

MicroPattern Gaseous Detectors Conference 2019

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Book of Abstracts

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2

3D microscopic space-charge effects simulation on GPU for gaseous detectors

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The design and optimisation of particle detectors is now widely based on computer simulations, whether analytically or by Monte-Carlo (MC). Gaseous detectors are no exceptions while a variety of simulation programs can be found or even home-made. However, most of them lack two main components in their architectures: i) a relatively fast MC simulation algorithm and ii) a 3D microscopic space-charge effects algorithm. In that sense, we developed a GPU-based MC program that allows the user to not only perform with great speed systematic studies for their gaseous detectors but also includes the dynamic 3D space-charge effects. These effects, by means of a fast boundary element method algorithm, include the modification of the electrode potentials induced by the presence of free charges as well as the generation of the electric field by the charges themselves. These effects are of high interest when dealing with high amplification factor detectors or for use in very high intensity beams. Capabilities of our GPU program will be shown along with comparisons to literature data.

3

Development of new MPGD structures for nuclear physics applications.

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I will present and discuss the operational principle and performance of innovative MPGD architectures based on the multi-layer Thick Gaseous Electron Multiplier (M-THGEM) concept [1]. In particular, we will discuss the following devices:

- The MM-THGEM [2] accommodates, in a single microstructure, the two most popular but very different MPGD concepts: the parallel-plate type micro-mesh and the hole-type (multi-layer THGEM) multiplier. The MM-THGEM comprises of a multi-layer hole-type multiplier (M-THGEM) combined with in-built electrode meshes. The electrons are largely multiplied by a strong uniform field established between the meshes, like in the parallel-plate avalanche geometry. The presence of the two meshes within the holes allows trapping a large fraction of the positive ions that are streaming back to the drift region, reducing ion back-flow secondary effects.
- The PIN-HOLE gas amplifier consists of a two-layers M-THGEM in a WELL configuration, where the bottom M-THGEM electrode is placed directly in contact with the anode surface. The insulator of each THGEM layer is of 400 μm . The anode consists of a thin conductive needle (with up to 10 μm tip radius point and a height of 100 μm), located at the center of the hole and acting as anode. The bottom area of the needle is surrounded by a cylindrical “cathode” surface. The electric field lines from the drift region above the M-THGEM are focused into the holes by the strong dipole field and then forced to converge on the needle tip. An extremely high field is reached at the top of the needle, creating a point-like avalanche process. Stable, high-gain operations are achieved at relatively low voltage, even in pure quencher gas at atm pressure (e.g. pure isobutane). The PIN-HOLE structure is produced by the innovative scalable additive manufacturing

technology for large-area, multiple-layer printed circuit boards, recently developed by the UHV technology company (USA).

The results of this work are relevant in the field of avalanche mechanism for applications of MPGD readout for active-target Time Projection Chambers (TPC) and tracking, in the field of low-energy nuclear physics and nuclear astrophysics with rare isotope beams.

Reference:

1. M. Cortesi et al., "Multi-layer thick gas electron multiplier (M-THGEM): A new MPGD structure for high-gain operation at low-pressure," *Rev. Sci. Instrum.*, vol. 88, no. 1, p. 013303, Jan. 2017.
2. R. de Olivera and M. Cortesi, "First performance evaluation of a Multi-layer Thick Gaseous Electron Multiplier with in-built electrode meshes—MM-THGEM," *J. Instrum.*, vol. 13, no. 06, pp. P06019–P06019, Jun. 2018.

4

Low-pressure TPC with THGEM readout for ion identification in Accelerator Mass Spectrometry

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A new technique for ion identification in Accelerator Mass Spectrometry (AMS) has been proposed based on measuring the ion track ranges using a low-pressure time projection chamber (TPC). As a proof of principle, the low-pressure TPC with charge readout using a THGEM multiplier was developed. The tracks of alpha-particles from various radioactive sources were successfully recorded in the TPC. The track ranges were measured with a rather high accuracy, reaching 3%. Using these results and SRIM code simulation, it is shown that the isobaric boron and beryllium ions can be effectively separated at the 10 sigma level. This technique is expected to be applied in the AMS facility in Novosibirsk for dating geological objects, in particular for geochronology of Cenozoic Era.

5

Study of GEM-based detectors spatial resolution

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Gas Electron Multiplier (GEM) based coordinate detectors are applied at different high energy physics centers and at the Budker Institute of Nuclear Physics particularly. These detectors possess a spatial resolution in ten micron scale together with high rate capability up to $10^7 \text{ cm}^{-2} \text{ s}^{-1}$. Thus, the precise investigation of best possible spatial resolution, achieved with GEM-detectors, is the subject of interest. The experimental data, accumulated by the moment, gives the possibility to compare

it with the simulation results. The simulation of applied detector configurations includes transport of electrons through the detector and tracking of avalanche evolution inside the working volume, as well as obtaining signal distribution on the readout strips. The simulation of electron transport through a single GEM and through a GEM-cascade shows that an electron cluster is compressed by GEM holes and an effective transverse diffusion is reduced by about 15%. The spatial resolution, obtained in the simulation of an individual detector, is found to be essentially better (the difference is about two standard deviations) than the experimental results. We are performing further efforts to find out the reasons of the contradiction between the simulation and measurements. In particular, the simulation of whole experimental set-up (including tracking detectors) is being performed and more measurements with better tracking detectors are being done.

6

Development of resistive Micromegas TPCs for the T2K experiment

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The long baseline neutrino experiment T2K has launched the upgrade project of its near detector ND280, crucial to reduce the systematic uncertainty to less than 4%. An essential component of this upgrade consists of two resistive Micromegas TPCs, for 3D track reconstruction, momentum measurement and particle identification. These TPC, with overall dimensions of 2x2x0.8 m³, will be equipped with 32 resistive Micromegas.

The thin field cage (3 cm thickness, 4% rad. length) will be realized with laminated panels of Aramid and honeycomb covered with a kapton foil with copper strips. The 34x42 cm² resistive bulk Micromegas will use a 500 kOhm/square DLC foil to spread the charge over the pad plane, each pad being appr. 1 cm². The front-end cards, based on the AFTER chip, will be mounted on the back of the Micromegas and parallel to its plane.

In Summer 2018 we have tested one resistive Micromegas detector on the ex-Harp TPC field cage in the CERN PS test beam (with electrons, pions and protons with momenta between 0.5 and 2 GeV/c) with excellent results both for the space point resolution (reaching 300 μm) and for the dE/dx. In particular we have tuned the charge spreading by varying the electronics shaping time from 100 to 600 ns. In 2019, with the first full TPC prototype, we will conduct further tests with cosmics at CERN and with a beam at DESY.

We have recently completed the detailed TDR describing all the components of this device (the installation is planned in 2021). In this talk we will report on the design of this detector, its performance, the results of the test beam and the plan for its construction.

8

Large Area Precision Cathode Boards for ATLAS Muon Upgrades

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The largest phase-1 upgrade project for the ATLAS Muon System is the replacement of the present first station in the forward regions with the so-called New Small Wheels (NSWs) during the long-LHC shutdown in 2019/20. The NSWs will be equipped with eight layers of small-strip thin gap chambers (sTGC) arranged in multilayers of two quadruplets, for a total active surface area of more than 2500 m². Large area circuit boards for the sTGC quadruplets have trapezoidal shapes with surface areas up to 2 m². To retain the good precision tracking and trigger capabilities in the high

background environment of the high luminosity LHC, each sTGC plane must achieve a spatial resolution better than 100 μm to allow the Level-1 trigger track segments to be reconstructed with an angular resolution of approximately 1mrad. The precision cathode plane has strips with a 3.2mm pitch for the precision coordinate and the cathode plane on the other side has large area pads for triggering. The position of each strip must be known with an accuracy of 40 μm along the precision coordinate and 80 μm along the beam. On such large area detectors, the mechanical precision is a key point and then must be controlled and monitored all along the process of construction and integration into quadruplets and wedges. The cathode boards are produced in industry by either CNC machining or chemical etching of copper plated FR4 boards. An insulating pre-preg layer is pressed on top of the copper readout elements. Material flow of the underlying FR4 boards during the cathode board manufacturing processes of CNC machining or etching and pressing have been found to have significant impact on the placement of the copper read-out elements. Production of the sTGC detectors is well underway, including the assembly of the 3 meter long wedges maintaining 100 μm position accuracy for installation into ATLAS. We will describe the technological innovations, production challenges in industry and sTGC construction sites, measuring and tracking the dimensional precision of the circuit boards, and alignment of the chambers in ATLAS

9

ACTAR TPC: a tool for nuclear physics applications

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The ACTAR TPC (Active Target & Time Projection Chamber) is a detector developed for fundamental nuclear physics studies such as nuclear reaction and structure studies as well as exotic decay and proton emission studies. It results from the joint efforts to build a second generation gaseous target and detector that merges the advantages of the first generation active target MAYA based on wire amplification and the CENBG TPC based on GEMs.

In addition to specific developments concerning the high density collection plane (with 16k pads) and the active volume, the device is equipped with the GET electronics that allows for time sampling of signal of each pad for a full 3D reconstruction of tracks. The pad planes are equipped with 128 and 256 μm bulk micromegas (64x128 mm²) either on standard PCB or on a specific metal-core PCD. After the realization of demonstrator detectors that have been tested in various conditions including in beam tests, the final detectors (2 pad plane geometries have been designed) are now almost completed, with in-beam commissioning runs at GANIL, for active target and decay detector modes of the device.

We propose to present the characteristics of the detector in terms of particle tracking and energy analysis, resulting from the various source and beam test measurements. We will also address the issues related to the gas used in Active Targets.

The ACTAR TPC device is planned to be used in 2 experiments at GANIL in 2019.

10

A new idea: Functional Polymer Detectors

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Until now, silicon, semi-conductor, gaseous detectors were used to detect sub-atomic particles. It is also known that polymeric structures are using in the GEMs.

As a recently developed technology, functional polymers have been used rapidly in various fields. We have made a new generation detector using functional polymers which is not using any material (gas, silicone e.g.), long-lasting, flexible, lightweight. A polymer derived from o-nitrobenzyl ester was used for this detector. It is known that the chain of this monomer can break by a radiation in the keV-MeV range and it can repair itself in microseconds. This polymer is coated on a flexy surface. Due to the high voltage applied on the inserted electrodes, the low current passing through the polymer is continuously measured. When radiation is applied to the polymer, its conductivity has changed due to breaking of the chains and this change is perceived as signal. The operation of this new generation polymer and the first results obtained will present.

11

FIRST RESULTS OF RAYLEIGH SCATTERING METHOD TO DEFINE SIZE OF CLUSTER IONS IN A GAS DETECTOR

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In gas detectors, ions have undesirable effects on the operation of the detector. They affect on signal through electromagnetic induction and break the surrounding electric field configuration by coming together in the drift area. Specially this problem is discussing on board of groups which are working on big volume gas detectors at CERN. In fact, numerous attempts have been made to solve such problems, but none of these approaches have been successful. As an accepted approach, it is very important to determine the behaviour of ions in the detector. However, we have proved that the ions are converted into ionic clusters until reaching the cathode. We have done shows the presence of ionic clusters including one or two atoms or molecules, but some scientists argue that hundreds of atoms or molecules can form ionic clusters. As a result, knowing the size of the ionic clusters will lead to a more comprehensive understanding and solutions that will be introduced in this direction.

This study suggests a different way to define ions in a gas detector namely Rayleigh scattering method. We used a standard GEM. Laser beam (532 nm), is sending to the drift area where the cluster ions are forming. Laser scattering on the ions and the scattered light detecting by a PMT (Hamamatsu H11901-110). Signal intensity will be analysed, so the dimensions of the cluster ions in detector can be determined by using scattered light. First time, cluster ions are defining in a gas detector during the standard operation of the detector. The first considerable results will present for Ar – CO₂ gas mixture.

12

Commissioning and beam test a high pressure time projection chamber

Author: We would like to define the speaker once we know the abstract has been accepted or not.^{None}

Due to their large active volume and low energy threshold for particle detection Time Projection Chambers (TPCs) are used in the T2K experiment to characterise the neutrino beam before it undergoes oscillations and TPCs are promising candidates for future long baseline neutrino oscillation

experiments. The higher target density in a TPC filled with gas at High Pressure (HPTPC), will potentially allow a better neutrino-nucleus interaction measurements as compared to TPCs at 1 atm. For this reason the DUNE collaboration has recently endorsed a HPTPC for its near detector.

We commissioned an HPTPC with about 0.5 m^3 active volume which is embedded into a pressure vessel rated up to 6 barA. Three meshes (diameter: 120 cm) amplify the primary ionisations. The photons emitted during the gas amplification are imaged by four CCD cameras focused on the readout plane, thus recording the 2D projection of particle's tracks on the transverse plane. Each camera pixel images a square with $230 \mu\text{m}$ side length on the readout plane. The third coordinate is reconstructed from the charge signal read out at the un-segmented meshes.

A report on the commissioning phase of the HPTPC will be given, including results from a four week long beam test at CERN's PS, where low momentum proton ($\leq 0.5 \text{ GeV}$) interactions with the counting gas have been measured. Several mixtures with Argon predominance have been tested for their light yield and gas gain at varying pressure and high voltage settings. We will report furthermore on the status of the analysis, which will eventually, the proton Ar cross section will be calculated from the data sample, which will in turn enter the calculations of final state interactions in neutrino Ar scattering.

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High space resolution μ -RWELL for high rate applications

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The micro-Resistive-WELL (μ -RWELL) is a compact, simple and robust Micro-Pattern Gaseous Detector (MPGD) developed for large area HEP applications requiring the operation in harsh environment. The detector amplification stage, similar to a GEM foil, is realized with a polyimide structure micro-patterned with a blind-hole matrix, embedded through a thin Diamond Like Carbon (DLC) resistive layer with the readout PCB. The introduction of a resistive layer ($\rho \sim 50 \div 200 \text{ M}\Omega/\text{square}$) mitigating the transition from streamer to spark gives the possibility to achieve large gains ($>10^4$), while affecting the detector performance in terms of rate capability. Different detector layouts have been studied: the most simple one based on a single-resistive layer with edge grounding has been designed for low-rate applications (few tens of kHz/cm²); more sophisticated schemes are under study for high-rate purposes ($O(\text{MHz/cm}^2)$).

The single-resistive layer scheme, extensively tested and validated, it is mature for the technology transfer towards the industry working into the rigid and flexible PCB photolithography.

The high-rate version of the detector has been developed in the framework of the phase-2 upgrade of the LHCB muon system, where strong requirements on the robustness and rate capability are required.

An overview of the different architectures studied for the high-rate version of the detector, together with their performance measured at the high intensity PiM1 beam of the PSI will be presented.

The presence of the resistive layer also affects the charge spread on the strips and consequently the spatial resolution of the detector: the results of a systematic study of the spatial resolution obtained with the charge centroid (CC) method for orthogonal tracks as a function of the DLC resistivity will be discussed.

For non-orthogonal tracks the spatial resolution with CC method is compared with the performance obtained with the micro-TPC mode: a readout approach that exploiting the combined measurement of the time of arrival and the amplitude of the signals on the strips allows a fine estimation of the position of the track for a wide incident angular range.

The excellent performance together with the high flexibility of the technology suggests the use of

such a detector as a high space resolution inner tracker in HEP. The possibility to exploit the μ -RWELL technology to build a full Cylindrical detector will be eventually discussed.

14

GEM detectors for the MAGIX focal plane: minimising materials for low energy experiments

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The new MAGIX experiment, to be built at the 105 MeV line of the ERL MESA at the institute for Nuclear Physics of the University of Mainz, features two high-resolution spectrometers looking at the target area where luminosity of the order of $10^{35} \text{cm}^{-2} \text{s}^{-1}$ will be achievable. To improve the momentum and angular resolution of the spectrometers, the greatest challenge is to minimise the material budget of their GEM-based focal plane detectors as much as possible.

In this talk we will present the solutions we developed to build a high-resolution MPGD tracker for those experimental conditions including a foil based readout plane with Chromium-GEM amplification and a short-drift TPC with an open field cage, the latter being the solution finally approved for the experiment.

15

The triple-GEM detector for a Laser Polarimeter facility at VEPP4-M collider.

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The VEPP4-M collider has a unique system for energy measurement based on Resonance Depolarization technique. The existing system is working well using the Touschek effect for measurement of polarization at the energies below 2 GeV. For higher energies it is suggested to use the effect of asymmetry of reflected polarized laser photons back-scattered from polarized beam. For the measurement of polarization degree of the beam the coordinates of Compton scattered photons are registered with different polarization of the laser. Since non-polarized beam does not produce asymmetry, thus difference in mean coordinate yields the information about polarization degree of the beam.

For registering of coordinates of reflected photons the special gaseous detector with triple-GEM was manufactured. The readout structure is a rectangular grid of 1120 pads, which are 2x1 mm sized in center and 4x2 mm on the edge where bigger pads are used for a rough alignment of the detector. In front of sensitive area the lead converter is placed which converts the reflected photons into charged particles registered by the detector. The trigger for the detector, which is the same signal fed to laser, is generated by frequency division of VEPP4-M bunch crossing signal and is in the range of 1-4 kHz

while the laser polarization can be switched on every flash. For the gathering of signals from the pads of the readout structure the DMXG64v1 front-end ASICs, which were developed at BINP, are used.

The prototype detector was tested and the principle was proved. At present the full size detector is being assembled and first results will be presented at the Workshop.

16

MPGD-based photon detectors for the upgrade of COMPASS RICH-1 and beyond

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After pioneering gaseous detectors of single photon for RICH applications using solid state Photo-Cathodes (PC) within the RD26 collaboration and by the realization of the MWPCs with CsI PC for the RICH detector of the COMPASS experiment at CERN SPS, in 2016 we have upgraded COMPASS RICH by novel gaseous photon detectors based on MPGD technology. Four new photon detectors, covering a total active area of 1.5 square m, have been installed in order to cope with the challenging efficiency and stability requirements of the COMPASS physics programme. The new detector architecture consists in a hybrid MPGD combination: two layers of THGEMs, the first of which also acts as a reflective PC thanks to CsI coating, are coupled to a bulk Micromegas on a pad-segmented anode; the signals are read-out by analog F-E based on the APV-25 chip. These detectors are the first application in an experiment of MPGD-based single photon detectors.

All aspects of the COMPASS RICH-1 Photon Detectors upgrade are presented, including R&D, engineering, mass production, quality assessment and performance.

Perspectives for further developments in the field of gaseous single photon detectors are also presented.

17

Study of LTCC-GEM gain properties

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Low Temperature Co-fired Ceramics (LTCC) is an insulator and has been used for an electronic circuit board. The features of LTCC are good electric discharge resistance and high rigidity. Using LTCC, GEM foil without being broken by an electric discharge can be manufactured. Manufactured LTCC-GEM foil is 10cm square and has a hole diameter of 100 μm , hole pitch of 200 μm . The thickness of an insulator (LTCC) are 100 μm and 200 μm . Since the gain of LTCC-GEM achieves around 3000 (200 μm thick), the stacking of GEM is not necessary to obtain enough signals. And LTCC-GEM didn't break by the discharge of more than 5000 times.

We will report on performance of LTCC-GEM, especially 200 μm thick, with X-ray source (Fe-55). The gain measures with three type of gases and can achieve over 1000 for all gases. And gain fluctuation in the long term is less than 10%. Other performances also will be presented.

18

A scalable High Voltage power supply system with SoC control for Micro Pattern Gaseous Detector

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A single channel high voltage power supply system based on an DC to DC converter, coupled to a high resolution ammeter and controlled via a System on Chip board has been developed and engineered. The hardware and software R&D activity has been driven with the precise goal of matching the needs of the Micro Pattern Gaseous Detector technology development, study and monitoring in terms of both high resolution diagnostic facilities and intelligent dynamic voltage control for detector stability. These characteristics are not available in commercial devices.

The system has been designed for multichannel applications exploiting both the high speed interconnectivity between the System on Chip Boards and the FPGA reconfigurability. the design, implementation and performance of the system are described in detail.

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CYGNO: Triple-GEM Optical Readout for Directional Dark Matter Search

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CYGNO is a project realising a cubic meter demonstrator to study the scalability of the performance of the optical approach for the readout of large-volume, GEM-equipped TPC. This is part the CYGNUS proto-collaboration which aims at constructing a network of underground observatories for directional Dark Matter search.

The combined use of high-granularity sCMOS and fast sensors for reading out the light produced in GEM channels during the multiplication processes was shown to allow on one hand to reconstruct 3D direction of the tracks, offering accurate energy measurements and sensitivity to the source directionality and, on the other hand, a high particle identification capability very useful to distinguish nuclear recoils.

Results of the performed R&D and future steps toward a 30-100 cubic meter experiment will be presented.

20

Study of charge-up processes in Gas Electron Multipliers

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In order to investigate the charge-up effect in Gas Electron Multipliers (GEM), two complementary approaches were chosen. On the one hand, the effect is simulated with an iterative method based on Garfield++. The main idea is to divide the polyimide part of the GEM into several slices and accumulate charge on each slice. On the other hand key properties of the charge-up effect (e.g. time-constant or percental gain increase) were measured. Hence, a dedicated test-detector with a single GEM foil was built.

The simulations and measurements are mainly focusing on standard GEMs but also different hole geometries were investigated.

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Stability tests performed on the multi-gap detector built using locally produced GEM foils

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Gas Electron Multiplier (GEM) technology is mainly based on thin polymer foil, copper clad on both sides with a regular matrix of holes. Due to the limited supply capacity of CERN, these GEM foils are now commercially manufactured elsewhere including India. With the experience of gain and rate measurements performed using triple GEM detector utilizing double-masked 10 cm × 10 cm GEM foils, we hereby present some advanced studies which are useful for long term operations of GEM detectors. In order to gain an insight on the behaviour of the detector, it is important to study various effects on the foil due to the applied voltage as well as the flux of the incident particles. We have studied the effect on gain stability of the triple GEM detector due to the polarising field induced by X-rays on the polyimide foils. Also, these foils are well known for stable operation at high particle flux. But when we cascade them to build a triple GEM detector, the effective gain remains constant initially and then varies as flux is further increased to higher values. We present measurements of such variations in the effective gain at very high particle flux of the order of MHz/mm².

23

Energy resolution and detection efficiency of optically readout GEM

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Optical readout approach of multiple-GEM structures in large TPC shown to provide very interesting performance for high energy particle tracking. Proposed applications for low-energy and rare event studies such as Dark Matter Search call for high capabilities in the keV energy release region.

By means of a ⁵⁵Fe source providing 5.9 keV photons, the performances of a 7 litre sensitive volume detector were studied in details as a function of the electric field configuration and GEM gain. The geometrical uniformity of the response was evaluated.

Obtained results show that a detection efficiency above 99% is achieved together with an energy resolution better than 20%, making this technics a very good solution also in the keV region.

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Development of high-performance DLC resistive electrodes for MPGDs

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Diamond-like carbon (DLC) films are a class of metastable amorphous low-dimensional materials characterized by a mixture of diamond-structure with sp³ type C bonds and graphite-structure with sp² type C bonds at the atomic level. DLC films open up new avenues to make high-performance resistive electrodes for Micro-Pattern Gaseous Detectors (MPGDs) that present numerous attractive properties, such as excellent mechanical performance, chemical inertness, thermal stability and a large range of electrical resistivity. The DLC resistive electrode not only replace the traditional carbon paste resistive electrode made by screen printing technique to avoid the occurrence of spark between electrodes, but also allow to develop new MPGD structures. In recent research, we have developed a thin DLC film on APICAL substrate with unbalanced magnetron sputtering technology.

The sputtering process has been optimized with regards to mechanical adhesion, internal stress and surface resistivity of the DLC coating. A systematical study of the factors affecting the DLC surface resistivity have been investigated, including target power, deposition time, vacuum degree, element doping, and annealing treatment. The results are summarized as follows: (1) the surface resistivity decreases with the increase of the target power and the sputtering time, and appears more stable and uniform at lower target power (0.55kw) with longer sputtering time (40min); (2) the vacuum degree during the sputtering has a significant impact on the surface resistivity: the higher the degree of vacuum, the lower the surface resistivity; (3) hydrogen doping can increase the surface resistivity, probably due to the increase of the sp³ component in the DLC film; (4) after the annealing treatment at 200 degree, the surface resistance decreases to about 1/3 of its original value and stays stable afterwards. We also briefly present several examples of application of the DLC coating in development of MPGDs, including DLC photocathodes for the Picosecond Micromegas detector, resistive DLC electrodes for the μ RWELL detector, and high-resistivity DLC coating for “charging-up free” THGEM detectors.

In conclusion, we have developed a manufacturing technique for high-quality DLC resistive electrodes for MPGDs as a result of interdisciplinary research involving both material science and particle physics. Development of DLC resistive electrodes opens up enormous opportunities for innovative development and application of MPGDs.

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R&D on THGEM with Resistive Diamond-like carbon coating

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THGEM detectors usually exhibit time-evolution of gain, caused by avalanche charges accumulating on open insulator surfaces (charging-up effect). Coating resistive layer on the insulator surfaces may help release the charges to overcome the charging-up effect. Diamond-like carbon (DLC) is a class of amorphous carbon material that can be used as resistive layer. We have coated DLC layer with stable and controllable resistivity on a series of THGEMs by Magnetron sputtering technique. The gas gain of DLC coated THGEMs (DLC-THGEM) are tested in detail and compared with normal THGEM. DLC-THGEMs with suitable resistivity show very low gain variation versus time and literally no charging-up effect. However, DLC-THGEMs show significant gain decrease with increasing irradiation dose. The results for DLC coated THGEM and Multi-THGEM, and THGEM with resistive electrodes will be shown. Simulation works with finite element method and Garfield++ toolkit are carried out to understand the difference in properties between DLC-THGEM and normal THGEM.

26

Development of a thermal bonding method for fabrication of Micromegas and new MPGD structures

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A thermal bonding method has been developed in the past decade for highly efficient fabrication of Micromegas detectors without etching. Resistive anodes made of resistive paste (RP) and germanium (Ge) film have also been studied for discharge protection of the thermal bonded Micromegas detectors. The anode with Ge film has exhibited very good performance in stability and controllability of the resistivity.

In this report, our research work on the thermal bonding method and resistive anodes is presented in detail. Many Micromegas prototypes were built with the thermal bonding method and were characterized with X-rays. A typical energy resolution of 14.8% (FWHM) and a gain of $> 1E4$ were obtained for 5.9 KeV X-rays. Thanks to its lab-friendly operation, the thermal bonding method allows to explore new MPGD structures rather easily. One of such structures is a Micromegas with double mesh, which shows very low ion-backflow ($\sim 0.05\%$) and very high gain ($> 1E6$ for single electrons).

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Application of micro-pattern gas detectors in the present and future experiments in Budker INP.

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Micro-pattern gas technology is planned for the upgrade of the tracking system of the CMD-3 detector at the VEPP-2000 electron-positron collider in Budker INP [1]. The upgrade includes a new cylinder tracking and trigger detector that consists of two tracking layers at a radius of 32 to 33 cm with coordinate resolution close to 0.1 mm in Z (along the beam axis) and trigger segments of about 1 cm in phi. Another new coordinate subsystem includes two end-cap discs with active area between radius of 50 mm and 250 mm, that provides spatial resolution in R and in phi close to 1 mm as well as trigger signal from the phi segments. For these two subsystems we plan to use micro-RWELL technology because it allows much simpler assembling of large cylindrical detector and large discs as compared to the triple GEM technology. This technology was introduced by INFN Frascati group and the first tests demonstrated possibility of its application for particle detection at medium and low rates ([2,3]) that satisfies the conditions of VEPP-2000 collider environment. The first tests of 10×10 cm² size micro-RWELL and micro-RWELL+GEM prototypes were performed with different gas mixtures. Maximum gas amplification above 20000 was demonstrated with the micro-RWELL prototype and close to 200000 with micro-RWELL+GEM. However, due to high capacitance of micro-RWELL structure, in order to get full efficiency for minimum ionizing particles with gas gap of 3mm and with front-end electronics that is planned (VMM3a ASIC), a gas gain above 20000 is needed. We plan to test two prototypes of full-size discs (50 cm diameter), one with single micro-RWELL and with 6 mm gap and another with micro-RWELL+GEM and make the final choice of the detector layout.

The new cylindrical detector and end-cap discs of the CMD-3 are considered as a prototypes of the Inner Tracker of the detector for the future Super C-Tau Factory (SCTF) at Budker INP. The SCTF is an electron-positron collider for the energy range of 3-7 GeV in the center of mass system that will provide luminosity of 10^{35} cm⁻²s⁻¹. Coordinate system of the detector for the SCTF will include among other systems, the Inner Tracker and the end-cap discs. The Inner Tracker will be 60 cm long and occupy radius up to 20 cm, while the end-cap discs will have radius up to 180 cm and will have to provide trigger signal. For the end-cap discs the MPGD option is considered based either on the triple-GEM or on the micro-RWELL, while for the Inner Tracker three main options are competing: compact Time Projection Chamber, silicon micro-strip tracker and cylindrical MPGD tracker. The first results of simulations with all these options will be presented with preliminary discussion about the choice of the option.

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28

Development of μ -PIC with glass substrate aiming at high gas gain

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A micro pixel chamber (μ -PIC) is a gaseous two-dimensional imaging detector, is adopted for various experiments: MeV gamma-ray telescope, neutron imaging, searching for dark matter, etc. A μ -PIC was made on polyimide substrate with a printed circuit board (PCB) technology from invention to now, but the PCB technical restriction limited the aspect ratio of through holes used to form the anode electrodes. Because of this, a PCB μ -PIC has only a substrate thickness of $\sim 100 \mu\text{m}$, which is not thick enough to prevent the gain reduction caused by the electric potential of back side anode strips affecting the gas multiplied region. Therefore, focusing on a glass substrate that is can be realized thicker substrate by a TGV (Through Glass Via) technology, we developed a TGV μ -PIC. In this work, two types of the first prototype TGV μ -PICs ($380 \mu\text{m}$ thickness), which respectively have a $5 \times 5 \text{ cm}^2$ detection area with a readout of $400 \mu\text{m}$ pitch and a $3 \times 3 \text{ cm}^2$ detection area with a readout of $215 \mu\text{m}$ pitch, was fabricated and tested. Each TGV μ -PIC was operated with a maximum gain of ~ 9700 ($400 \mu\text{m}$ pitch) and of ~ 1000 ($215 \mu\text{m}$ pitch) using argon ethane (9:1) gas mixture.

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Advanced Aging study on Triple GEMs detector

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In this work, a new concept of aging study is proposed and performed with the goal to better understand the aging issues in contaminated gas mixtures and in a densely ionizing particles environment. This test, on a $10 \times 10 \text{ cm}^2$ triple-GEM prototype with $3/1/2/1 \text{ mm}$ gap configuration, occurred at CMS - GEM QA/QC lab.

The aim is to better understand if there are new, ever studied, aging issues related to the outgassing of some materials and to comprehend if particles with different specific ionization, may induce aging effects which were absent in previous X-rays and γ -rays studies.

The prototype is irradiated in two different regions at the same time with two types of source: a 5.5 MeV alpha emitter (^{241}Am) and 5.9 keV X-ray source (^{55}Fe), to investigate if different behaviors in the two areas develop.

Hydrocarbons and silicon-based molecules are released inside the gas volume as contaminants. This

will simulate the pollutants released in a clean mixture during many years of normal detector operation.

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Long-term Ageing and Rate Capability Studies of Resistive Micromegas at the CERN Gamma Irradiation Facility

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Resistive Micromegas are nowadays used in many applications and considered for future experiments. It is then of paramount importance to assess their ageing properties and the behaviour under high irradiation.

Two resistive Micromegas detectors have been installed in the Gamma Irradiation Facility at CERN in 2015 and continuously operated for three years with a Ar:CO₂ (93:7) gas mixture. They have accumulated more than 0.3 C/cm², a charge equivalent to about 15 years of operations at the highest particle rate expected in Muon Systems at High Luminosity LHC runs.

The detector current has been constantly monitored; the efficiency for muon has been measured before and after the irradiation and the sensitivity to photons has been measured. Finally, the detector performance, in particular resolution and gain, has been measured as a function of the photon background rate with a muon beam combined with a photon background. Based on these results we conclude that the resistive Micromegas under study have a rate capability well beyond 50 kHz/cm² and did not show any significant performance degradation due to aging.

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Development of a Spark-Detection System for the Quality Assurance of Large-Size GEM Foils

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Gaseous detectors based on large-size GEM foils are planned to be used for a variety of upgrades and new experiments using high-rate and high-intensity particle beams. An excellent quality control of GEMs is a mandatory prerequisite to select the best foils for the assembly of the GEM detectors. The high voltage stability of the foils is here of uppermost importance. In particular discharges that occur at the same position need to be detected. A spark detection system has been developed to automatically detect and record the time and position of sparks. The system is based on a commercial web camera

installed in a housing for the tests and a custom-made, LabView-based software for control and operation.

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Medica-Plus: a Novel Micromegas Detector for High Resolution Beta-Imaging

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For many years, ³H and ¹⁴C labelling of molecules of pharmaceutical interest has been performed to study their in vivo biodistribution on animal tissue sections through β -particles detection. β imaging was classically obtained by film autoradiography, but this technique suffers from long acquisition-times (low detection sensitivity), absence of real-time imaging and easy access to quantitative data. For this reason, film autoradiography has been supplanted in most of its applications by the development of digital autoradiography imagers (β imagers) that overcome most drawbacks of classical autoradiography, by offering high sensitivity and real-time imaging, but at the cost of lower resolution. However, a major limitation of current commercial β imagers resides in their prices, different sensitivity between radioelements (³H versus ¹⁴C) and absence of dual-imaging (detection of both ³H versus ¹⁴C) in the same acquisition.

In the frame of the Medica-Plus project aiming at performing quantification of a drug inside single cell, our team is developing a new gaseous detector based on the Micromegas technology to overcome the current limitations of current β imagers. The poster will present a brief overview of the obstacles and challenges encountered on the way, and our strategies to solve them.

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Performance analysis of a double THGEM UV detector using single electron pulse height spectra

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Abstract: We present a detailed study of Thick GEM (THGEM) based UV photon detector operated in single electron counting mode. The detector is coupled with double THGEM and semi-transparent CsI photocathode. Performance parameters like gain, Electron transfer efficiency (ETE) and counting efficiency have been derived from pulse height spectra recorded for different operating parameters such as drift field, multiplication voltage, transfer field and induction field. In single electron mode, average charge collected at anode represents the gain. Counting efficiency is estimated from pulse

height spectrum for each condition. It is shown that ETE can be estimated from single electron pulse height spectrum. Secondary effects, observed at higher gains are also studied from the deviation of exponential function. This study helps to optimize detection efficiency from single electron spectrum and design high sensitive UV detectors.

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CMS high eta upgrade using GEM detectors

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To cope with the high rate environment in the very forward eta region of the CMS experiment, Muon community has proposed the development and installation of triple Gas Electron Multiplier (GEM) detectors in its upgrade plan. The detector technology will be integrated with the CMS over the next several upgrades in the form of many stations. One such station known as GE1/1 will be installed during 2019-2020. In total 144 trapezoidal shape chambers are assembled and tested at various production sites which will cover $1.6 < |\eta| < 2.2$ region of the CMS endcap. We report on the assembly and performance of these chambers including gain, efficiency, timing etc. estimated during a decade of R&D.

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Small-pad resistive Micromegas: Comparison of patterned embedded resistors and DLC based spark protection systems

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We present the development of resistive Micromegas aiming at precision tracking in high rate environment without efficiency loss up to several MHz/cm².

The optimization of the spark protection resistive layer and the miniaturization of the readout elements, are key elements of the project.

Several Micromegas detectors have been built with an anode plane matrix of 48 x 16 rectangular readout pads, with dimensions 0.8 x 2.8 mm².

With this anode/readout layout, the spark protection resistive layer has been realized with different techniques: a pad-patterned embedded resistor with screen printing, and a uniform DLC (Diamond Like Carbon structure) layer by sputtering.

Characterization and performance studies of the detectors have been carried out by means of radioactive sources, X-Rays, and test beam.

A comparison of the performance obtained with the different resistive layout is presented, in particular focusing on the response under high irradiation and high rate exposure.

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New MPGD-based muon telescopes for ScanPyramids and associated R&D on gas consumption

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The muography team of CEA/Irfu has built and deployed several MPGD-based muon telescopes and muon scanners in the last 4 years. Three of them participated to the ScanPyramids mission and in particular to the announcement in 2017 of the existence of a big void within Khufu's pyramid. Since then, the team has built 2 new instruments to be operated within the Grand Gallery to explore this void in more details. In order to operate such telescopes in a confined area, a dedicated R&D was performed to reduce the gas consumption, including a study of the outgassing of the different components, the use of passive absorbers and a semi-sealed circuit, and a precise, online monitoring of H₂O and O₂ contaminations with low cost, low consumption modules. Thanks to these developments, the telescopes were able to take good and stable data during more than 6 months in a particularly humid and hot environment, thus increasing the gas autonomy of the instrument by a factor more than 2. Further improvements are investigated now, with the aim to build a fully sealed tracker in the coming 2 years.

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TIGER chip readout with triple-GEM detector

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Gas Electron Multipliers (GEMs) represents one of the most efficient tracking gas detector, thanks to the high-rate capability, radiation hardness and excellent spatial resolution. Additional improvements in the tracking performance can be achieved by the design of a proper analog electronics that allows the readout of both charge and time information from each strip. The TIGER (Torino Integrated GEM Electronics Readout) has been recently developed for such scope. It is a custom 64-channel ASIC based on UMC 110-nm CMOS technology providing time and charge measurements with analogue readout and fully digital output. For the first time, a dedicated test beam has been performed into H4 line in CERN North Area to test the ASIC capabilities with triple-GEM detectors. In this talk, we report the results of this test by applying both charge centroid and micro-TPC to measure the incident particle position and a comparison with standard APV25 performance.

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Optical readout of MPGDs: developments and perspectives

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Recording scintillation light emitted during avalanche multiplication by imaging sensors has proven to be a versatile readout concept for MicroPattern Gaseous Detectors (MPGDs). By using gas mixtures containing CF_4 and exploiting low noise imaging sensors, optical readout of MPGDs such as Gaseous Electron Multipliers (GEMs) has been shown to be an easily realisable as well as effective readout approach. We will review previous developments of optically read out MPGD-based detectors and discuss how novel technologies and detector concepts can be used to extend the applicability of this readout modality.

We report on developments of X-ray imaging detectors, radiation imaging as well as beam monitoring with GEM-based detectors. The integrated imaging enabled by imaging sensors is well-suited for radiographic imaging and fluoroscopy as it allows virtually dead-time free acquisition.

Novel developments of optically read out detectors overcoming previously limiting aspects associated with optical readout are presented. Modern ultra-fast CMOS cameras can be used to extract particle track depth information from image sequences for reconstruction in TPCs. Optical readout can also be applied to other MPGD technologies such as MicroMesh Gaseous Structure (Micromegas) integrated on transparent substrates. The geometry of the Micromegas detector is shown to be well-suited for X-ray radiography and to achieve a higher spatial resolution compared to an optically read out GEM-based detector.

Novel developments in imaging sensors and MPGD technologies make optical readout of MPGDs a capable readout modality. Its flexibility makes it an attractive candidate for a wide range of radiation detector applications including radiographic imaging, X-ray fluoroscopy, beam monitoring and 3D track reconstruction.

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Chromium GEM detectors performance studies

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We would like to present our progress in the studies of the GEM detectors equipped with a special GEM foil type having reduced copper content. In the applications like a soft X-ray imaging decreasing of fluorescence radiation flux induced inside the detector inner components is very appreciated. Moreover, any reduction in the radiation length, which is introduced by the GEM detector (and its components), can also play a significant role in many other applications.

Some preliminary results have already been presented and published [1]. The mentioned results clearly showed the necessity for further and more detailed studies with more GEM detectors based on this type of foils. We have prepared a dedicated test set-up, which allows us to make systematic studies of a few GEM detectors. These measurements have been done with a standard Ar/CO₂ (70/30) gas mixture. The following results we are planning to present: gas gain as a function of detector bias voltage, gas gain variation across the detector active area, energy resolution and long-term behaviour.

[1] B. Mindur, T. Fiutowski, S. Koperny, P. Wiącek and W. Dąbrowski, Performance of a GEM detector with copper-less foils, 2017 JINST 12 P09020.

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A modular mini-pad photon detector prototype for RICH at the Electron Ion Collider

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Experiments at the future Electron Ion Collider require excellent hadron identification in a broad momentum range, in harsh conditions. A RICH capable to fulfill the PID requirements of the EIC could use MPGD-based photon detectors with solid photocathodes for covering large surfaces at affordable cost, providing good efficiency, high resolution and compatibility with magnetic field.

Photon detectors realized by coupling THGEMs and Micromegas have been successfully operated at the RICH-1 detector of the COMPASS Experiment at CERN since 2016. A similar technology could be envisaged for an EIC RICH, provided a large improvement in the photon position resolution is achieved.

An R&D effort in this direction is ongoing at INFN Trieste. Few prototypes with smaller pixel size (down to 3 mm x 3 mm) have been built and tested in the laboratory with X-Ray and UV LED light sources. A modular mini-pad detector prototype has also been tested at the CERN SPS H4 beamline. New data acquisition and analysis software called Raven DAQ and Raven Decoder have been developed and used with the APV-25 based Scalable Readout System (SRS), for the modular mini-pad prototype tests.

The main characteristics of the new mini-pad Hybrid MPGD-based detector of single photons are described and the results of laboratory and beam tests are presented.

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A direct read-out of primary ionization electrons without gaseous amplification for high pressure TPC

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Time projection chambers (TPC) are widely used in particle physics to track charged particle trajectories. Almost all of them use detectors based on gaseous amplification using avalanche phenomena, like for instance proportional chambers, Micromegas or GEMs. However this step implies several constraints on the characteristics of the TPC: choice of a gas mixture able to stand a gaseous amplification, degradation of the energy resolution due to stochastic effects of the avalanche, rise of numerous ions in the drift volume which can degrade the uniformity of the electric field. These constraints could be very limiting for several important applications which have specific requirements: hydrogen TPC, excellent energy resolution, very low ion back-flow,... The project presented here proposes to avoid processing any gaseous amplification, and instead to directly measure the primary ionization electrons. The primary electrons would be detected by an electronics based on very low-noise multi-channels read-out chips, the IDeF-X LXE chips, which were developed at CEA Saclay. The read-out electronics will be associated to a read-out plane with a small enough pitch to obtain a spatial resolution in the order of a few millimeters. The design of the read-out pads collecting the ionization electrons would be optimized in order to collect most of the primary electrons while keeping the internal capacitance, and thus the electronics noise level, low enough to obtain a good energy resolution.

A low-scale prototype TPC based on such a direct read-out of the primary ionization is presently under development, with a major focus on the optimization of the read-out plane and of the front-end electronic cards. The prototype will be ready by Spring 2019 and tests are foreseen with radioactive sources and cosmic radiations, in order to measure the performance in terms of noise level, of signal

to noise ratios, of spatial and of energy resolutions, and to compare them with regular TPCs. After a presentation of the project, results of the Garfield++ simulation of the read-out plane will be presented, and first results of the tests on the prototype will be shown.

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A high-gain and low ion-backflow double micro-mesh gaseous structure

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Micro-pattern gaseous detectors (MPGD) with very low ion-backflow (IBF) provide very cost-effective solutions to large-area and position-sensitive photon detection and readout of high-rate TPCs. We present a double micro-mesh gaseous structure with two avalanche stages which has a low IBF ratio and high gain. The structure was fabricated with a thermal bonding technique and characterized with X-rays and UV laser light. An IBF ratio down to 0.05% was obtained and a gain of up to $3 \cdot 10^6$ was maintained for single electrons. The double-mesh structure was optimized to further suppress its IBF by varying its geometry and aligning the two mesh layers with a crossing angle. A IBF ratio lower than 0.03% was achieved after the structure optimization.

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A numerical investigation on the track distortion at the Micromegas based LPTPC endplate

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A Time Projection Chamber (TPC) is foreseen as the central tracker of the International Large Detector (ILD) at the International Linear Collider (ILC) and is expected to be installed just beyond the vertex detectors to accomplish continuous 3-D tracking. The R&D activities for the linear collider TPC (LCTPC) are currently focused on the adoption of the Micro-Pattern Gaseous Detectors (MPGD) for the gaseous amplification stage.

Different MPGD modules which are commissioned on the endplate of a Large Prototype TPC (LPTPC) at DESY, were tested with a 5 GeV electron beam, under a 1 T magnetic field. During experiments, reduced signal sensitivity as well as distortion in the reconstructed track, were observed at the boundary of these modules. Electrostatic field inhomogeneity near the module boundaries was considered to be the possible major reason behind these observations.

We have numerically investigated the origin of the track distortions observed close to the module edges. The study clearly shows that the electric field non-uniformity near the inter-modular gaps

is responsible for such track distortion. We have been able to simulate the observed patterns and magnitudes of distortion successfully. The obtained agreements encourage us to continue with the study and, to propose module design modifications that can alleviate the problem of electrostatic field distortion at the module boundaries. In this presentation, we will discuss results obtained for an endplate designed using Micromegas modules.

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Production of Micromegas and progress on the HV stability issues

Author: Muon Collaboration ATLAS^{None}

The ATLAS collaboration at LHC has endorsed the resistive Micromegas technology, along with the small-strip Thin Gap Chambers (sTGC), for the high luminosity upgrade of the first muon station in the high-rapidity region, the so called New Small Wheel (NSW) project. After the R&D, design and prototyping phase, the first series production Micromegas quadruplets have been constructed at all involved construction sites: in France, Germany, Italy, Russia and Greece. This is a big step forward towards the installation of the NSW foreseen for the LHC long shutdown in 2019 and 2020. The construction of the four types of large size quadruplets, all having trapezoidal shapes with surface areas between 2 and 3 m², will be reviewed. The achievement of the requirements for these detectors revealed to be even more challenging than expected, when scaling from the small prototypes to the large dimensions. We will describe the encountered problems, to a large extent common to other micro-pattern gaseous detectors, and the adopted solutions. Final quality assessment and validation results on the achieved mechanical precision and on the High-Voltage stability during operation will be presented

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Test-beam results & performance studies of the ATLAS Micromegas production modules

Author: Muon Collaboration ATLAS^{None}

The LHC at CERN plans to have a series of upgrades to increase its instantaneous luminosity to $7.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$. The ATLAS experiment will upgrade its inner end-cap muon chambers to cope with the increased collision rate expected from the High-Luminosity-LHC. This project, called New Small Wheel, includes resistive Micromegas chambers together with small-strip Thin Gap Chambers (sTGC), conforming a system of ~ 2.4 million readout channels in total. This is the first time that large Micromegas are built in such a scale. In total, 128 Micromegas modules up to 3 m² in size, and from different production sites spread in Europe, will be produced, with target installation at the end of Long Shutdown 2 (LS2) of the LHC. One of the first series modules, equipped with a prototype of the final front-end electronics based on VMM chip, was tested in muon/pion beam at the H8 line of SPS at CERN during the summer of 2018. We present the test setup and performance results on efficiency and resolution for perpendicular and inclined tracks. These studies were focused on determining the working point of the ATLAS Micromegas detectors. Results are also compared with the initial requirements for operation in ATLAS, namely spatial resolution of 100 μm at high background hit rate of up to 20 kHz/cm². Studies with several gas mixtures were also carried out and will be presented.

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Performance and Calibration of large area Micromegas Detectors for the ATLAS Muon Spectrometer Upgrade Using Cosmic Muons

Author: Muon Collaboration ATLAS^{None}

The steadily increasing luminosity of LHC requires an upgrade to high rate and high-resolution capable detector technology for the inner end cap of the muon spectrometer of the ATLAS experiment. For precision tracking 4 types of 2 and 3 m² large micromegas quadruplets will provide 8 consecutive active layers, each, with 100 μm spatial resolution per individual plane.

Cosmic muons are an extremely powerful tool to validate these detectors over their full surface in terms of gain, homogeneity and efficiency. We report on the performance and full-size behaviour of these Micromegas and in addition on position resolution and precise reconstruction of geometrical parameters of the module with an accuracy better 50 μm for modules having been investigated by the use of two 8 m² reference tracking detectors

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Irradiation and stability studies of production chambers for the ATLAS-NSW MM

Author: Muon Collaboration ATLAS^{None}

The ATLAS upgrade for the HL-LHC phase involves the construction of two New Small Wheel (NSW) for addressing the high rate expected at high rapidity, up to 14 kHz/cm², with both tracking and triggering capabilities. The wheels will be equipped with two different technologies, small Thin Gap Chambers (sTGC) and MicroMegas (MM). The first MM production modules have been tested at the Gamma Irradiation Facility (GIF++) at CERN, where they were exposed to a 14 TBq ¹³⁷Cs source. The chambers were tested at different particle fluxes, up to 60 kHz/cm². Long-term irradiation tests were also performed in order to test the MM performance stability.

Several parameters have been studied, among them the current linearity as a function of the applied flux and the uniformity among layers and sectors. The role of gas parameters, such as humidity and gas flow, on the chamber performance were also studied. The whole set of tests proved the MM technology is capable to afford the high rate expected at the ATLAS for the HL-LHC phase, providing very good linearity and uniformity.

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Large Area GEM based muon tracker for CBM experiment at FAIR

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The Compressed Baryonic Matter (CBM) experiment at the upcoming FAIR facility is a fixed target heavy ion collision experiment aiming to explore the phase diagram of hadronic matter in the region of highest baryon densities. At an unprecedented interaction rates of 10 MHz Au + Au collisions, in the energy range upto 11 AGeV, the Muon Chamber (MUCH) system of CBM comprising of alternating detector stations and instrumented absorbers will perform the task of di-muon detection. Strong radiation environment and high particle rates exceeding 100 kHz/cm² in the first stations of MUCH impose severe constraints on the detector design. Large acceptance, triple GEM modules having pad readout will be employed in the first two stations of MUCH. Such prototypes (~2000 sq.cm.) have been built and successfully tested coupled to self-triggered electronics, which is another unique feature for all CBM detectors. Two such prototypes were tested with Pb + Pb collisions at CERN SPS, for the first time in a free-streaming mode. The entire detector area was exposed to a wide spray of particles coming from these collisions. Event reconstruction, based on time-stamps of the detector hits, straight-line track fitting using three GEM layers along with other results will be discussed. In addition to this, two large trapezoidal GEM chambers based on final MUCH design,

having 2k readout channels each, and with a novel high voltage biasing scheme of the foils, have recently been commissioned in the mCBM experiment at GSI with $Ag + Au$ collisions at 1-1.5 AGeV. Data with first version of MUCH-XYTER electronics coupled to actual CBM DAQ has been taken. As part of FAIR phase0 experiment, a dedicated data taking will take place in March 2019. First such performance study of the MUCH GEM chambers at high interaction rates along with mCBM experimental details and all the relevant detector design, fabrication and operational issues will be presented and discussed.

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Noise optimisation of GEM-based full-field XRF imaging system

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One of the possible detectors to be employed in full-field XRF imaging is a GEM detector with 2-dimensional readout. In the paper, we report on the development of an imaging system equipped with a standard 3-stage GEM detector of $10 \times 10 \text{ cm}^2$ and readout electronics based on dedicated full-custom ASICs and DAQ system.

With a demonstrator system, we have obtained a 2-D spatial resolution of the order of 1 mm and energy resolution at a level of 20% FWHM for 5.9 keV for the detector chamber filled with Ar/CO₂ (70/30) gas mixture. For the present system, we have designed new ASIC called ARTROC with carefully optimized noise performance to achieve the energy resolution at a level of 15% FWHM for 5.9 keV.

In the paper, critical design aspects of the system will be discussed and detail test results will be presented.

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Industrialisation of Micro Pattern Gaseous Detectors: the Experience of ATLAS Micromegas

Author: Muon Collaboration ATLAS^{None}

The muon system of the ATLAS Experiment will be upgraded in 2021 with Micromegas detectors covering an active area of about 1280 m², being the largest MPGD-based system ever built so far.

The key element of the detectors are the anode boards which carry the readout strips, the resistive protection layer and the insulating pillars supporting the mesh. In total more than 2000 boards of 16 different types with size up to 40x220 cm² have to be produced.

The boards are produced by two industries in Europe, which opened the road to MPGD mass production, with the production being now well advanced.

The talk will review the technological transfer effort made by CERN and ATLAS to make the Micromegas board production an industrial process. The main problems encountered during the industrialisation and the production phase will be presented in detail, together with the current status of the production.

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Beam tests of the large area BM@N GEM detectors

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Tracking system of the BM@N experiment will provide precise momentum measurements of the cascade decays products of multi-strange hyperons and hyper-nuclei produced in central Au-Au collisions. Triple-GEM detectors were identified as appropriate for the tracking system located inside the analyzing magnet. Seven GEM chambers are integrated into the BM@N experimental setup and data acquisition system. The detectors have been studied in the d, C, Ar, Kr beams of the Nuclotron accelerator. First obtained results are reviewed. Seven GEM chambers with the size of 1632 mm × 450 mm are the biggest GEM detectors presently produced in the world.

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Effect of mesh geometry on resistive Micromegas for the ATLAS experiment

Author: Muon Collaboration ATLAS^{None}

The ATLAS Experiment will use resistive Micromegas detectors for the upgrade of the forward Muon System (NSW, for New Small Wheel). With the test of the first production modules, instabilities in the detector operation have been observed, leading to a systematic revision of the selected construction components and working parameters.

In particular, the effect of the mesh geometry with respect to the discharge behaviour was studied using a special Micromegas detector designed and built by the ATLAS CERN group in 2014.

The detector has a Micromegas structure similar to the one later on adopted by the NSW project, moreover it provides the possibility to easily replace the mesh.

The test procedure consisted in measuring current, gain and counting rate from 55Fe gamma source, as function of the amplification voltage up to the discharge limit.

The systematic analysis of the data allowed to conclude on the stability interval of six different types of mesh, including the one used for the NSW, consistent with the expectations.

Results showed that the mesh selected for the NSW was not optimal for the detector discharge behaviour, however cost and schedule constraints prevented the replacement of the selected one

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Optimisation of gas composition for Micromegas of the ATLAS experiment.

Author: Muon Collaboration ATLAS^{None}

Resistive Micromegas detectors will be used for the upgrade of the ATLAS muon system foreseen in 2021. The gas mixture so far considered for Micromegas operation is Ar:CO₂ 93:7 which is widely used for other ATLAS Muon detectors, thus requiring only little changes of the present gas system of the experiment.

After the observation of high voltage instabilities on the first detectors, measurement campaigns with different mixtures have been performed with the aim of increasing the stability region, defined as the HV difference between the start of the efficiency plateau and the start of the instability.

The gas selection for the ATLAS Micromegas should however fulfil a number of constraints, as non-flammability and good ageing properties as well as a drift velocity above 2.5 cm/us and optimal transverse diffusion.

Different measurements have been carried out at CERN, LMU, and Saclay on prototypes and full-size ATLAS Micromegas detectors.

The tests have been focused on Argon-based gas mixtures with different CO₂ concentration and with the addition of small fraction of isobutane.

A systematic review of the results obtained from laboratory tests with radioactive source and cosmic rays will be presented together with the performance recently measured at CERN on pion and muon beam. Conclusions about the current understanding of the gas optimisation for the ATLAS Micromegas will also be discussed

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VMM3a, an ASIC for tracking detectors

Author: Muon Collaboration ATLAS^{None}

The VMM3a is a System on Chip (SoC) custom Application Specific Integrated Circuit (ASIC). It is the production version which will be used as the front ASIC for both Micromegas and sTGC detectors of the ATLAS Muon New Small Wheels upgrade. Due to its highly configurable parameters it can be used in a variety of tracking detectors and it is already proposed for another five experiments. It is fabricated in the 130nm Global Foundries 8RF-DM process. The ASIC integrates 64 channels, each providing charge amplification, discrimination, neighbour logic, amplitude and timing measurements, analog-to-digital conversions, and either direct output for trigger or multiplexed readout within a data-driven readout system. The front-end amplifier can operate with a wide range of input capacitances, has adjustable polarity, gain and peaking time. The ASIC has been tested on resistive Micromegas and sTGC prototypes in test beam campaigns at CERN. The performance of the VMM3a as a production stage will be presented.

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A novel opto-coupler based biasing schematic for powering large area GEM detectors

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Large area GEM detectors are widely used for charged particle detection in particle physics. To reduce damages due to discharges, the large surface is segmented into smaller areas of about 100 sq. cm, in order to reduce the capacitance. Resistive chains have been conventionally used for biasing GEM foils, so each of these segments of one foil can be parallelly connected to one point of the resistive chain. In this scheme of things, however, during long term operation, if some segment of any GEM-layer gets bad or shorted due to some reason, then the increased branch current would alter the GEM layer potentials, rendering the entire module virtually non-functional. Power supplies facilitating individual inputs to the GEM segments in different layers are being proposed as an alternative. Besides being very expensive, these also have limitations on the number of shorted segments that can be handled. For the triple GEM detectors of Muon Chambers (MUCH) of the CBM experiment, we have proposed a novel biasing scheme wherein each GEM segment is powered from the resistive chain via an opto-coupler switch. A faulty segment can be identified and thus disconnected by disabling the particular opto-coupler after an iterative investigation procedure using FPGA controlled switches, thus allowing a successful operation of the detector. The GEM foils of MUCH consists of 24 segments. Prototypes employing this novel technique of HV biasing have been built. The foils, spacers and drift board were specially designed to facilitate the routing of numerous high voltage connections. These have been successfully tested with radioactive sources in lab and this scheme is also used for powering the triple GEM detectors currently under operation in the mCBM experiment at GSI. The detailed detector layout, functioning, lab test results along with spark-resilience of the opto-couplers will be reported and discussed.

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A numerical investigation on the discharges in Micromegas

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The Micro-Pattern Gaseous Detectors (MPGD), for their fast response and other excellent characteristics, have been widely adopted in nuclear and particle physics experiments during last two decades. Sometimes they are operated at a high voltage range to achieve the required signal strength and detection efficiency. This often challenges the limit of high voltage stability of the detector and may lead to discharge. The detector geometry itself may influence the limit.

Micromegas is a type of MPGD which is famous for its simple single stage amplification with very stable high gain, intrinsically very low ion feedback and high electron transparency, as well as good space and energy resolution. Like other MPGDs, it also has a physical limit of gain. In this study, we are numerically investigating the discharge probability of non-resistive Micromegas. Within the COMSOL framework, a 3-dimensional model is developed to observe the occurrence and the development of discharge in Micromegas. The model allows to tune the geometrical parameter space to conduct a systematic study on the Micro-mesh and the gap size and hence to examine how much effect of geometry is there on the discharge probability of the detector. The charge transport properties are plugged in from the Magboltz framework and a variation of different gas mixtures has also been studied. In this presentation, we will discuss the numerical procedure and the results of the discharge study.

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MPGD hole-by-hole gain scanning with the "Leopard" system

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The developed high resolution scanner using focused UV light gave the possibility to study single photoelectron response of MPGDs on the sub-millimeter scale. This technology reveals the microstructure of photo-efficiency and local gain to quantitatively compare different GEM geometries and thus provides a powerful tool for GEM quality assurance. High resolution gain map allows us to measure edge-effect, chargeup and the effect of GEM faults amongst others. The presentation will introduce the scanning system and share results from photoelectron yield and gain maps from different types of GEMs.

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Micromegas for beam loss monitoring

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The early detection of beam losses and alarm to the machine protection system in accelerators are crucial for the well-functioning of the machine and the security of the installation. A new kind of beam loss monitors have been conceived to extend the sensitivity to the low energy region of the high intensity hadron accelerators. They are based on Micromegas detectors sensitive to fast neutrons. In the low energy region of the accelerators, only neutrons and photons are produced in the case of a beam loss. However, photons are also emitted by electrons from the RF cavities, becoming a natural background for losses identification. The appropriate configuration of the Micromegas operating conditions will allow a fast response, a sensitivity to small beam losses and a suppressed sensitivity to photons. In this work the operation principle and the system developed for the European Spallation Source will be presented, with focus on the results obtained at different irradiation facilities. First time proof of operation in real conditions, with the detection of beam losses, will be also shown with measurements performed at LINAC4 (CERN).

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3D Muography with a gaseous TPC equipped with 2D multiplexed Micromegas

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Potential applications of muon tomography, or muography, as non-invasive scanning methods have increased in the last years together with the performance of the particle detectors used for muon detection, known as muon telescopes. However the use of new muon detection concepts could enlarge even more the range of application of this technique. Thus, a new concept muon telescope is presented. It is based in a compact TPC equipped with a 2D pixelated Micromegas detector with multiplexed readout. This detector will overcome some of the limitations of the instruments currently used as they limited acceptance keeping other features required for muography as stability, robustness or portability. Moreover, it will be capable to reconstruct the 3D direction of the incident muons with a single instrument.

With this design and features, this kind of detectors can be fitted at boreholes from where they can scan the surroundings, being an interesting technique for mining exploration, geotechnics or monitoring of dykes or bridges which has arouse the interest of industry. In a further phase it is expected to develop a network of these detectors which will allow the 3D reconstruction of the studied object by the combination of the images registered by each of the telescopes. Main features and first tests and results of this new instrument will be presented together with some studies, performed by Monte Carlo simulations, of the capabilities of this muon telescope both in single and multi-detector configuration.

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Studying discharge propagations with an optically read-out GEM

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Gas Electron Multiplier (GEM) has become a commonly employed technology for modern high-rate particle and nuclear physics experiments (e.g. upgraded ALICE TPC). A key parameter for their long-term sustainability is stability against electrical discharges. Typically, these electrical breakdown events occur within the holes on the GEM foil, but they may also propagate into the gap between subsequent GEM foils resulting in secondary discharges. It is crucial to mitigate secondary discharges since they can result in irreparable damage to the detector. Accordingly, many successful methods have been developed to increase their stability against discharges. However, the propagation of discharges is still not fully understood.

In this study, an optically readout GEM detector incorporating a sCMOS camera was built as a new tool to investigate the formation of secondary discharges. We used optical imaging to capture the time evolution of the light from discharges. Studying the glow in instances leading and not leading to a secondary discharge, we pursue to determine the underlying mechanisms for discharge propagation.

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Gas Electron Multiplier (GEM) Detector for Super BigBite Experiment

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The Super BigBite Spectrometer (SBS) is a high performance and large acceptance detector package in Jefferson Laboratory Experimental Hall A. It can provide angular coverage up to ≈ 70 msr, luminosity up to 10^{39} electron/s-nucleon/cm² with a momentum resolution below 1% at momentum of 8 GeV/c. By adopting the open geometry detection, the SBS detector package can be arranged in specialized configurations to meet the special needs of a number of highly-ranked experiments for the 12 GeV program. To achieve high counting rate and high angular resolution requirement of the experiment, GEM detector with a capability of sub-millimeter (< 100 μ m) spatial resolution will be used in the experiment. In this report, we will give an introduction about our current work on the assembling of GEM Layers for the spectrometer, performance of the GEM Layers and our preparation for the installation for the spectrometer.

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Electron and Ion Transmission of the gating foil for the TPC in the ILC Experiment

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We have developed a real size gating foil to prevent secondary ions created in gas amplification from entering the drift volume of the TPC for the international linear collider experiment (ILD-TPC). The gating foil has a structure similar to GEM with a higher optical aperture ratio and functions as an ion gate without gas amplification. It is essentially a double-mesh layer with a thin insulating layer in-between and is easy to be integrated in the modularized readout unit employing a micro-pattern gas detector (MPGD). Its transparency for drift electrons in a gas mixture of Ar-CF₄ (3%)-isobutane (2%) was studied using an 55Fe source and a UV laser for a wide range of the bias voltages applied

across the foil, under a uniform electric field of 230 V/cm in the absence of a magnetic field. The maximum electron transmission rate was measured to be about 86% at a forward bias voltage of +3 V across the foil, whereas the minimum was $(3.36 \pm 0.05 \text{ (stat. only)}) \times 10^{-4}$ at a reverse bias voltage of -15.5 V. The minimum transmission rate quoted above for the electrons is the upper limit of the transmission rate for positive ions at the same reversed bias voltage. The ion blocking power of the gating foil is high enough to keep the drift region of the MPGD-based ILD-TPC virtually free from back-drifting ions. The maximum electron transmission rate under an axial magnetic field of 3.5 T is expected to be close to the optical aperture ratio of the foil (82%) with the foil unbiased. In this talk, the blocking power against positive ions of the gating foil is focused.

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Nanodiamond photocathode for MPGD-based single photon detectors at future EIC

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The construction of a Ring Imaging Cherenkov (RICH) detector for the particle identification in the high momenta range at the future Electron Ion Collider (EIC) is a challenging task. A compact collider setup imposes to construct a RICH with a short radiator length, hence limiting the number of photons. The last can be increased by detecting the photons in the far UV region. However, as standard fused-silica windows are opaque below 165 nm, a windowless RICH approach represents a possible choice. CsI is a widely used photo-cathode (PC) to detect photons in the far UV range, but because of its hygroscopic nature, it is very delicate to handle. Its Quantum Efficiency (QE) degrades in high intensity ion fluxes. These are the key reasons to quest for novel, less delicate PC with sensitivity in the far UV region. Layers of hydrogenated diamond nano grains have recently been proposed as alternative PC material and shown to have promising characteristics. The performance of nanodiamond PC coupled to THGEM-based detectors is the objects of an ongoing R&D. Preliminary results on the initial phase of these studies are reported.

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Channel Loss Investigation in VFAT3 Hybrids for CMS GEM Detectors

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VFAT3 is a 128-channel charge sensitive amplifier chip designed for the readout of GEM detectors in the Compact Muon Solenoid (CMS) experiment at CERN. High Voltage Discharges have been observed in the large (1 m long) CMS GEM detectors, which damaged the input channels of the chip despite the built-in internal protection diodes for channel protection. This paper presents preliminary results for three different versions of the hybrids designed to protect the VFAT3 from GEM discharges. First, with the base-line hybrid called V2, which has no external protection we produced controlled discharges to observe the protection capabilities of the built-in diodes. The baseline hybrid showed channel loss at 28uJ of energy. We then developed two new versions of hybrids, one with external series resistors, called V3 and another with external protection diodes, called V4. The V3 also showed slight increase in the cross talk and ENC due to coupling between neighbouring channels. The hybrid designs and their performance will be discussed in this contribution.

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Effect of deformation due to stretching of the Gas Electron Multiplier (GEM) Foil

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The Gas Electron Multiplier (GEM) was first introduced by Fabio Sauli in 1997, which is a thin layer of an insulating polymer, coated on both sides with copper and chemically perforated with a high density of microscopic holes. The GEM detectors, which are built using GEM foils, have been utilized for various applications due to their excellent spatial resolution, high rate capabilities and flexibility in design. CMS GEM collaboration is planning to install large-area triple GEM detectors in forward region of CMS muon endcaps. During the assembly of these detectors, the GEM foils are manually stretched to maintain the required gap configuration throughout the detector area. This stretching procedure can introduce local variation in the size or the shape of the perforated holes in GEM foil which can further vary the operational characteristics of the foil as well as the detector. Therefore, the distribution and size of the holes over a GEM foil should be uniform to achieve uniform functionality of the detector over the active surface. We can prevent the deformation of the perforated holes by optimizing the stretching force which is used during the assembly. We also present the effect on the gain of the detector due to over stretching of the foil leading to deformation of the holes.

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Production, Quality Control and Performance of the GEM detectors for the CMS Muon System upgrades

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The Large Hadron Collider (LHC) will be upgraded in several phases that will allow to significantly expanding its physics program. After the long shutdown in 2019 (LS2) the accelerator luminosity will be increased to $2 - 3 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ and later up to $5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ in 2024-26. The physics program of the LHC experiments will benefit from the augmented luminosity; the sensitivity of the CMS experiment to the new physics and to Standard Model will be fully exploited, providing that a suitable upgrade will enable the CMS detector to cope the future data-taking conditions. Among the upgrades, the installation of new muon stations based on Gas Electron Multiplier (GEM) technology in the endcap will start in early 2019 (GE1/1 station), followed by the installation of two additional stations (GE2/1 and ME0) in 2023. The CMS GEM Collaboration produced the 144 GEM detectors to be installed in the GE1/1 station, sharing the assembly and testing of the detectors among several production sites spread all over the world. A detailed common assembly protocol and quality control procedure (QC) has been deployed, with the ambitious goal to ensure standardization of the performance of the detectors produced by the different sites. The same procedure has been successfully adopted to test the first prototypes of the GE2/1 detectors. In this contribution the final results of the QC tests performed on the GEM chambers, assembled by all the production sites following the common specification parameters, will be presented.

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Study of discharges and their effects in GEM detectors

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This study of the CMS GEM group focused on the precise measurement of the discharge effects in GEM technologies. In particular, we investigate the resistance of GEM holes against electrical breakdown in different conditions of operation (e.g. RC component, gas, HV protection) and for different geometries. The initial study was performed with a single-hole setup in order to identify and isolate the components that can influence the process the discharges. The investigations were then scaled up to larger GEM sizes in order to validate the previous observations and study additional effects such as the discharge propagation and the damage probability. A systematic microscopic study was conducted together with the laboratory development in order to visualize the different types of damages that can be induced by discharges.

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Study and improvement of the planarity of large GEM detectors for the CMS muon upgrade

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The CMS GEM Collaboration has developed a specific design of large triple-GEM detectors for the upgrade of the CMS muon end-caps. In particular, a new technique was introduced to mechanically stretch the GEM foils without using spacer grids or glue inside the gas volume. This technique however may introduce irregularities in the planarity of the detectors, which can potentially affect the uniformity and the operation of the chambers. Therefore the collaboration has established a set of tests and quality controls in order to quantify these irregularities and mitigate their impact on the detector performances. Additionally, new solutions and design upgrades have been implemented to prevent such effect in future CMS GEM upgrade projects.

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Gas electron multiplier based on the CVD diamond film: current status.

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Gas electron multiplier (GEM) is modern gas detector of ionizing radiation. GEM-detectors are widely using in nuclear and high-energy physics experiments at different accelerator complexes.

Usually, GEM-detectors are based on dielectric polyimide foil (kapton), with metall electrodes on each side, and regular matrix of biconical etched holes.

Gas electron multiplier made by radiation-hard dielectrics or wide band-gap semiconductors are desirable for some applications. We introduce the results of the tests gas electron multiplier made of polycrystalline CVD diamond film with laser-perforated holes.

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Lessons learned from sustained operation of triple-GEM detectors at CMS and recommendations for future MPGD design

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In January 2017 the CMS collaboration installed a set of double layer triple-GEM detectors on the negative endcap of the CMS detector as a “slice test” of an upgrade of the detector’s Forward Muon Spectrometer during the second long shutdown (LS2) of the CERN LHC. The VFAT2 ASIC, also used by the TOTEM experiment, is used as the readout chip of this slice test; but will be replaced by its successor, the VFAT3 ASIC, for the LS2 upgrade of CMS. During Run II of the LHC, CMS has observed that the VFAT2 chips have slowly accumulated irreversible channel loss. Such loss has not been reported by the TOTEM experiment. A set of measurements were launched to study the origin of this loss under four different hypotheses: 1) improper detector operation, 2) avalanches triggered by ionization from the tail of the muon landau, 3) avalanches triggered by background particles that release a larger amount of primary electrons, and 4) discharges to the anode plane. The cause of this channel loss in CMS has been traced to propagating discharges to the detector anode. Here we present a method for detecting channel loss; the results of measurements 1-4; a discussion on propagating discharges in micro pattern gaseous detectors (MPGD). Finally, we provide recommendations on how to increase detector and electronics robustness during discharge events, and how to mitigate such events, by making implementing certain design changes in both detectors and readout electronics.

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New Results from GridPixes

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GridPix detectors consist of a high granularity readout based on a pixel ASIC with a Micromegas gas amplification stage, which is produced by photolithographic postprocessing. This technique allows for good alignment of each grid hole with one readout pixel. Therefore, each single primary electron guided into one hole and multiplied in the amplification gap can be detected separately. This leads to an excellent spatial and energy resolution based on the primary electron statistics only.

To improve the performance of detectors the production has switched from using Timepix to Timepix3 as a basis for the GridPix detectors. In 2017 a first testbeam with 2.5 GeV electrons from the ELSA accelerator at Bonn was performed. The good results encouraged the development of a Quad featuring four GridPix detectors in one readout unit. The optimized design of the Quads leads to an active area of 69 % and good alignment of the GridPixes with respect to each other. A first Quad was tested in 2018 in the same test beam showing equally good results.

In this presentation the results of the two test beams as well as the status of the readout systems will be discussed along with possible applications in the ILD-TPC and the IAXO experiment.

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Correlation of optical and electrical measurements of the delayed discharge propagation in GEM detector

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Recent research conducted on discharges in GEM (Gas Electron Multiplier) detector will be presented. The occurrence of the delayed discharge propagation is recognized as a potential threat to stable GEM detector operation. The special experimental setup enabled detailed simultaneous electrical and high-speed camera measurements of delayed discharge. The temporal correlation of the acquired data provides novel insights regarding the physical mechanism of the microsecond delay between the primary and the delayed discharge. Three different regimes are recognized in the time interval in between the primary and delayed discharge. Based on the charge transfer to the readout electrode, the indicators of the delayed discharge occurrence are identified.

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The Fast Timing Integrated Circuit (FATIC)

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Progress in Gaseous Detector physics is a process where the development of new detectors goes hand in hand with the development of new frontend electronics that can exploit the capabilities of the new detectors. One of the main directions of research in micro pattern gaseous detectors is to push the limits of the time resolution with which signals of subatomic particles can be registered.

Fast timing electronics typically relies on high gain detectors with charges in the 10fC-10pC range, which is out of reach for single-stage MPGD detectors. In this contribution we will present the design and development of the Fast Timing Integrated Circuit (FATIC). The FATIC is a 32 channel ASIC that consists of a charge sensitive amplifier (CSA) after which the amplified signal is split in a timing branch, with fast comparator and TDC, and a charge branch with a shaper and arming comparator, followed by digital logic that allows multiplexing of the output signal. The CSA is designed to have a peaking time of 7 ns and jitter of 300 ps at 1fC input charge and 15pF input capacitance, while maintaining a low Equivalent Noise Charge (ENC) of ~500e-, and able to reach a gain of 50mV/fC. We will discuss the results of a first prototype production, the problems encountered and identified solutions for a second production envisioned in 2019.

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MPGD simulation in Negative-ion gas for direction-sensitive dark matter search

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Negative-ion Time Projection Chamber(NITPC) with several negative ion species achieved full-fiducial analysis recently. These ion species have different drift velocity and we can determine absolute z-position from their arrival time difference. This TPC is a strong tool for background reduction from TPC. NITPC is a promising device for the application, such as dark matter search, which requires small diffusion and low-background now. To develop NITPC for our dark matter search experiment, NEWAGE, we have started to study characteristics of MPGD in negative-ion gas by both experiments and simulations. We are developing MPGD simulation method in negative-ion gas with Garfield++ because that has not been established yet. In this talk, we present the results of MPGD simulation in negative-ion gas, SF₆ gas, to describe and understand experiment result, such as gain, energy resolution and signal creation from MPGD for NITPC optimization.

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Charge density as a driving factor for discharges in GEM- and THGEM-based detectors

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In Gas Electron Multiplier (GEM)- and Thick Gas Electron Multipliers (THGEM)- based detectors the discharge stability constrains the safe operating limits in terms of achieved gain and signal amplification. Thus, this is an important optimization parameter for the overall performance of these detectors.

The discharge probability has been determined for GEMs and THGEMs in different Ar- and Ne-based gas mixtures as a function of gain. A comparison with GEANT4 simulations allows to extract the critical charge density leading to the formation of a spark in a GEM hole.

Discharges are triggered by charge densities close to the Raether limit (10⁶-10⁷ electrons) in single GEM holes.

We compare the results of GEMs and THGEMs and it occurs that the critical charge density depends within the Raether limit on the gas mixture in the detector and hole density of the foil.

Therefore, we conclude that the critical charge density in a GEM hole is a driving factor for discharge formation in GEM- and THGEM-based detectors.

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Recent Development of Glass GEMs and Their Uses

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We have been developing Glass GEMs at AIST, and brushing up the fabrication process. We succeed in fabricating high-gain and stable Glass GEMs, and tested in various applications. In the conference, we report on the detailed fabrication process and recent results of 3D X-ray CT, neutron reflectometer, and hadron therapy achieved with Glass GEMs.

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Choice of bulk or microbulk Micromegas detectors for rare event search in the PandaX-III experiment

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The PandaX-III experiment aims to search for the rare neutrinoless double beta decay in Xenon 136. To achieve this goal, it is mandatory to select carefully the main detectors that have to achieve a very good energy resolution (at the level of 1% at 2.5MeV) and a good spatial resolution for the discrimination between double beta events and external gammas coming from radioactive isotopes. It seems then compelling to choose microbulk Micromegas that displays a better energy resolution and a good radio-purity with a 20x20 cm area. The gain and the energy resolution of these detector will be assessed alongside the challenges that come with the manufacturing of large area Microbulk detectors. It is important to reduce at the maximum small defects that can cause leakage current, or a dead strip inside the active area. As these detectors will be used in array, the detector homogeneity will be emphasized. Our recent measurements on a 20x20cm large Microbulk prototype show large unexpected gain inhomogeneities up to 25% from one spot to the other on the detector surface. It is possible to improve the energy resolution of individual detectors by taking these inhomogeneity of gain into account and correct them through a good 2D calibration. I will discuss the performances of the microbulk Micromegas compared to a bulk micromegas with the same design. Through a comparison of the gain and its homogeneity, the energy resolution and the radiopurity of each detector, I will present a study in order to find the better design of micromegas for the search for the double beta decay in Xenon 136.

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Gain measurement of large size GEM foils

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A detector system has been developed with the aim of measuring large size GEM foils (up to 90cm x 48cm) with position resolution of a few mm and precision of better than 5%. The main application of the detector was within the “Budapest QA Center” of the ALICE TPC Upgrade project, and in this framework, about 30 foils have been measured, which will be part of the upgraded TPC. There is an earlier observed correlation between GEM hole size and the gain, which has been studied, and most cases verified. The talk presents the detector system, which consists of a 2 dimensional MWPC-based detector, the performance parameters, and experiences during regular operation.

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LHM-based “local dual-phase TPCs” – potential tools for future noble-liquid detectors

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LHM-based “local dual-phase TPCs” – potential tools for future noble-liquid detectors

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We report on recent advances in the operation of bubble-assisted Liquid Hole Multipliers (LHM). They Three types of LHM electrodes were investigated: a THGEM, a standard double-conical GEM, and a single We will present the latest results of this "bubble-assisted local dual-phase" detector concept in L.

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Development of GEM based Transition Radiation Detector and Tracker (GEM-TRD/T)

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Transition Radiation Detectors (TRD) have the attractive feature of being able to separate particles by their gamma factor and are widely used for electron identification in various particle physics experiments. Classical TRDs are based on Multi-Wire Proportional Chambers (MWPC) or straw tubes detectors, filled with Xenon based gas mixture to efficiently absorb transition radiation photons. While the MWPC or straw tubes TRD work very well for experiments with relatively low particle multiplicity, for high-luminosity environment such as the electron-ion collider (EIC), their performance is significantly deteriorated due to the high particle multiplicity. Replacing MWPCs by Micro Pattern Gas Detectors (MPGDs) technologies like GEM, would improve the performance

of TRD and, in addition, allow the combination of a high precision tracking with TRD capability at low cost in EIC hadron endcap. In this talk, we report the development and characterization of GEM-TRD/T prototype in test beam with the 3-6 GeV electrons of the Experimental Hall D at Jefferson Lab. Preliminary results of test beam measurements with different types of radiators will be presented and comparison of electron efficiency / pion rejection between test beam data and Geant4 simulation studies will be discussed.

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Recent advances with RPWELL Detectors – physics and potential applications

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Derived from Thick Gaseous Electron Multiplier (THGEM) concept, the Resistive Plate WELL (RPWELL) detector successfully utilizes resistive material, coupled to the readout electrode, to prevent electrical instabilities. While developed mainly as a sampling element for Digital Hadronic Calorimetry (DHCAL) in future linear colliders, the RPWELL concept is suitable for a variety of applications. Single- and dual-stage RPWELL-based UV photon detectors exhibit Polya-like spectra at high gains, under stable operation; it could make them applicable for single-photon imaging in RICH detectors. RPWELL-based cryogenic gaseous photomultipliers would operate more stably in single- and dual-phase noble-liquid detectors – potentially attractive for neutrino physics, Dark Matter and other rare-event searches. We will discuss here the results of recent studies aiming to understand the underlying physics processes governing the operation and performance of the RPWELL detector in the context of the above two applications.

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Effects of Gas Mixture Quality on GEM Detectors Operation

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Gas Electron Multiplier (GEM) detectors have been successfully operated in the LHCb experiment and they will be installed in the CMS and ALICE experiments during LHC Long Shutdown 2. As for others LHC gaseous detector systems, gas mixture is individually provided by dedicated Gas Systems. Several studies have been performed in laboratory to characterize GEM performance from the point of view of their use in LHC Gas Systems, where many variables can influence detectors operation. A Triple-GEM prototype was tested with the aim of probing the possible effects of specific changes that could occur in the Gas System, such as variations in gas mixture composition, input gas flow and presence of impurities. A complete overview of the obtained results will be presented. The test confirms the importance of having a stable gas mixture composition, as it influences GEMs

working point, with significant variations in the amplification gain. It was also seen how the input gas flow can affect GEMs performance, since it conditions the accumulation of humidity and air. Moreover, it was found that the presence of pollutants such as O₂, N₂ and H₂O, commonly present during operation in the experiments, influences GEMs performance in terms of rate capability and amplification gain. While detector gain is weakly affected by the presence of N₂, the presence of even small concentrations of O₂ causes a significant performance decrease in terms of amplification gain.

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SRS VMM: A generic readout system for detector R&D and instrumentation of the next generation

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In 2009, the RD51 collaboration introduced the multi-purpose Scalable Readout System (SRS). The architecture simplifies the implementation of different front-end ASICs due to a common hardware part. Examples are the Timepix and the most commonly used APV25.

The SRS became widely used for R&D on Micro-Pattern Gaseous Detectors (MPGDs) and found its application in other fields of research like muon tomography for geology. The APV25 front-end implementation plays a significant role for research on gaseous detectors with strip readout as for example R&D and quality control for the ATLAS New Small Wheel (NSW) or CMS GEM upgrade projects. Due to the scalability, table-top systems for small test detectors as well as large readouts with several 10000 channels have been realised.

The analogue APV25 designed in 2001 has meanwhile been superseded by more advanced digital ASIC technologies and will not be produced any longer. It has a fixed gain and shaping time and can only be used for detectors with a capacitance of up to 50 pF per channel.

In order to overcome these limitations and provide the community with an adequate continuation of the SRS, the RD51 collaboration decided to implement the VMM ASIC developed in the scope of the ATLAS NSW upgrade in the SRS. The RD51 group at CERN carried out this task. The project was part of prototyping for an instrument and its readout at the European Spallation Source in the framework of the Horizon2020 project BrightnESS. Additional fundings are provided by AIDA2020. FPGA firmware for the general-purpose SRS Front-End Concentrator (FEC) card has been developed. A new frontend hybrid carrier with VMM ASICs and a new digital adapter card were designed, built in several iterations, tested at CERNs SPS and the IFE neutron facility in Norway. Currently, the hardware is under final commissioning and first pilot system will be provided to the community within the coming months. Slow control, data acquisition and online monitoring software are developed to provide users a complete and ready to use package.

Groups from different fields are committed as primary users for testing and supporting the developments. They will apply the system to generic detector R&D as well as medical science, neutron scattering, cosmic ray detection and fundamental physics research. The SRS with VMM is expected to play a significant role in the next decade of detector R&D, but will also find its application in operational physics experiments.

The presentation will focus on the implementation of the VMM in the SRS with related hardware, firmware and software followed by an overview of its application and plans for further upgrades of the system.

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T2DM2 muography project

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The use of Micro-Patter Gaseous Detectors in geophysics and civil engineering applications has experienced an increase related to the incorporation of muon tomography in these fields.

The Temporal Tomography of Density by the Measurement of Muons project (T2DM2) has developed a new direction-sensitive tool for muon flux measurement based on a thin time projection chamber with a bulk-Micromegas readout and SRS electronics. This configuration presents interesting distinctive features, allowing a wide angular acceptance of the detector with a low weight and volume. The functioning principle of the device, field measurements and the challenges that faces the project are presented.

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Quality Control and Quality Assurance of the ATLAS NSW Micromegas readout boards: procedure and status

Author: Muon Collaboration ATLAS^{None}

Micromegas with a spark protection scheme were selected as instrumentation of the first forward muon station in the upgrade of the ATLAS detector for the operation of the Large Hadron Collider at high luminosity. The anode boards carrying the readout strips, the resistive protection scheme and the mesh distance holders (pillars) are industrially produced in Europe. A detailed quality control and quality assurance scheme has been developed and implemented at CERN to closely follow the industrial production. Up to today, about 2000 anode boards have been checked for their quality in a dedicated test facility at CERN. The detailed procedure, highlighting the crucial aspects leading to the rejection or acceptance of an anode board, as well as the statistical overview of the results will be presented.

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Development of a Resistive Plate Device with micro-pattern technique.

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We present an RPC built with techniques developed for micro-pattern gaseous detectors. It consists in two equal electrode plates made of FR4 substrate with 250 Cu readout strips. A 50 um insulating foil, carrying resistive lines, is glued on top of the substrate. Both the Cu and the resistive strips have a pitch of 400 um and width of 300 um.

The plates are spaced by a 2 mm gap and rotated by 90 deg., providing a 2D tracking capability. With such a device the surface resistivity can be tuned to values below the ones of existing RPC (either glass or phenolic-melamine). The thin separation layer between the electrodes and the readout strips provides a better signal induction, allowing to operate the detector at lower gain. Moreover, the strip-shaped resistive pattern reduces the induced charge size in the direction perpendicular to the strips.

All these features go in the direction of improving the rate capability.
The basic concept of this new device will be presented together with preliminary results of ongoing tests at CERN.

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Test of the first MPGD-based (S)DHCAL

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Digital and Semi-Digital Hadronic Calorimeters (S-DHCAL) were suggested for future Colliders as part of the particle-flow concept. Though studied mostly with RPCs, MPGD-based sampling elements could significantly improve the calorimeter performance thanks to their proportional response.

In 2018, several large-area resistive Micromegas and Resistive Plate WELL (RPWELL) of 48x48 cm² were tested at CERN. The performance of the first produced detectors were studied with high energy particles delivered by the SPS machine. Then, all detectors were grouped with steel absorber plates into a small MPGD-based SDHCAL prototype which recorded hadronic showers of low-energy pions from the PS.

The response of the individual sampling elements and of the calorimeter will be reported. For the former, emphasis will be put on MIP efficiency and hit multiplicity, spatial uniformity, HV stability, and rate effects. The calorimeter response is derived from data samples recorded at different pion momenta, from 2 to 6 GeV/c. To minimise leakage at the rear of the calorimeter, pions showering in the first layers were selected. This way, the energy resolution of the prototype could be assessed as well. Results will be shown and when possible, compared to simulated ones.

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A Study of a Combination TPC and Cherenkov Detector with GEM Readout for Tracking and Particle ID

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A combination Time Projection Chamber and Cherenkov detector was studied in order to determine its simultaneous tracking and particle identification capabilities for possible use at a future Electron Ion Collider. A small prototype detector was tested in the test beam at Fermilab in order to provide a proof of principle that the detector is able to measure charged particle tracks and provide particle identification information within a common detector volume. The TPC portion consists of a $10 \times 10 \times 10 \text{ cm}^3$ field cage which drifts the ionization from charged tracks onto a $10 \times 10 \text{ cm}^2$ quadruple GEM detector equipped with a high resolution zigzag readout plane. Cherenkov light is produced in the same gas volume which passes through an open region of the field cage and is detected with second quadruple GEM detector equipped with a CsI photocathode. The common detector volume is filled with pure CF_4 which serves as the operating gas for the TPC and GEM detectors as well as the radiator gas for producing Cherenkov light. Preliminary results on this detector was presented at the last MPGD conference (MPGD 2017) which demonstrated that the detector worked well and delivered good position and angular resolution as well as a high (as expected) photoelectron yield. The detector was also able to provide good electron-hadron separation using the detected Cherenkov signal. The analysis of the data is now complete and the final results from this study will be presented at this conference.

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Development and performance tests of mu-PIC with DLC electrodes

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The micro pixel chamber (mu-PIC) with resistive cathode has been developed as particle tracking / imaging detectors in high rate HIP environments. One of main target of the development is the forward muon detector in ATLAS phase-2 upgrade. The cathode is made from DLC thin foil with liftoff method. The discharge (spark) probability with HIP environment was reduced (10-1000 times) using resistive cathodes. Two dimensional readouts for incident particles are available using separated pixel array of 400 micron pitch. In this presentation, recent results of performance tests will be show. The tracking performances for charged particles have been measured using 140GeV/c muon beam at H4 beamline of CERN. Also imaging properties for 8keV X-rays have also been measured. Fine position resolutions (< 100 micron) have been obtained with both two dimensions. Those test results shows that the resistive mu-PIC has enough performances for forthcoming high rate particle experiments.

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sPHENIX Prototype TPC Data Analysis

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A compact Time Projection Chamber (TPC) is currently under construction for the upgraded sPHENIX detector at Brookhaven National Lab (BNL). Its goal is to study certain aspects of the Quark Gluon Plasma (QGP), such as jet correlations and upsilons. A unique zig-zag pad shape of the TPC will allow for high position resolution to distinguish between the 1s, 2s, and 3s upilon states, which has never been measured before at RHIC. It will answer many questions, such as the QGPs Debye radius. The sPHENIX TPC will be in a 1.45T magnetic field, which will help to improve the position resolution by lowering the transverse diffusion as the electrons will cyclotron around the B-field lines. In this presentation, I will show the results from our prototype TPC that we tested at FermiLab Test Beam Facility (FTBF) in June 2018. The prototype is a one-sided TPC and has a drift length 40% of the full TPC. Using known diffusion parameters, we're able to accurately infer the TPC's performance by measuring drift lengths without a B-field.

Data from a 120GeV proton beam were collected and various fit functions were used to obtain the most accurate results. These were compared to simulations and a noiseless limit scenario was examined. The test beam data shows that our TPC performs better than the required sPHENIX specifications.

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Recent photocathode and sensor developments for the PICOSEC micromegas detector

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Precise timing measurements of charged particles with a timing resolution of a few tens of picoseconds at high rates are required to mitigate the strong pile-up effects expected at the high luminosity LHC. A detector concept based on a Micromegas detector coupled to a Cherenkov radiator with a photocathode has been proposed (PICOSEC). Single channel prototypes of this detector equipped with a Cesium Iodide (CsI) photocathode have demonstrated an excellent time resolution of up to 24 ps for Muon beams in the Minimum Ionizing Particle (MIP) regime. In addition, photocathodes and resistive readouts are studied to improve the detector life and robustness in certain condition, which are the focus of this talk.

CsI is an intensively studied and widely used photoelectric conversion material with good quantum efficiency. However, its life time in the PICOSEC detector is affected by several factors such as aging under ion bombardment, which will reduce the life of detectors in high dose condition. A large ion backflow (IBF) is inevitable for a PICOSEC detector in order to preserve fast timing performance. Many photocathode materials including pure metal Al, Cr, Diamond, and Diamond-Like Carbon (DLC) were studied with a single channel PICOSEC detector to find a more robust solution. Ultra-violet (UV) laser and beam tests have been performed to understand their performances. DLC photocathodes exhibit promising quantum efficiency as well as robustness against IBF. A time resolution of the order of 45 ps along with a detection efficiency of 97% for MIPs has been achieved.

In high rate environments, spark protection principles must be considered in the PICOSEC detector because sparks can damage the detector, photocathode, and readout electronics and lead to significant dead times. By adding a resistive layer on top of a thin insulator directly above the readout electrode, the detector becomes spark-insensitive. PICOSEC detectors with resistive micromegas sensors have been tested and the effects of the resistive layer on the timing properties of the signal have been studied. Good time resolution is obtained with muons and the detector worked stably under a high intensity pion beam.

The last, potential improvements and future work will be also presented, such as robustness to sparks, photocathode materials and electronics.

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Development of a Low Power and High Integration Readout ASIC for CEPC-TPC in 65 nm CMOS

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The paper presents the development of a low power readout ASIC for time projection chambers (TPCs) for the CEPC (Circular Electron Positron Collider) experiments. In order to achieve high spatial and momentum resolution, large number of readout channels is demanded with waveform sampling capability in 8-10 b and 10-40 MSPS. Power consumption became critical and has been addressed by using advanced 65 nm CMOS process and simplifying the analog circuits in our design. Prototype chips have been designed including a 5-channel analog front-end, a SAR ADC and a full function ASIC combined with the analog front-end and the SAR ADC. The separated analog front-end and the SAR ADC chips have been tested and the results showed in good agreement with the specifications. The characteristics of TID radiation effect for the analog front-end and the SAR ADC were also evaluated. No significant degradation has been found after 1 Mrad (Si) total ionizing dose radiation. The full function ASIC has also been tested and similar noise performance has been achieved to the separated chips. More detailed design and test results will be given in the paper.

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Study of discharge mechanism in cascaded systems

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In this work we describe simulation and experimental studies of the possible reasons for discharge development in multi-GEM devices. Two main hypotheses are analyzed: first, a diffusion-dominated charge spread reducing the density in individual holes, acting as independent amplifiers and therefore an increase of the discharge limit with the number of cascaded electrodes; the second possibility claims that total avalanche charge before transition to a discharge (Raether limit) strongly depends on the field value and is therefore much higher in a cascade than in single-stage system.

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Charging up study in resistive Micromegas detectors

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Study of the charging up effect in Micromegas detectors

During the last decade, a major improvement in the field of the Micro-Pattern Gaseous Detectors has been achieved by adding a layer of resistive material above the readout strips to drastically reduce the effect of discharges.

This protective layer made of resistive material can be, either, a serie of resistive strips or a single resistive pad covering the entire active area of the anode plane. It is separated from the readout strips by a thin layer of insulator.

When the detector is operated under irradiation, one can observe a gain reduction over the first seconds or minutes after switching-on the source, stabilising after some time.

The charging up effect is well-known in detectors containing dielectric materials and it is due to the charges created in an avalanche and collected on the dielectric surfaces. But is it only related to the presence of insulator or are there other mechanisms that take places?

We report here the results of a detailed study of this effect for several detectors' configuration (resistive and metallic, bulk and non-bulk, variation of the inter strip distance).

We will present our understanding of the charging up mechanism and quantify the main characteristics of this effect, i.e, the absolute and relative gain drop and the time to reach a stable regime, as a function of the detector configuration and current. In addition we measured the time to go back to initial conditions after stopping the exposure of the detector.

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Study of the long term stability of a GEM detector using different Argon based gas mixtures

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A systematic study on the stability of a triple GEM detector prototype in terms of its gain and energy resolution has been carried out under a high rate of X-ray irradiation with two different gas mixtures. The 10cm × 10cm triple GEM prototype has been operated with Ar/CO₂ gas mixture in the volume ratio of 70/30 & 90/10. For this study, same Fe 55 X-ray source has been used to irradiate the chamber as well as to measure the gain and energy resolution. The position of the source on the detector has been kept undisturbed for the entire duration of the study. The effect of temperature and pressure on the gain and energy resolution of the detector has been studied and also the gain and energy resolution are normalized in order to eliminate the temperature and pressure effects. The amount of accumulated charge per unit area has been found to be ~6.5 mC/mm² for the continuous operation with Ar/CO₂ in 70/30 ratio for >1200 hours and 2.5 mC/mm² with Ar/CO₂ in 90/10 ratio for >300 hours. After the normalization, the variation in normalized gain and energy resolution are found to be ~15% and ~20% for Ar/CO₂ in 70/30 ratio, ~10% and ~15% for 90/10 ratio respectively. No significant degradation has been observed in gain and energy resolution for both the mixtures. Currently, the stability study is going on using Ar/CO₂ gas mixture in 80/20 volume ratio and also we are modifying our setup in such a way so that we can study the effect of radiation on the detector independent of all the effects including temperature and pressure variation. All the details of the experimental setup, techniques of measurements, and the results will be presented.

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Development of a Time Projection Chamber for Hadron Experiments at J-PARC

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A new time projection chamber (HypTPC) has been developed for high-statistics hadron experiments at J-PARC[1-3]. In order to cope with a high rate beam at J-PARC, the HypTPC has adopted the triple-layered GEM for the signal amplification and the gating grid plane to suppress the ion back-flow. A target is located in the drift volume which is defined by the large octagonal field cage structure. The amplified electrons from GEM are collected in approximately 6 thousand pads and read out by the GET(Generic Electronic System for TPCs)[4]. We will utilize the partial readout mode and the zero suppression mode, which provides us with a reduction of the dead time of DAQ. In this talk, we will report the overall performance of the particle tracking of the HypTPC and the data readout speed, in particular, with high rate beam test results.

[1] J.K. Ahn and K. Imai, J-PARC Proposal E42, Search for the H-dibaryon with a Large Acceptance Hyperon Spectrometer.

[2] K. Hicks and H. Sako, J-PARC Proposal E45, 3-Body Hadronic Reactions for New Aspects of Baryon Spectroscopy.

[3] K. Tanida and K. Hicks, J-PARC Proposal E72, Search for a Narrow Λ^* Resonance using the $p(K^-, \Lambda)\eta$ Reaction with the hypTPC Detector.

[4] J. Giovinazzo et al., Nucl. Instrum. Methods A 840 (2016) 15-27.

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A machine learning approach for reconstructing X-ray polarization information acquired with micro-pattern gas polarimeters

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We present a data processing algorithm with machine learning for angular reconstruction applied to 2-D photoelectron track images taken with micro-pattern gas polarimeters for X-rays. The method reconstructs the initial emission direction and 2-D position of a photoelectron from each track image with a deep convolutional neural network. In addition, we developed a novel method to flatten the angular distribution for unpolarized X-rays by adding a nonuniform penalty to the cost function evaluating the network model. The developed method improves polarimeter sensitivity by 10–20%, compared to the traditional method with image moments.

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GEM-based imaging system using the SRS in São Paulo — first results

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Micropattern Gaseous Detectors have shown very good imaging capabilities since their first prototypes. The use of low noise, multi-channel discrete readout electronics allows to easily achieve position resolutions of a couple hundred μm , with chances to improve by off-line image processing techniques. The energy resolution can be kept at values very close to the intrinsic one, even using the whole detection area and despite the spatial gain non-uniformities of the GEMs. An SRS with APV25 hybrids with 512 channels was recently coupled to a triple GEM setup in the High Energy Physics and Instrumentation Center in the Institute of Physics of the University of São Paulo. The setup was equipped with a pinhole for X-Ray fluorescence imaging and tests were made in some samples. In most of them it was possible to determine the elemental content with a position resolution limited by the size of the pinhole. Taking into account the area of this type of detectors and the possible geometries of this setup, which allows magnification and, consequently, some versatility in the size of the samples, this type of setup is very competitive, even when compared to the recent solid state pixelated solutions. A thorough discussion on the main issues and future prospects to overcome them is also presented.

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Irradiation test with heavy ions of fine-pitch LCP-GEMs for the IXPE satellite mission

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We have evaluated the robustness of fine-pitch gas electron multipliers with liquid crystal polymer insulator (LCP-GEMs) against cosmic-ray ions for NASA's Imaging X-ray Polarimeter Explorer (IXPE) satellite mission. We irradiated LCP-GEMs with 500 MeV/u Fe ions and confirmed that they are robust enough for approximately 100-years-equivalent operation in Low Earth Orbit (LEO). It is the first time that the 50-micron-pitch and 50-micron-thick GEMs have been tested for resistance to heavy-ion irradiation.

The GEM designed for IXPE is a 50-micron-thick LCP substrate with cylindrical holes of 30-micron-diameter arranged in a hexagonal lattice with 50-micron-pitch (fine-pitch GEM). During the two-years mission life in space, many heavy ions pass through the detectors and it might cause the fatal damage to the GEMs. Although 80-micron-pitch and 100-micron-thick GEMs were tested for resistance to heavy-ion irradiation [1], fine-pitch GEMs has never been tested. Therefore, we injected fully stripped Fe ions with an energy of 500 MeV/u to the fine-pitch GEMs at Heavy Ion Medical Accelerator in Chiba (HIMAC) in Japan and investigated the robustness.

During the irradiation, the GEMs were operated with an applied voltage of 490 V (gain~700), which is a nominal gain in orbit. The number of incident Fe ions to each GEM foil was totally 10^5 counts (100-years-equivalent). Intermittently the GEM performance was evaluated with an Fe-55 isotope and no significant change was observed throughout the period. Thus, we confirmed that the fine-pitch LCP-GEMs are robust enough for the IXPE operation in LEO.

Reference:

[1] T. Iwahashi, et al., IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 58, NO. 5, OCTOBER 2011

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A flexible and efficient microscopic simulation of multiple GEM chamber based on Garfield++

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The detailed response of gaseous detectors requires microscopic simulations; such simulations are computationally demanding due to the modelling of the low energy processes and to the high segmentation required for the 2D/3D field maps.

In order to investigate the performances of the triple GEM (which are 2-dimensional tracking chambers of the Super BigBite Spectrometer under finalization at Jefferson Laboratory in Newport News (VA-US) for high luminosity experiments), we defined and implemented a flexible and rather efficient simulation based on either ANSYS or GMSH+ELMER for 3D CAD and electrostatic field modelling, used by Garfield++, that is a toolkit for the detailed simulation of particle gaseous detectors.

The modular approach, the analysis of potential systematic effects and some results on the comparison of the simulated and real data will be presented.

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A new scheme for Micromegas TPC readout : the encapsulated resistive anode with reverse grounding

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In a resistive anode Micromegas TPC, a resistive-capacitive continuous circuit covers the pad plane. This RC circuit is obtained by lamination of a resistive material on a dielectric material. This coverlay, with adequate resistivity, spreads evenly the charge, allowing the spatial resolution to be considerably improved, by permitting a barycentre to be evaluated between the pad receiving the charge and its neighbours. Moreover, it stabilises the operation of the detector compared to a non-resistive Micromegas. In this standard scheme, however, the mesh is at a negative high voltage while the resistive foil, the readout electronics and the mechanical frame are all grounded, giving rise to inhomogeneity of the potential near the module boundary.

A new scheme is proposed, where the mesh is grounded as well as the frame and the readout electronics, and the resistive foil is maintained at a positive high voltage. Two prototypes have been equipped this way, one for the T2K/ND280 upgrade and one for the ILD TPC, and they have been subjected to tests in beams. The operational advantages of the new scheme (self-shielding, distortion mitigation and flexibility) will be demonstrated.

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Development and Properties of 100 mm-square size LTCC-GEM

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We will report concise review 100 mm square size GEM foil using Low Temperature Co-fired Ceramic (LTCC) as an insulator layer (LTCC-GEM). Since LTCC is inorganic material and high resistance, LTCC-GEM enables to overcome the drawback of conventional polyimide GEM, such as breakdown by discharge and the outgas from material. We tested prototype LTCC-GEM (15 mm square size), and confirmed for robust against discharge (Komiya, MPGD2015). Recently, we succeed in fabricating 100 mm-square size LTCC-GEM with Au layer electrodes. The 100 micron-thick LTCC-GEM has a hole diameter of 100 micron, hole pitch of 200 micron. To evaluate design accuracy of LTCC-GEM, we measured hole diameter and pitch in whole effective area. In the results, hole diameter and pitch conformed to the design with under 4% error. We also evaluated single-GEM properties by using 5.9 keV X-ray (55Fe) in Ar/CO₂ (70:30) gas flow. The gain was approximately 2,000 with the applied voltage of 700 V. The gain stability was less than 10% for 15 hours operation. Although we counted the number of discharges over 2,000 times during the test, LTCC-GEM was not breakdown.

Recent Developments on Precise Timing with the PICOSEC Micromegas Detector

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A detector concept based on a two-stage Micromegas coupled to a Cherenkov radiator with a photocathode (hereafter named PICOSEC) has been developed to provide precise timing information needed for high rate experiments in High Energy Physics (HEP). Single channel prototypes of this detector equipped with a Cesium Iodide (CsI) photocathode have demonstrated an excellent resolution, of 24 ps, for timing the arrival of particles in the minimum ionizing regime (MIPs). The PICOSEC timing characteristics have been extensively studied with laser beams and have been understood in terms of detailed simulations and phenomenological models.

Due to the fact that ion backflow in the drift region damages the CsI photocathode, alternative photocathode materials (including pure Al, Cr, diamond, and Diamond-Like Carbon, DLC) have been investigated. An analysis technique, based on the comparison of the charge distribution of the PICOSEC response signal to UV light and muons, has been developed to consistently estimate the photoelectron yield of the photocathode, a parameter which affects critically the PICOSEC timing resolution.

Towards the development of this detector concept for practical applications, a multi-channel PICOSEC prototype which has a CsI photocathode and segmented anode with hexagonal pads (5 mm

side) has been recently tested in muon beam. Several signal analysis techniques have been developed to correct for systematic errors due to imperfections on the anode planarity, resulting to a uniform timing resolution of 25 ps for each pad. Furthermore, similar timing resolution has been found in case of shared signal across pads.

Following a brief introduction of the PICOSEC concept, this talk presents data analysis techniques and results on estimating the photoelectron yield of various photocathodes, and it focuses on the methods and results concerning the multi-channel PICOSEC prototype performance.

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Fast neutron spectroscopy from 1 MeV up to 15 MeV with MIMAC-FASTn, a mobile and directional fast neutron spectrometer

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Fast neutron spectroscopy is a challenge and needed in many different domains, such as neutron dosimetry, identification of special nuclear material, and nuclear physics. Some applications require measurements above 10 MeV and a large energy range. Among these applications, we can mention the characterization of cosmic neutrons, and secondary neutrons in the radiotherapy.

We will describe a fast neutron spectrometer called MIMAC-FASTn, that provides neutron energy measure within an adjustable range from 1 MeV up to more than 15 MeV. MIMAC-FASTn is a micro-TPC (Time Projection Chamber) based on a micro-pattern detector coupled to a fast self-triggered electronics. Without ³He, regulated matter, or high pressure gas, this technology is based on the 3D detection of nuclear recoils resulting from elastic diffusions of neutrons with gas nuclei.

MIMAC-FASTn is a patented solution, entirely developed at CNRS. The first manufactured prototype was acquired by IRSN (French public authority for nuclear and radiological risks).

The recently developed mobile demonstrator will be presented, as well as its performance and the results of measurements conducted with mono-energetic neutron beams at GENEPI facility at LPSC, at 3 MeV and 15 MeV.

The MIMAC-FASTn detector project is currently a CNRS valorization project, benefiting of a public organization funding (LINKSIUM) who supports valorization projects issued from laboratories research projects.

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Particle Identification Algorithms for GEM-based TPC with an Optical Read-Out

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Preliminary results on event reconstruction and particle identification with the LEMOn detector will be presented. LEMOn is a small prototype of the CYGNO experiment which aims at searching Dark Matter candidates in the low mass region. The detector consists of TPC deploying multiple-GEM structures for gas amplification and optical readout for signal collection. The optical sensor is a sCMOS camera with 4 Million pixels. Such a high spatial granularity in conjunction with diffusion information allows 3D track reconstruction. Several data-collection campaigns have been carried out exposing the LEMOn detector to photon and neutron radioactive sources.

In this contribution we present the algorithms used for pattern recognition together with their performances. Such algorithms, based on machine learning techniques, are essential for a successful particle identification, which is a key capability for background discrimination and rejection.

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Diamond Like Carbon for the Fast Timing MPGD

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The present generation of Micro-Pattern Gaseous Detectors (MPGDs) are radiation hard detectors, capable of dealing with rates of several MHz/cm², while exhibiting good spatial resolution ($\leq 50 \mu\text{m}$) and modest time resolution of 5–10 ns, which satisfies the current generation of experiments (High Luminosity LHC upgrades of CMS and ATLAS) but is not sufficient for bunch crossing identification of fast timing systems at FCC-hh.

Thanks to the application of thin resistive films such as Diamond Like Carbon a new detector concept was conceived: Fast Timing MPGD (FTM). In the FTM the drift volume of the detector has been divided in several layers each with their own amplification structure. The use of resistive electrodes makes the entire structure transparent for electrical signals.

After some first initial encouraging results, progress has been slowed down due to problems with the wet-etching of DLC-coated polyimide foils. To solve these problems a more in-depth knowledge of the internal stress of the DLC together with the DLC-polyimide adhesion is required. We will report on DLC produced in Italy with Ion Beam Sputtering and Pulsed Laser Deposition, where we are searching to improve the adhesion of the thin DLC films, combined with a very high uniformity of the resistivity. We will report on the various techniques used to evaluate the internal stress and to measure the resistivity as well as on first wet-etching test results.

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Technological aspects and properties requirements of MPGDs for Energy Dispersive X-ray imaging analysis

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MPGDs are being used in applications ranging from particle or photon counting to position and energy sensitive imaging. Their sensitivity to low-energy X-rays and fair energy resolution together with their high spatial resolution allows for energy resolved imaging and elemental mapping distribution studies in X-ray fluorescence measurements.

In order to better fit the requirements for EDXRF imaging, MPGDs based detectors have to fulfill requirements of detection efficiency, linearity, spatial and energy resolution, high sensitive area and low cost of the detectors used. Relying on state-of-the-art manufacturing techniques, MicroPattern Gaseous Detectors (MPGDs) technology are able to meet most of the requirements for this purpose.

The relevant features and strategies to gaseous detectors for EDXRF imaging applications will be discussed and different approaches and strategies for the optimization of the systems performance in terms of energy and position resolution, detection efficiency, X-ray optics and system architecture will be presented together with some applications examples.

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Performances of the Micromegas Vertex Tracker at the CLAS12 experiment for the 2017-2018 physics run.

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At Jefferson Lab, the brand new CLAS12 spectrometer has been commissioned and has collected its first physics data with a 10.6 GeV electron beam at a luminosity of $10^{35} \text{ cm}^{-2} \text{ s}^{-2}$ in the winter 2017 to spring 2018. Its Central Vertex Tracker (CVT) is situated within a 5T-solenoidal field surrounding the liquid hydrogen target. It consists of a tracker based on Micromegas and silicon detectors used in combination, in order to balance spatial resolution and low material budget, aiming for the best reconstruction of low momentum recoil protons.

We will report on the performances of the Micromegas Vertex Tracker (MVT) and its operation during CLAS12 physics run. The MVT consists of 18 cylindrical resistive Micromegas which are the first of their kind to be used in a physics experiment. The 5T magnetic field, 2 MHz integrated particle rate, and the compact design, makes of the MVT a challenging and ambitious detector system. The 18k channels of the MVT is read-out by the DREAM electronics which is deported ~2 m away from the strong magnetic field and high radiation of the CLAS12 central region. The design and construction, of the detectors and electronics, both made at CEA Saclay, followed by the performances with detection efficiencies, spatial resolutions during physics run will be presented.

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dE/dx Resolution Studies of a Pre-Production Read Out Chamber for the ALICE GEM TPC

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The ALICE Collaboration is currently conducting a major upgrade of its central barrel detectors to be able to cope with the increased LHC luminosity in 2021 and beyond. In order to record at an increased interaction rate of up to 50 kHz in Pb–Pb collisions, the TPC will be operated in an ungated mode with continuous readout. This demands for a replacement of the currently employed gated Multi-Wire Proportional Chambers by GEM-based (Gas Electron Multiplier) readout chambers, while retaining the performance in particular in terms of particle identification via the measurement of the specific energy loss.

The increase in interaction rate and the requirements of a continuous readout demand for significant modifications of the readout chambers, front-end cards and the corresponding software framework. To validate the performance of a newly built GEM-based readout chamber from the pre-production, the dE/dx resolution was evaluated with a beam of electrons and pions at the CERN proton synchrotron. The results are used to benchmark the digitization in the new software framework $O(2)$.

This research was supported by the DFG cluster of excellence ‘Origin and Structure of the Universe’.

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Improving the charge resolution of bulk Micromegas.

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In Micromegas MPGDs, attaining optimal resolutions depends on a number of factors. In particular as to how close one can reach a perfect parallel plate geometry to shape the electric field. Bulk Micromegas have distortions that are associated with mesh structure, supporting pillars, lack of flatness and parallelism. In this work we present attempts to reduce these effects to reach charge and time resolutions compatible with building detectors with relatively large surfaces. This study has in part, lead to development of an optic Micromegas for high resolution X-ray imaging.

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A free streaming 2D readout GEM detector for X-ray imaging

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GEM detectors are considered to be good candidates for radiation imaging purpose. In this direction, we have successfully performed object-imaging using 5.9 keV X-ray source. The novel feature of the setup is the use of a triggerless system. A 10 cm x 10 cm triple GEM detector with 2D strip-readout was built and operated with Ar/CO₂(70/30) gas mixture. A thin Kapton window allowed the radiations to pass through. Data with different objects placed on the window surface were taken. The strip-signal in each plane was read out using two 128 channel nXYTER based self-triggered electronics. Events having the source-hits were reconstructed from the free-streaming data, by grouping the detector hits on the basis of their time-stamps. Centroids of the hits in each readout plane was obtained and the x-y coordinates calculated. A portion of a fish skeleton was among the objects imaged successfully using this detector. A sub-millimeter position resolution was inferred from the observed images. Efforts are on to improve the quality of image by varying the gain, exposure time, etc. The details of the detector configuration, radiation dose, the free-streaming DAQ, the noise characteristics, and simple reconstruction procedure will be presented and discussed.

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Laser ablation as a novel manufacturing technique of high-precision 1D- and 2D-readout boards for Micro-Pattern Gaseous Detectors

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Laser ablation is routinely used in industry to cut PCBs, drill vias and trim unwanted artifacts, left after the chemical processing stage. Using standard production equipment at two different PCB shops (TTM, US and Elvia, France) we successfully applied this technology as a primary process to carve finely structured charge-sharing patterns with feature sizes as small as 100-200 microns on 1D-strip and 2D-pad boards. We conclude that the laser ablation technique is feasible for mass production and (compared to standard chemical etching) is capable of producing very fine resolution patterns in a well-controlled fashion, with strip-to-strip gaps as narrow as 20-25 microns. The latter is essential to precisely reproducing the optimal design shape of the readout strips and pads of the MPGD anode planes. As a consequence, one can noticeably enhance the detector performance, in particular eliminate differential nonlinearity and attain higher spatial resolution with the same electronics channel count.

Several details of the production technique will be given. Application in various types of Micro-Pattern Gaseous Detectors will be discussed and illustrated by already implemented pad and strip configurations.

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new MPGD-based structures for electroluminescence TPCs

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Optical TPCs, specially those operating in electroluminescence mode, are widely used in the searches for rare events, particularly in those involving the reconstruction of very faint energy deposits (down to single photon/electron sensitivity) or outstanding energy resolution.

Unlike avalanche multiplication, electroluminescence depends just on the maximum voltage that the structure can sustain, hence thick structures are preferable. In order to work in these conditions, a new type of very thick GEM ('FAT'-GEM) based on acrylic has been developed at CERN workshop. Acrylic is a rugged and homogeneous radio-pure material, easy to machine and widely available, therefore it holds some promise for a new generation of optimised structures in the field of rare event searches. First measurements under an Ar/Xe mixture at 10bar already showed an energy resolution extrapolating to 2%(FWHM) for the Q_{bb}-energy of ¹³⁶Xe, at an optical gain of around 1000ph/e. We will report in this contribution results of this ongoing effort, presenting results for a wide range of structures, gases and pressures.

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Development of novel ultra-thin Micromegas and a Time Projection Chamber for animal ion transmission tomography

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At the LMU Department of Medical Physics a proton irradiation platform is under development, intended for pre-clinical research with tumor bearing mouse models. It will adapt clinical proton beams to the needed energy range and focus and contains several beam monitoring and animal imaging systems.

In this context, we are developing an proton computed tomography system (pCT), which combines particle position information with a residual energy measurement of the transmitted protons with energies between few and 80MeV.

To ensure precise tracking even of the lowest energy particles at minimum Coulomb scattering, we are developing ultra-thin floating strip Micromegas detectors with two-dimensional strip readout structures. The latter consist of aluminum electrodes on a Kapton substrate.

For determining the residual energy with high precision, we build a small-size Time Projection Chamber (TPC) as rear detector of the imaging system with a discharge insensitive floating strip Micromegas readout structure. Transmitted particles are successively slowed down and then stopped by more than 50 0.5mm thick Mylar absorbers inside the TPC drift region, alternating with few mm wide gas layers.

The pCT system is introduced, the production techniques, construction and performance of an ultra-thin tracking detector are discussed. The TPC prototype is described and detailed results from several testbeams with protons and simulations are presented. We discuss the behavior of field-shaping and of insulating absorbers and present the imaging capabilities of the complete system as simulated by FLUKA.

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Performance of the uMegas and uRWELL detector prototypes equipped with the modern laser etched readout planes with improved charge sharing properties

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We fabricated several uRWELL and uMegas detector prototypes (the latter both in “bare metal” and resistive implementation), equipped with readout boards of various complexity, and benchmarked their spatial resolution performance both in the lab by using a collimated X-ray gun and with the particle beam at the Fermilab Test Beam Facility. Various comparative studies will be presented in the talk: chemical-vs-laser etching of the readout boards with the similar geometry, same pitch straight-vs-zigzag strip spatial resolution, uMegas-vs-uRWELL amplification stage performance, effects of the resistive layer in the uMegas implementation. Other practical aspects like influence of pillar geometry on the uMegas spatial resolution, detector performance in the so-called micro-drift operation mode for the inclined tracks, charge sharing in 2D-pad geometry for RICH application will be covered as well.

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New Developments in MPGDs for a Future Electron Ion Collider

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The prospect of a future Electron Ion Collider (EIC) in the US has generated much interest in the detector development community for pursuing applicable detector technologies beyond the present state of the art. In particular, an EIC Tracking Consortium consisting of members from US and European based institutions dedicated to advancing MPGD technology for use at the EIC has made significant contributions in this area. Specific topics of investigation include the development of large area, low mass planar GEM-based detectors coupled to either zigzag shaped or U-V anode strip readout planes to achieve high position resolution with minimal channel count. Other topics include the optimization of the avalanche structure used to read out a TPC and the development of a thin profile, mRWELL-based cylindrical tracker to provide fast hits to compliment the TPC. There is also a concentrated effort to optimize the detailed geometry of highly interleaved anode structures

(including zigzags and more complex 2D patterns) used for the readout planes of various MPGD avalanche schemes. Additionally, a novel pID detector which utilizes a photosensitive THGEM+MM hybrid coupled to a specialized readout plane has been successfully studied. An overview of the progress on a broad range of activities will be presented at the conference with an emphasis on innovations in MPGD technologies.

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sPHENIX TPC Overview and Design

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The proposed sPHENIX detector at RHIC is being designed to study with unprecedented precision the nature of the Quark Gluon Plasma, or QGP, through measurement of jets, jet correlations and upsilon particles. To reach the goal of producing a high mass-resolution reconstruction of the three states of the

upsilon, a compact TPC covering pseudorapidities $< |1.1|$ is under construction to provide sPHENIX with the necessary momentum resolution.

Similar to the ALICE-TPC upgrade, the sPHENIX TPC design presently utilizes quadruple-GEM detectors.

As an alternative solution, a double-GEM-Micromegas hybrid arrangement is currently being tested. Utilizing novel zigzag patterned readout pads, a modified SAMPa readout chip, and an optimized Ne-CF₄ gas mixture immersed in a 1.4 T magnetic field to reduce ion backflow, sPHENIX will have a unique lens into the QGP. The motivation behind the design and innovations of the TPC will be presented, along with the current status of the project.

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Study of a passive gating grid for IBF suppression

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A Time Projection Chamber is one of the main tracking systems for the proposed sPHENIX experiment at RHIC. It measures space points of charged tracks, which provide momentum resolution to separate the Upsilon states in decays to $e^+ e^-$.

The strong magnetic field of the BaBar solenoid, a Neon-based fast gas mixture, and a high drift electric field will improve the E-field distortions due to ion backflow significantly in the current sPHENIX TPC design. Furthermore, a quadruple GEM stack with special hole patterns or a MicroMegas based amplification will reduce the ion backflow also.

Nonetheless, due to the expected high luminosity at sPHENIX, we are considering to include a passive gating grid as well. We have studied several options to achieve good electron transparency for the primary electrons and high blocking for the ions coming from the amplification stage.

We have simulated woven wire meshes, different patterns of etched meshes, hexagonal micropattern meshes and static bi-polar wire gating.

In this presentation, I will discuss the simulation results for different designs and their comparison suitable for sPHENIX TPC.

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Design and Construction of sPHENIX TPC Field Cage

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The sPHENIX experiment at RHIC plans to build a Time Projection Chamber (TPC) to resolve the epsilon states, which were not previously accessible at RHIC energies. The TPC will span 20 to 78 cm in radius and $|1.1|$ units in pseudorapidity. The sPHENIX TPC is constrained in size by the BaBar solenoid, which poses design limitations. In this poster we will discuss the design and construction of the sPHENIX field cage.

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Latest test results of a thick gas amplifier with a new design

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The results obtained in the study of the avalanche process of electron multiplication in a thick gas amplifier of a new design are presented. The main feature of the device is the separation of the upper and lower parts of the amplifier by a gas gap with the preservation of the polyimide film as an insulator on the inner surface of the hole electrodes. The width of this gap can vary in the range of 0.1-1.0 mm, depending on the electrode sizes. With this separation the surface leakage currents are absent between the electrodes and the charge is not induced on the inner surface of the gas-discharge gap. Due to this solution, it is possible to minimize the probability of both surface and volume streamer phenomena that turn into a Geiger or spark discharge. As a result a pulse amplitude of a few volts was measured across a load of 50 Ω in a gas mixture of Ar+20% CO₂ when the detector was irradiated with a Sr90 β -source.

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RD51 activities and perspectives

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New Physics frontiers and future accelerators

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Neutrino physics : current and future experiments

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Picosecond timing detectors and applications

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TPC technologies using MPGDs

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MPGD applications outside high energy physics

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MPGD and neutron detection techniques and applications

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Astroparticle Physics

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Tribute to A. Oed and Charpak Award / 141

The Early Times

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The Early Times

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Tribute to A. Oed: Anton Oed's Pre-MSGC-History at the Institut Laue-Langevin

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Tribute to A. Oed: MSGCs and their descendants. Past, Present, and Future

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Tribute to A. Oed: MSGC for neutron scattering instruments at the ILL

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Charpak and Oed Award ceremonies

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The Micro Strip Gas Chambers for the X-Ray monitor (JEM-X) onboard ESA's INTEGRAL mission

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MPGD-based photon detectors for the upgrade of COMPASS RICH-1 and beyond

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Development of new MPGD structures for nuclear physics applications

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LHM-based “local dual-phase TPCs” – potential tools for future noble-liquid detectors

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First results of Rayleigh scattering method to define the size of ion clusters in a gaseous detector

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Micromegas for beam loss monitoring

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Charging up study in resistive Micromegas detectors

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Performances of the Micromegas Vertex Tracker at the CLAS12 experiment for the 2017-2018 physics run

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A new scheme for Micromegas TPC readout : the encapsulated resistive anode with reverse grounding

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A high-gain and low ion-backflow double micro-mesh gaseous structure

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New MPGD-based muon telescopes for ScanPyramids and associated R&D on gas consumption

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Study of a passive gating grid for IBF suppression

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Development of μ -PIC with glass substrate aiming at high gas gain

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Recent photocathode and sensor developments for the PICOSEC micromegas detector

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Laser ablation as a novel manufacturing technique of high-precision 1D- and 2D-readout boards for Micro-Pattern Gaseous Detectors (cancelled-included in next talk)

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New Developments in MPGDs for a Future Electron Ion Collider

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Development of resistive Micromegas TPCs for the T2K experiment

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R&D on THGEM with Resistive Diamond-like carbon coating

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Development of a thermal bonding method for fabrication of Micromegas and new MPGD structures

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CMS Phase II Upgrade with GEM detectors

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Lessons Learnt from the GE1/1 Slice test

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VMM3a, an ASIC for tracking detectors

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Production, Quality Control and Performance of GE1/1 Detectors for the CMS Upgrade

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Production of Micromegas and progress on the HV stability issues

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Recent Developments on Precise Timing with the PICOSEC Micromegas Detector

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Diamond Like Carbon for the Fast Timing MPGD

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New Results from GridPixes

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Application of micro-pattern gas detectors in the present and future experiments in Budker INP

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CYGNO: Triple-GEM Optical Readout for Directional Dark Matter Search

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Correlation of optical and electrical measurements of the delayed discharge propagation in GEM detector

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A numerical investigation on the discharges in Micromegas

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Development of GEM based Transition Radiation Detector and Tracker (GEM-TRD/T)

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Development and Properties of 100 mm-square size LTCC-GEM

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Study of discharges and their effects in GEM detectors

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Recent advances with RPWELL Detectors – physics and potential applications

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High space resolution μ -RWELL for high rate applications

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A scalable High Voltage power supply system with SoC control for Micro Pattern Gaseous Detector

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Development of a Time Projection Chamber for Hadron Experiments at J-PARC

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Development of novel ultra-thin Micromegas and a Time Projection Chamber for animal ion transmission tomography

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Small-pad resistive Micromegas: Comparison of patterned embedded resistors and DLC based spark protection systems

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Recent Development of Glass GEMs and Their Uses

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Fast neutron spectroscopy from 1 MeV up to 15 MeV with MIMAC-FASTn, a mobile and directional fast neutron spectrometer

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dE/dx Resolution Studies of a Pre-Production Read Out Chamber for the ALICE GEM TPC

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SRS VMM readout for Gadolinium GEM-based detector prototypes for the NMX instrument at ESS

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RD51- Discussions on VMM electronics (open for everyone)

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Information