# GDS Topical Meeting: GDS coupling to auxiliary detection systems

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INFN Laboratori Nazionali di Legnaro

# Book of Abstracts

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## Welcome

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**Gas Detectors and Systems** / **25**

## Gaseous detectors for radioactive beam experiments

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Various gaseous detectors have been developed in the last decade to study reactions and decays of radioactive nuclei. These new detectors mostly rely on the micro-pattern gaseous detector technology, but with different concepts and characteristics, depending on experimental purposes and strategies. A overview will be presented.

**Gas Detectors and Systems** / **27**

## Trend and new developments in gas amplifiers

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A centenary after the discovery of the basic principle of gas amplification, gaseous detectors are still the first choice whenever the large area coverage and low material budget is required. The introduction of the Multi-Wire Proportional Chamber by G. Charpack 1968 represent one of the glories moment in the history of gas detector (Nobel price in 1992), for it provided for the first time fine space resolution and it revolutionized the field of position-sensitive detectors. Over the past two decades advances in photo-lithography, microelectronics and printed-circuit board (PCB) techniques triggered a major transition in the field of gas detectors from wire structures to the Micro-Pattern Gas Detector (MPGD) concepts. In particular the Gas Electron Multiplier (GEM), the Micro-Mesh Gaseous Structure (Micromegas), and more recently other micro pattern detector schemes, offers the potential to develop new gaseous detectors with unprecedented spatial resolution, high rate capability, large sensitive area, operational stability and radiation hardness. In the present contribution we will briefly overview the historical roadmap of gaseous detector development and we will discuss basic concepts, operational mechanisms and performance of the most popular new gas amplifier structures.

**Particle Detectors** / **22**

## The heavy-ion magnetic spectrometer PRISMA: present status and ongoing upgrades

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PRISMA is a large acceptance magnetic spectrometer designed to be used with heavy-ion beams accelerated at energies up to E = 10 AMeV by means of the Tandem/PIAVE-ALPI accelerator complex of Laboratori Nazionali di Legnaro. Its large solid angle and the high resolving powers of its detection systems allowed to investigate the transfer process around and well below the Coulomb barrier. Moreover, the coupling of the spectrometer with large gamma-ray arrays, such as CLARA or the AGATA Demonstrator, also allowed to make in-beam gamma-spectroscopy of moderately neutron-rich nuclei populated by multinucleon transfer reactions through the identification of individual excited states and their population pattern.
Experimental campaigns were mainly addressed to obtain information on the shell evolution and the onset of new regions of deformation (collectivity, critical point symmetries) in medium-mass moderately neutron-rich nuclei, on the interplay between single and pair transfer modes and the population of neutron-rich heavy nuclei via multinucleon transfer reactions.
A detailed description of the spectrometer and its detectors as well as some selected results of recent studies will be presented.
Several developments are also being carried out around the target area of PRISMA in order to obtain additional experimental information and to improve its performances by equipping the spectrometer with ancillary detectors. The status of these ongoing upgrades will be also presented.

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## FARCOS: a new telescope array for correlations and spectroscopy

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A prototype of a new correlator FARCOS (Femtoscope ARray for COrrelations and Spectroscopy) has been recently developed in the frame of INFN - NewCHIM collaboration [1].
FARCOS is an array of triple telescopes (DSSSD[300μm]-DSSSD[1500μm]-CsI(Tl)[6 cm]) with high

pixelation and energy resolution, designed to study multi-particle correlations and spectroscopy of un-bound states in Heavy-ion collisions at Fermi energies (E=10-100 AMeV). The new correlator is characterized by high flexibility and modularity in order to be used in different configurations at various facilities with both stable and exotic beams (LNS, LNL-SPES) and to be coupled to other devices.
The FARCOS project will be presented, together with preliminary results of tests and experiments in which the detector prototypes and different front-end solutions, like the GET electronics [2], have been used.

References
[1] FARCOS TDR available at https://drive.google.com/file/d/0B5CgGWz8LpOOc3pGTWdOcDBoWFE/view
[2] E. Pollacco et al., Phys. Procedia 37, 1799 (2012)

**Particle Detectors** / **21**

## The FAZIA modules: recent results and possible couplings with gas detectors

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The FAZIA detector is a new-generation modular detector array for heavy-ion collisions designed for intermediate energies . The basic detection module consists of two transmission-mounted silicon detectors (300 um and 500um) followed by a CsI(Tl) scintillator, grouped in order to compose 4x4 single telescopes. Significant improvements in ΔE-E and pulse-shape techniques were obtained by controlling the doping homogeneity and the cutting angles of silicon and by putting severe constraints on thickness uniformity. Purposely designed digital electronics contributed to identification quality which is very good.
The general characteristics and some possible couplings of the FAZIA telescopes with gas detectors will be discussed in the talk in the perspective also of low energy applications.

**Particle Detectors** / **29**

## OSCAR: a modular low-threshold hodoscope for low energy nuclear reactions

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The increasing availability of new low-energy radioactive ion beams facilities in the world calls for the building of new detectors. They should have very low detection and identification thresholds, good isotopic resolving power and large granularity. In this way it would be possible to make correlations studies that are needed to probe the structure and/or the dynamics of nuclear systems very far from the stability valley. In this respect, the use of active gas target system seems very promising, especially for the study of low energy direct nuclear reactions. In some cases it would be useful to couple these gas target systems with modular, high granularity hodoscopes to detect high energy reaction ejectiles (that can punch through the gas). As a possible ancillary detector for low energy studies, we developed a new hodoscope, OSCAR. It is formed by a single-sided silicon strip detector (16 strips, 20 \mum nominal thickness, the strip dimension being 3×50 mm) coupled with 16 silicon pad detectors (arranged in a 4×4 configuration, 300 \mum thick, the pad dimension being 10×10 mm).

The observed identification thresholds are of the order of ≈ 1 A MeV for isotopes up to Be. A careful analysis of the thickness uniformity has been performed on the silicon strip detector, both with \alpha-source and with reaction ejectiles; this led to determine the maximum gradient of thickness that allows a good isotopic identification of light fragments (up to Li/Be). The very good energy and angular resolution of this hodoscope has been exploited in the study of the \alpha-\alpha correlations due to the 8Be decay in 40,48Ca+40,48Ca reactions at 35 A MeV. Possible physical cases of couplings of this hodoscope with active gas target systems will be discussed.

**Gamma-ray and neutron detectors / 33**

## NEDA - The New High Performance Neutron Multiplicity Filter

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The currently being built NEutron Detector Array (NEDA) is the neutron multiplicity filter, which will be used as ancillary device for the state of the art germanium arrays (like AGATA, GALILEO), with both intense stable and radioactive ion beams. The gain in detection efficiency, especially for the events of high neutron multiplicity, will allow to address regions of nuclear chart not achievable so far employing the existing arrays of neutron detectors.

Extensive Monte Carlo simulations were performed in order to establish optimum size of a single NEDA detector unit, as well as the geometry of the entire array. Series of measurements were performed for choosing the best scintillator and photomultiplier, optimising the neutron-gamma discrimination (NGD) and timing properties of the array. The digital algorithms both for NGD and timing were developed and their performance compared with the one of analogue methods.

The findings from the years of research and development phase of NEDA will be shown during the talk. Possible coupling with gaseous detectors will be discussed.

**Gamma-ray and neutron detectors / 17**

## CLYC: a new scintillator detector for nuclear physics

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The R&D work on new scintillator materials produced several high performing scintillators with an energy resolution better than that of NaI (6-7% at 662 keV).
The best known is LaBr3:Ce because of its excellent and unmatched properties in term of energy (3 % at 662 keV), time (< 500 ps) resolution and efficiency (density of 5.1 g/cm3) for gamma ray detection. However, very new materials as CLYC, CLLB, CLLBC, Co-Doped LaBr3:Ce are appearing together with the new but better known scintillators as SrI2:Eu and CeBr3:Ce. These detectors could compete with LaBr3:Ce and, in general, outclasses NaI in terms of performances.
The Cs2LiYCl6:Ce (CLYC) scintillator, that belong to the Elpasolite family, is an interesting scintillator for its capability to measure and discriminate gamma rays and neutrons simultaneously with excellent resolution. A CLYC scintillator can measure thermal neutrons , (if 6Li is used) but it can be used as a clean fast neutron spectrometer (if 7Li is used), due to 35Cl ions. We have tested the properties of i) two 1" x 1" CLYC scintillators (one enriched with 6Li and one enriched with 7Li) using either standard ⍰ and neutron sources and monochromatic neutrons beams ii) a 2"x2" CLYC

scintillators (enriched with 7Li) and iii) we will test a 3”x3” (enriched with 7Li) CLYC crystal. Here we will present some results of the measurements

**Gamma-ray and neutron detectors** / **20**

## Scintillation array development for the SpecMAT Active Target - Time Projection Chamber

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The SpecMAT Active Target will consist of a Time Projection Chamber (TPC) surrounded with a gamma-detection array. This detector will be used for studies of exotic isotopes produced via transfer reactions. In an active target, an inner volume is filled with a gas which functions as both a target and a detection medium. Interacting with the gas reaction products ionise the gas along their path. Under electric field ionised electrons are collected on a segmented charge sensitive plane and thus particle’s trajectories can be reconstructed based on the collected charge. The first peculiarity of this detector is positioning in a magnetic field of up to 4T. Experiencing Lorentz force particles will move by spiral trajectories. This approach allows extracting particles energies based on a trajectory curvature. Secondly, the array of scintillation detectors will be used for gamma spectroscopy of populated states in transfer reactions for achieving a significant improvement in resolution.

GEANT4 simulations, prior detector design and results from several tests in high magnetic fields will be presented.

**Projects** / **13**

## Auxiliary detectors for direct reactions studies

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We have plan several physics cases to study the structure of nuclei far from stability with direct and resonant reactions using active targets. In this talk I will present the experimental requirements of the auxiliary detectors to be implemented depending on the physics goals of the experiments.

**Projects** / **15**

## An optical chamber for fission

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The interaction between a charge particle and a fissile nucleus might produce a new type of fission resonances below the Coulomb barrier. These resonances are still to be found experimentally.
We propose to use an optical chamber to observe directly the fission products of the interaction between a low-energy proton beam and a U target. The optical chamber works as a gas-filled TPC where the light emitted by the ionised gas is picked up by a comercial CMOS camera and the resulting image is analysed to reconstruct the reaction.
In this talk we will present the physical case as well as the plan to build such optical TPC chamber.

**Projects** / **28**

## ELITPC - a TPC detector for photonuclear reaction studies using intense, monochromatic gamma-ray beams at the ELI-NP facility

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A newly built Extreme Light Infrastructure – Nuclear Physics (ELI-NP) facility in Bucharest-Magurele, Romania will provide monochromatic, high-brilliance gamma-ray beams that will allow one to study key nuclear reactions in modern astrophysics by means of the inverse photo-dissociation process [1]. Such inverse reactions exhibit larger cross sections due to detailed balance principle and have smaller experimental backgrounds in comparison with direct measurements. In particular, Oxygen-16 photo-dissociation process plays a key role in explaining carbon-to-oxygen abundance ratio observed in the Universe. In order to measure this and other (gamma, alpha) or (gamma, p) reactions of astrophysical interest, an active-target gaseous Time Projection Chamber (ELITPC) is being developed by the University of Warsaw, IFIN-HH / ELI-NP and the University of Connecticut [2].

The ELITPC detector has active volume of about 35 cm x 20 cm (readout area) by 20 cm (drift length) that is centered around the axis of the gamma beam. The working gas mixture, rich with target nuclei to be studied, is kept at a lower-than-atmospheric pressure (~100 mbar) in order to optimize three-dimensional kinematical reconstruction of the events. The ionization electrons from tracks of charged particles emerging from photo-dissociation reactions drift in a uniform electric field towards several Gas Electron Multiplier (GEM) structures before reaching the segmented readout anode. The whole internal structure is embedded in a vacuum vessel equipped with gamma-beam windows, gas and high-voltage ports as well as analogue signal feedthroughs. The ELITPC detector is complemented by: low-pressure generation and recirculation gas system, electron drift velocity monitoring and real-time gamma-beam intensity diagnostics.

The detector will employ fast digitizing front-end electronics developed by the Generic Electronics for TPCs (GET) collaboration for nuclear physics experiments [3]. The readout anode is constituted from interconnected pads that are arranged in three arrays of strips, which form a redundant three-coordinate u-v-w system. About 1000 electronic channels are envisaged in the full-scale ELITPC detector.

A scaled demonstrator detector operating at atmospheric pressure was constructed and tested with an alpha-particle beam at the IFIN-HH Tandem facility Romania [4]. The beam-induced experimental background for the expected gamma-ray intensities and energies has been simulated using Monte Carlo. The current R&D program focuses on testing thicker versions of GEM foils that will be more suitable for operation at low gas densities, further development of FPGA-based DAQ electronics, optimizing segmentation of the readout strips and number of electronics channels and optimizing composition of the working gas mixture (e.g. He + CO2).
A brief status of these developments will be presented in the talk.

[1] D. Filipescu et al., "Perspectives for photonuclear research at the Extreme Light Infrastructure - Nuclear Physics (ELI-NP) facility," European Physical Journal A, 51, 185 (2015).
[2] O. Tesileanu et al., "Charged particle detection at ELI-NP," Romanian Reports in Physics, 68, S699 (2016).
[3] E. Pollacco et al., "GET: A Generic Electronic System for TPCs for Nuclear Physics Experiments," Physics Procedia, 37, 1799 (2012).
[4] M. Cwiok, "Nuclear reactions at astrophysical energies with gamma-ray beams: a novel experimental approach," Acta Physica Polonica B, 47, 707 (2016).

**Projects** / **26**

## Probing the structure of exotic nuclei with protons and antiprotons targets

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The study of exotic nuclei has triggered the development of innovative target and detection systems. Protons and antiprotons are unique structure probe. Protons can be used to study the spectroscopy of exotic nuclei via quasi-free scattering reactions. Antiproton annihilation at the nuclear surface can be used to probe neutron/proton density ratio, and therefore characterize halos and skins.
The possibility to use a thick proton target coupled to a vertex tracker to increase the luminosity has been successfully realised with the MINOS project. The use of antiprotons to probe the surface of exotic nuclei is the goal of the PUMA project. Both projects will be presented in this talk.

**Projects** / **19**

## Investigation of Ceramic based Resistive Plate Chambers for high rate beam environments

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A solution proposed for timing detectors in new high rate beam environments as FAIR, LHC and ILC could be Resistive Plate Chambers (RPC) with semi conductive electrodes. The gas gap between two electrodes amounts to less the 300 µm, to increase the electric field strength up to 100 kV/cm. Different electrode materials are under investigation. RPC prototypes with semi conductive Si3N4/SiC ceramic sheets have been tested with relativistic electrons at the accelerator ELBE (HZDR) where a beam flux of up to 1.5x10Ê5 cm-2 s-1 was used, and with pions at the T10 beam-line (CERN). In both tests a detection efficiency of 98% and sub nanosecond timing resolution was achieved.

**Projects** / **31**

## The NUMEN project at INFN-LNS: R&D activity on new detection technologies

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The physics case of neutrino-less double beta decay and in particular, the crucial aspect of the nuclear matrix elements entering in the expression of the half-life of this process will be briefly introduced. The novel idea of using heavy-ion induced reactions as tools for the determination of these matrix elements will be then presented in the framework of the NUMEN project of INFN [1]. The proposed strategy to this research will be sketched also in view of the proposed upgrade of the Superconducting Cyclotron and of the MAGNEX spectrometer [2]. In particular, the challenges of a focal plane detector for heavy ions able to guarantee high resolution in tracking and particle identification up to detection rates as high as several MHz will be discussed. The crucial technologies of micro-pattern gas detectors for the tracker and of SiC for the stopping detector will be presented.

[1] F.Cappuzzello et al., Eur. Phys. J. A (2015) 51: 145
[2] F.Cappuzzello et al., Eur. Phys J. A (2016) 52: 167

**Projects** / **30**

## The experimental set-up of the RIB in-flight facility EXOTIC

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We will present the experimental set-up [1] of the Radioactive Ion Beam (RIB) in-flight facility EXOTIC [2-6] consisting of: a) two position-sensitive Parallel Plate Avalanche Counters (PPACs), dedicated to the event-by-event tracking of the produced RIBs and to time of flight measurements; b) the new high-granularity compact telescope array EXPADES (EXotic Particle DEtection System), designed for nuclear physics and nuclear astrophysics experiments employing low-energy light RIBs. EXPADES is a compact, versatile and portable array that consists of eight \DeltaE-Eres telescopes arranged in a cylindrical configuration around the reaction target. Each telescope is made up of two Double Sided Silicon Strip Detectors (DSSSDs) with a thickness of 40/60 \mu m and 300 \mu m for the \DeltaE and Eres layer, respectively. For experiments requiring the detection of more energetic particles than those stopped in the Eres layer, few 1 mm-thick DSSSDs were recently purchased, to substitute the 300 \mum -thick DSSSDs or to be used in addition to the previous stages. Additionally, eight ionization chambers were constructed to be used as an alternative \DeltaE stage or, in conjunction with the entire DSSSD array, to build up more complex triple telescopes. Very innovative read-out electronics was designed for both DSSSD stages. New low-noise multi-channel charge-sensitive preamplifiers and spectroscopy amplifiers, associated with constant fraction discriminators, peak-and-hold and Time to Amplitude Converter circuits were developed for the electronic readout of the \DeltaE stage. Application Specific Integrated Circuit-based electronics was employed for the treatment of the Eres signals. An 8-channel, 12-bit multi-sampling 50 MHz Analog to Digital Converter, a Trigger Supervisor Board for handling the trigger signals of the whole experimental set-up and an ad-hoc data acquisition system were also developed.

The components of the EXPADES array can be easily reconfigured to suit many experiments. Moreover, it can be used as an ancillary detection system with \gamma-ray (like the BaF2 scintillators of the SERPE array or other detectors) and neutron arrays.

EXPADES and PPAC B (the second PPAC of the RIB monitoring system) are housed in the reaction chamber, placed at the final focal plane of the EXOTIC facility and designed for an optimal use of EXPADES in different configurations . To allow the realization of experiments with RIBs impinging on both solid and gas reaction targets (like experiments studying \alpha clustering phenomena in light exotic nuclei or experiments of astrophysical interest with RIBs impinging on gas targets in inverse kinematics), a small chamber housing the PPAC B was built. When requested, this small chamber isolates, through a 2 \mu m-thick Havar window, the two PPACs and the beam line (held at vacuum) from the reaction chamber that is filled with gas at pressures ranging from 0.4 to 1 bar. In this case, the reaction between the RIB and the gas target can occur at any point along the RIB trajectory inside the reaction chamber.

References
[1] D. Pierroutsakou et al., Nucl. Instr. and Meth. A 834 (2016) 46
[2] V.Z. Maidikov et al., Nucl. Phys. A 746 (2004) 389c
[3] D. Pierroutsakou et al., Eur. Phys. J. Special Topics 150 (2007) 47
[4] F. Farinon et al., Nucl. Instr. and Meth. B 266 (2008) 4097
[5] M. Mazzocco et al., Nucl. Instr. and Meth. B 266 (2008) 4665
[6] M. Mazzocco et al., Nucl. Instr. and Meth. B 317 (2013) 223

**Electronics anf Front-end electronics / 18**

## The low-noise low-power multi-channel ASIC preamplifier of TRACE: design, results and perspectives

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In this talk the new ASIC preamplifier of TRACE is presented. The discussed topics will include the design philosophy, the experimental results and the foreseen perspectives. The first prototype realized in the end of 2014 has been extensively characterized, both with a pulser on the test-bench and with a detector prototype and an alpha source. With an overall power consumption of 12mW / channel, the ASIC's energy resolution is in the order of 1.1keV (best case ever 0.75keV).

**Electronics anf Front-end electronics / 32**

## Custom digitizers with on-board pulse shape discrimination.

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The digitization of the signals coming from nuclear detectors signals is becoming widespread. In many applications, the digitized signal is also used for the identification of the detected nuclear fragments from pulse-shape related parameters (Pulse Shape Discrimination). In large detector arrays, the data throughput and calculation power required when the full waveforms are transferred to a PC farm for the analysis can be too cumbersome. A possible solution is to distribute the calculation over the single digitizing channels, i.e. extracting the relevant information already on the digitizing board, by using an on-board digital signal processor or a FPGA. This solution has been implemented at the GARFIELD+RCo apparatus, whose digitizing electronics is about to be upgraded.

**Electronics anf Front-end electronics / 23**

## FAZIA electronics: from detectors to acquisition

**Author:** Simone Valdré[1]

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FAZIA is a modern apparatus based on Si-Si-CsI(Tl) telescopes designed to have excellent particle identification capabilities with relatively low energy thresholds and high efficiency. To achieve the desired goals, besides the use of carefully designed and selected detectors, a state-of-the-art digitizing front-end electronics is mandatory. Compact and integrated front-end cards are used to implement many functions just next to the telescopes, under vacuum. Moreover, digital signal processing techniques are used to extract every possible information from signal shapes. Such an advanced front-end electronics is accompanied with a modern acquisition system to reconstruct the event and to handle high data throughput. The whole apparatus and all the electronics are modular and easily transportable among laboratories, allowing to arrange the blocks in almost any configuration and to couple them to many other detectors, such as four-pi arrays or active targets. In my contribution I will review the operation and the performance of a typical FAZIA module from the detectors to the data transport. I'll focus on the characteristics which make FAZIA a cutting-edge apparatus in the panorama of heavy-ion experiments with stable and radioactive beams.

**The SPES facility / 34**

## Status of the SPES project

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SPES, a new accelerator facility for both the production of exotic ion beams and radio-pharmaceuticals, is presently being installed at the Laboratori Nazionali di Legnaro in Italy (LNL). The new cyclotron, which will provide high intensity proton beams for the production of the rare isotopes, has been installed and is now in the commissioning phase. We present here the status of the project devoted to the production and acceleration of exotic beams. The expected SPES radioactive beams intensities, their quality and their maximum energies (up to 11 MeV/A for A=130) will allow forefront research in nuclear structure and nuclear dynamics far from the stability valley. The developments in nuclear physics technology will be applied in nuclear medicine for the study and production of innovative radioisotopes.

**Electronics, DAS, Simulations / 11**

## Synchronizing GET with GTS systems

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**Electronics, DAS, Simulations / 24**

## Characterization of the GET electronics for Si detector applications

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Auxiliary detectors including Si and Si strip detectors placed inside the gas volume of the Active Target and Time Projection Chamber (ACTAR TPC) [1] represent an integral part of the overall detection system. Readout of the total number of 16384 channels from the highly segmented pad plane of ACTAR TPC will be performed using the electronics and data acquisition system recently developed by the General Electronics for TPCs (GET) collaboration [2]. To equip the additional ~512 channels of Si strip detectors the simplest solution was therefore to consider the use of these electronics for Si detector applications. In this talk, we will present a number of recent test results that were obtained to characterize the GET system for Si detectors including noise levels, gain, energy resolution, the GET internal trigger option and the overall system dead time.

*The research leading to these results have received funding from the European Research Council under the European Union's Seventh Framework Program (FP7/2007-2013)/ERC grant agreement no 335593. Research and development of the GET system was supported by the Agence Nationale de la Récherche (ANR) in France under contract no ANR-09-BLAN-0203-02 and the National Science Foundation (NSF) in the United States.

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[1] J.Pancin et al. Nucl. Instrum. Meth. Phys. Res. A 735, 532 (2014).
[2] E.C.Pollacco et al. Phys. Procedia 37, 1799 (2012).

**Electronics, DAS, Simulations / 14**

## Status and perspectives of the ACTARSim simulation

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ACTARSim is a simulation package developed to determine the response of the ACTAR-TPC Active Target and other similar Active Target projects, as well as their ancillary detectors.

The code has recently been upgraded to the last ROOT and Geant4 versions. Physics results and future developments will be discussed.

**Round Table, final remarks / 35**

## Summary Talk

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## A Generic Approach for Gas Detectors Instrumentation in Nuclear Physics

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An outline of the trends in conceptual designs for Time Projection Chambers, Active Targets and Trackers to render them generic for changing requirements in Nuclear Physics instrumentations. Examples will be drawn from several experiments that are being built today.