting 6*10e5 MeV n/s as well as 3.5E6 4.4 MeV gammas/s
and 3.6E9 60keV gammas/s. Using this cocktail the
SM2 chamber was irradiated on a several cm^2 large region with
a dose rate well exceeding the HL-LHC equivalent local charge densities
for three years. In between the irradiation periods the performance of the
SM2 chamber regarding spatial resolution and efficiency
on cosmic muon tracking was tested several times.
We report on the irradiation and the performance studies
of the SM2 Micromegas quadruplet
and come to the conclusion that no sign of loss in performance
has been observed in contradiction to an earlier experience using
drift tube wire chambers.

Longevity studies / 43

Longevity test of ATLAS Micromegas detectors at the CERN GIF++ facility

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The ATLAS muon spectrometer will face an increase of particle rate, specially at high rapidity, consequently of the larger instantaneous luminosity for the HL-LHC phase, expected to attain 5x10^{34} cm^{-2}s^{-1}.
The New Small Wheel (NSW) of the ATLAS muon spectrometer endcap is equipped with small-strip Thin Gap Chambers (sTGC) and Micromegas (MM), able to provide good tracking and triggering performances in this dense environment.
MM detectors were foreseen to operate with Ar:CO2 93:7% gas mixture, however the ternary Ar:CO2:iC4H10 93:5:2% gas mixture has demonstrated to provide a better high voltage stability and a larger pulse height, useful for inclined track reconstruction.
Due to the hydrocarbon content in the mixture, an extensive aging campaign is ongoing at the Gamma Irradiation Facility (GIF++) at CERN on MM production detectors,
where they are long term exposed to a 11.6 TBq 137Cs source, accumulating so far a charge equivalent to several years of HL-LHC operations.
Several parameters have also been studied and optimised, such as current dependency on the gas flow, mesh transparency and ion back flow as a function of drift voltage,
as well as tracking performances using 80 GeV muon beam.
This contribution will describe the results obtained from the above studies, showing the good response of the detector after several years of irradiation
and demonstrating the robustness of ATLAS MM detectors under intense particle rates.

New gas mixtures and gas mixture degradation / 44

Search for environment friendly CO2 gas mixtures for the glass-based RPC detectors

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Resistive Plate Chambers (RPCs) are widely used in high-energy physics experiments because of their excellent ability to cover large detection areas with high particle detection efficiency and good time resolution. Often these properties are achieved by RPC detectors when they are operated with Freon-based gaseous mixtures that cause high global warming potential (GWP). Therefore, in order to take care of the environmental issues and various restrictions it is imperative to obtain an alternative gaseous mixture that is comparatively environment friendly and yet does not compromise on the performance of RPCs.

The present study is aimed at investigating the effect of using a CO2-based gas mixtures in an glass-based RPC detector compared to the standard C2H2F4/i-C4H10/SF6 gas mixture. The performance parameters of the RPC detectors, such as dark current, count rate, and efficiency, have been obtained and compared when the RPC has been operated at different fractions for these two different mixtures, i.e. the CO2 based and the standard gas mixtures. The data for our study has been collected with cosmic rays utilizing HARDROC-based front-end electronics.

New gas mixtures and gas mixture degradation / 45

Performance of new generation of Resistive Plate Chambers operating with alternative gas mixtures

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The standard gas mixture for the Resistive Plate Chambers (RPC), composed of $\mathrm{C_2H_2F_4/i-C_4H_{10}/SF_6}$, allows the detector operation in avalanche mode, as required by the high-luminosity collider experiments. The gas density, the low total charge delivered inside the gas and the comfortable avalanche-streamer separation guarantee high detection efficiency, rate capability and slow detector ageing.
The standard RPC gas mixture is mostly based on Hydrofluorocarbons, HFCs, extensively used in the refrigeration industry. The Hydrofluorocarbons are now considered to be non-eco-friendly gases for their high Global Warming Potential (GWP). The $\mathrm{SF_6}$ has the largest GWP, 22900, but, due to its low concentration, it contributes only with few tens of units to the total value. The major contribution comes from the main standard gas mixture component, the $\mathrm{C_2H_2F_4}$ (R134a, GWP $\sim$ 1300). This gases are not recommended for industrial uses anymore, thus their availability will be increasingly difficult over time and the search for an alternative gas mixture is then of absolute priority within the RPC community.
There are several studies on going which use different approach to find an alternative gas mixture suitable for experiment which work in high-radiation environment, as those operating at the Large Hadron Collider (LHC). One approach is to replace the standard gas with a mixture of HFO1234ze/$\mathrm{CO_2}$/i-$\mathrm{C_4H_{10}/SF_6}$, being the HFO1234ze/$\mathrm{SF_6}$ the main gas component and obtaining a gas mixture with a GWP $\approx$ 200, totally due to the $\mathrm{SF_6}$.
The second approach, currently under study by ATLAS and CMS collaborations, is to introduce a small fraction of $\mathrm{CO_2}$ in the standard gas mixture and by reducing the amount of $\mathrm{SF_6}$. This approach gives a higher-GWP gas mixture, $\approx$ 1162, but leads to the possibility to use it even for RPC with thin gas gap (1 mm) without observing worse performance in terms of efficiency. Moreover, the presence of less fluorine molecules inside the gas could lead to the possibility to not observe an accelerate aging.
In this presentation the results on the performance achieved using a 1 mm gas gap RPC with both types of gas mixtures are reported. For several gas mixtures, the detection efficiency, streamer and after-pulse probability, current and time resolution are reported. Moreover, the possibility to reduce the $\mathrm{SF_6}$ fraction and to replace it at all with a new gas, the HFO1233zd, is also reported.
The RPC performance are studied under strong photon irradiation which reproduces the gamma background of the ATLAS cavern and that expected during the High-Luminosity phase of the LHC.

Ageing phenomena / 46

Radiation Hardness Studies of RPC Based on Diamond-Like Carbon Electrodes for MEG II Experiment

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The MEG II experiment searches for the $\mu \to e\gamma$ decay which is charged lepton flavor violating process. A new type of resistive plate chamber (RPC) using diamond-like carbon (DLC) electrodes is under development for the identification of gamma ray from the radiative muon decay background, in the MEG II experiment. In order to identify the background, low energy positrons on the muon beam line need to be detected, hence the DLC-RPC is planned to be installed in a high-rate (10^8 μ/s) and low-momentum ($28~\mathrm{MeV}/c$) muon beam. There are several strict requirements on the DLC-RPC − the extremely low material budget of $0.1~\%$ of radiation length, the high detection efficiency for MIP positrons of $90~\%$, the high-rate capability of up to $4~\mathrm{MHz/cm^2}$ and the radiation hardness for 30 weeks of operation. The radiation hardness of the DLC-RPC has never been investigated before, although irradiation doses corresponding to a total energy deposit of $\mathcal{O}(100)~\mathrm{C/cm^2}$ are assumed. As the DLC-RPC uses the same gas configuration used in conventional RPCs ($\mathrm{C_2H_2F_4}$, isobutane, and $\mathrm{SF_6}$), fluorine deposition due to irradiation is expected, which is an aging phenomenon observed with conventional RPCs. Aging tests were carried out using a single-layer prototype detector with $2~\mathrm{cm} \times 2~\mathrm{cm}$ size to investigate these effects. This presentation will describe the aforementioned the DLC-RPC and the results of the aging tests on the DLC-RPC.

Detector operation and performance / 47

Long Term Irradiation Study of ATLAS sMDT Drift Tubes Using Beta-Electrons From a Sr90 Source Accumulating Almost 40 C Per Wire

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Two 50 cm long protype sMDT drift tubes have been irradiated using beta-electrons from ^{90}Sr-^{90}Y decays with end point energy of 2.28 MeV. Over two periods of 100 days and 125 days, respectively, the tubes were drawing constant currents of 3 uA and 1.25 uA. Regions of approximately 10 cm of the wires were irradiated intensively. Almost 40 C of charges have been accumulated in these regions on each wire.
As detector gas Ar:CO2 93:7 Vol-% was used at 3 bar absolute, the anode voltage of 2730 V was extremely stable over the whole period.
Pressure and temperature were monitored together with anode-voltage and amplification-current in the drift-tube.
We report on the experimental method and the setup and conclude from the observation of constant current over the whole period that no reduction in performance has been observed and thus no sign of long-term deterioration.

New detector materials / 49

Nanodiamond photocathodes for MPGD-based single photon detectors

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Gaseous Ring Imaging Cherenkov (RICH) detectors are the natural choice to perform hadron identification at high momenta; they require efficient and accurate detection of single Cherenkov photons over large surfaces. MPGD detectors of single photons are sensitive in the vacuum ultraviolet (VUV) domain. In present, CsI is the only photoconverter adequate with gaseous detector due to its wide wavelength sensitivity (cut-off wavelength ˜210 nm) and high quantum efficiency (QE) in VUV ranges, as well as the deposition ability over large surfaces. Anyhow the hygroscopic nature of CsI and the limited resistance against ion/photon bombardments are severe limits in terms of manipulation, QE preservation and single photon detection efficiency. The key quest to overcome these limits is to develop a faster and more robust photocathode capable of coping with challenging conditions. Hydrogenated nanodiamond (H-ND) particles have emerged as a potential alternative material with intriguing characteristics. Our continuing research focuses on the functionality of ND photocathodes coupled with THGEM-based detectors. The study includes the characterization of THGEM coated with ND layers in the single photon detection mode, along with determining the robustness of its photoconverting properties against the bombardment by ions from the multiplication process in the gaseous detector. In addition, the performance of the ND photocathode in various Ar:CH_4 and Ar:CO_2 gas mixture is thoroughly investigated. The results of the first phase of these studies are reported.

Discharge and spark studies / 50

Spark Protection System for the sPHENIX TPC GEMs

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The sPHENIX experiment is currently under commissioning at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Lab (BNL). The Time Projection Chamber (TPC) serves as a tracking detector for the experiment. The sPHENIX TPC uses a stack of four Gas Electron Multipliers (GEM' s) as a gain stage in a reduced ion back-flow configuration. In non-ideal conditions, the high voltage across the GEMs can create sparks which can cause physical damage and result in dead time as the detector settles. In order to monitor the occurrence of sparks and mitigate damage in the TPC GEMs it is important to have a spark monitoring system. In this talk, we will present the development and operation of the spark protection system for the sPHENIX TPC.

Poster session / 51

Gas tracking detectors for beta decay studies

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At low energy frontier among the Standard Model testing methods and searches for new physics beyond it are precision spectrum shape and correlation coefficient measurements in nuclear and neutron beta decay. For identification and 3D-tracking of low-energy electrons a special type of gas-based detector was designed that minimizes scattering and energy loss. In the first approach the gas tracker was successfully used in the miniBETA project to study tiny effects in beta spectrum shape on the allowed Gamow-Teller transitions. The miniBETA spectrometer consists of a hexagonally structured multi-wire drift chamber (MWDC), filled with a mixture of helium and isobutane gas and a plastic scintillator serving as a trigger source and energy detector. The drift time information is used to track particles in the plane perpendicular to the wires, while a charge division technique provides spatial information along the wires. Inspired by the performance of this tracker we are building a Mott polarimeter to be used in the ultimate phase of the BRAND experiment to study the neutron decay correlation coefficients. In this contribution, measurement techniques, detector stability, applied front-end electronics and current challenges for both experiments will be discussed.

Detector operation and performance / **52**

First operational experience for GEM detector with mixture recirculation system at the CERN Gamma Irradiation Facility

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Good and safe long-term operation of gaseous detectors are mainly guaranteed by the quality and stability of their gas mixture. Among Micro Pattern Gaseous Detectors (MPGD), Triple Gas Electron Multipliers (Triple-GEMs) have lately been more and more considered as tracking devices for LHC Experiments Muon Systems, as well as for others physics applications. Triple-GEM detectors are commonly operated with Ar/CO2 or Ar/CO2/CF4 gas mixtures, and the correct proportion between the different gas mixture components is fundamental for stable detector operation. Moreover, common impurities such as N2, O2and H2O can affect their performance, mining their response reliability. This study presents a characterization of Triple-GEM detectors performance in relation to their gas mixture composition. Results are reported in terms of experimental measurements as well as computer simulations of the Triple-GEM electron amplification process.

Detector operation and performance / **53**

Aging effects in the COMPASS hybrid GEM-Micromegas pixelized detectors

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Large size hybrid Micromegas gaseous detectors (40x40 cm² active area) were developed and installed in 2015, in view of the COMPASS2 physics program which started that year. That program

involved in particular two years of Drell-Yan studies based on a high intensity pion beam on a thick polarized target. Although the detectors were placed behind an thick absorber, they were exposed to important flux of low energy hadrons, in particular neutrons. The detectors were designed to get a huge reduction of the discharge rate, a major issue for non-resistive Micromegas at high hadron flux, by a factor of above 100 compared to former ones, using the hybrid solution where a pre-amplifying GEM foil is placed 2 mm above the micromesh electrode. A pixelized read-out was also added in the center of the detector, where the beam is going through, in order to track particles scattered at very low angles. The combination of the hybrid structure and the pixelized central read-out allowed to detect particle flux above 10 MHz/cm^2 with very good detection efficiencies and spatial resolution. Their performance remained stable since 2015 in term of gain and resolution, showing the interest of hybrid structures associating a GEM foil to a Micromegas board to protect gaseous detection against discharges and aging effects.

The hybrid Micromegas structure will be described, with an emphasis on the huge reduction of the discharge rate induced by this structure. Detector performance, in term of gain, detection efficiency and spatial resolution will be presented, and the evolution of these performance between 2015 and 2022 will be exposed to show the stability of the detectors along the time.

New gas mixtures and gas mixture degradation / 54

Studies on the fluoride production from gaseous detectors operated with fluorinated gas mixtures

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In the context of particle physics, different families of gaseous detectors are operated with fluorinated-gases for different purposes. It is well known that under the effect of high electric field and radiation, fluorinated molecules may break and form, among other species, free fluorine ions. Such ions may react with water molecules present in the gas, leading to the formation of highly aggressive compounds that could affect the long term performance of the detector.
To quantify the production of fluoride several techniques are used by the CERN Gas Group. In particular, the use of Ion Selective Electrode was largely employed in both large LHC gas systems as well as small R&D setups.
In this study two different setups for measuring the F- concentration are shown. First, measurements were conducted on single gap, High Pressure Laminate RPC detectors of 2 mm installed at the CERN' s Gamma Irradiation Facility operated with different gas mixtures and under different gamma background radiation. The F- production of the standard gas mixture was compared with the one of the standard gas mixture with the addition of 30% CO2 at several gamma rates. Different concentrations of SF6 were also investigated to understand if and how the SF6 could affect the fluoride production. Finally, two gas mixtures containing R-1234ze, R-134a and He or CO2 were used to study the RPC fluoride production in presence of the R-1234ze, which is less stable in atmosphere with respect to the R-134a.
Second, a setup in collaboration with the CMS CSC group was built to evaluate the production of F- from straw tubes operated with a gas mixture of Ar/CO2/CF4 and Irradiated with a 90Sr source at different CF4 concentration and flow conditions. Preliminary tests and considerations on the setup are shown.
Finally, novel detection techniques to measure HydroFluoric acid and F2 molecules are presented.

Poster session / 56

First stability studies of sealed Resistive Plate Chambers

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The expected limitations on the use of HFCs and other fluorinated gases motivated the opening of a new line of R&D in RPCs: sealed RPCs. This approach requires only very low amounts of gas and dispenses with the very complex and expensive recirculation and/or recycling gas systems.

At the moment it is not clear if this solution can cover all the fields of application of RPCs, but it seems that it can be considered as a valid option for triggering/tracking at low particle flux, for instance in cosmic-ray or rare-event experiments.

The results obtained in the last couple of years will be presented, advances and setbacks will be shared and discussed. All practical quantities, their dependence on the environmental variables and the evolution over time will be presented, with main focus on the performance stability.

Ageing phenomena / 57

Aging phenomena of Multi-gap Resistive Plate Chambers in high rate environment

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The future fixed target high-rate Compressed Baryonic Matter (CBM) experiment is one of the experimental pillars of the Facility for Antiproton and Ion Research (FAIR) located in Darmstadt/Germany. Since CBM aims to operate at an interaction rate of up to 10 MHz for Au+Au collisions radiation hard and high rate capable detector have to be installed. In order to provide an excellent particle identification (PID) of charged hadrons the CBM Time-Of-Flight (TOF) group has developed a concept of a 120 m^2 large TOF wall with a system time resolution below 80 ps based on Multi-gap Resistive Plate Chambers (MRPC) with rate capabilities above 30 kHz/cm^2. The MRPC detectors were extensively tested in terms of efficiency, time resolution and rate capability in several beam campaigns at particle fluxes of up to a 30 kHz/cm^2 and reached by now the close to final design. The hereby observed aging phenomena of MRPCs, mainly arising during operation at high rates, will be discussed in this presentation together with the for CBM contemplable mitigation strategies.

Detector operation and performance / 58

Ageing experience in Thin Gap Chambers (TGCs)

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The presentation will deal with the numerous irradiation tests performed before the construction of the ATLAS Big-Wheels (BW) TGC's, as well as irradiation tests performed before the construction of
the New Small Wheel (NSW) sTGC's. The results achieved by following the charge deposited by MIP's
in each individual detector plane after 11 years of operation will be shown. A presentation will be followed by explaining the source of issues that have developed with time, that are mainly related to
either chemical effects (independent of radiation) and construction issues, where not always full care was taken during the detector assembly. The conclusions will emphasize that not only irradiation is important in the long term behavior of a wire chamber, but that every detail counts.

Poster session / 63

Long-Term Stability of SWPCs in Monitoring CF4-Based Gas Mixture in CMS CSC Detectors

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In the CERN CMS experiment, CSC detectors are employed and operated with a gas mixture based on CF4. Since 2016, two Single Wire Proportional Chambers (SWPCs) have been installed along the gas line to monitor the quality of the gas. The first SWPC was positioned immediately after the gas mixer unit, while the second was placed within the gas loop. SWPCs exhibit a high sensitivity to the presence of pollutants, which can emanate from external components or the detector materials themselves. The presence of such pollutants can significantly impact detector performance, potentially leading to aging effects and irreversible deterioration.

Remarkably, the performance of the SWPCs has remained stable over time. Even after nearly seven years of continuous operation, they continue to effectively detect impurities within the gas mixture without exhibiting signs of aging.

In this presentation, we will share the results of recent years' monitoring efforts, along with details of the setup upgrades. Additionally, we will present a study that explores the correlation between oxygen (O2) concentration within the gas mixture, as determined through GC analysis, and the observed decrease in gain in the SWPCs.

Longevity studies / 64

Longevity studies for the CMS Resiste Plate Chambers for HL-LHC phase

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The present Compact Muon Solenoid (CMS) Resistive Plate Chambers (RPC) system has been certified for 10 years of Large Hadron Collider (LHC) operation at a maximum background rate of 300 Hz/cmˆ2 and integrated charge of 50 mC/cmˆ2. In the next years, during the Phase 2 of the LHC physics program, called High Luminosity LHC (HL-LHC), the accelerator will increase the instantaneous luminosity up to factor five more than the nominal LHC luminosity, providing to experiments an additional integrated luminosity of about 3000 fbˆ-1 over 10 years of operation. At the HL-LHC phase, the expected rate and integrated charge are about 600 Hz/cmˆ2 and 840 mC/cmˆ2, respectively (including a safety factor of three) based on Run 2 data and assuming a linear dependence of the background rates as a function of the instantaneous luminosity. A longevity test is then needed to estimate the impact of HL-LHC conditions on the RPC detector performance in order to confirm that the RPC system will survive the harsher background conditions expected at HL-LHC. A dedicated long term irradiation program has been started at CERN Gamma Irradiation Facility (GIF++) since 2016, where few RPC detectors are exposed to intense gamma radiation for long term to mimic the HL-LHC operational conditions. The main detector parameters (currents, rate, resistivity) are continuously under monitoring as a function of the collected integrated charge and the detector performance has been studied with muon beams. The latest results of the irradiation test will be presented.

65

Registration

66

Conference opening

67

Gas Counters Aging for Dummies

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Gas Counters Aging for Dummies

68

coffee break

69

coffee break

70

Gaseous Detectors and Radiation Hardness: challenges and requirements from the next generation of experiments

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Gaseous Detectors and Radiation Hardness: challenges and requirements from the next generation of experiments

71

Exploration of Alternatives to Greenhouse Gases

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Exploration of Alternatives to Greenhouse Gases

72

Aging of Photocathodes and Exploration of Novel PC materials - ZOOM

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Aging of Photocathodes and Exploration of Novel PC materials

73

Aging Validation Setup at CERN

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Aging Validation Setup at CERN

74

Discharge Stability and Resistive Structures

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Discharge Stability and Resistive Structures

75

Plasma Chemistry (molecular dynamics) and Aging Effects

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Plasma Chemistry (molecular dynamics) and Aging Effects

77

Conference Summary

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Conference Summary

78

Detector stability and Discharges in GEM

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Detector stability and Discharges in GEM

79

conference closure and outlook

80

Bye bye lunch

81

Conference dinner

82

info