# Final Report Hadron Physics3 Project
# Contract 179EU/11.07.2012

## Project duration: 2012 - 2014

**Project Objective**: Development of new detector prototypes and associated front-end and digitization electronics in order to fulfill the requirements of CBM experiment at the future experimental facility FAIR, in Darmstadt, aiming to investigate the QCD phase diagram at high net baryon densities.

The activities within the frame of the project were:

1 Mixed electron and pion in-beam test of the two TRD detector prototypes developed in HPD/IFIN-HH department: Multi-Wire Proportional Chambers with a symmetric structure relativ to the readout electrode and Single Multi-Wire Proportional Chamber coupled with a small drift region.

2 Central detector of SIDDHARTA-2 experiment at INFN-LNF.

Determination of the pion rejection factor of the two TRD detector prototypes developed in HPD department: Multi-Wire Proportional Chambers with a symmetric structure relativ to the readout electrode and Single Multi-Wire Proportional Chamber coupled with a small drift region.

3 High counting rate in-beam test of the RPC prototype based on low resisivity glass with the granularity required by the inner zone of the CBM-TOF subdector.

**Objectives of the project activities**:

1 Design and construction of the experimental setup for in-beam test; on-line data monitoring and calibration. Development of the software for data analysis.

2 Development of the SIDDHARTA-2 central detector for kaons detection using plastic scintillators read out by the SiPM devices. Development of the data acquisition system and associated software.

Pion rejection factor estimation as a function of number of TRD layers for the two TRD detector prototypes developed in HPD department: Multi-Wire Proportional Chambers with a common readout electrode and Single Multi-Wire Proportional Chamber coupled with a small drift region.

3 Experimental results in terms of time resolution, efficiency and cluster size as a function of counting rate.

The R&D activities for a TRD prototype for high counting rates, up to $10^5$ part.$\cdot$cm$^{-2}\cdot$s$^{-1}$ and of a RPC prototype for counting rates up to $2.5\cdot10^4$ part.$\cdot$cm$^{-2}\cdot$s$^{-1}$ were developed whithin the framework of HP3/WP19 of FP7 Program of European Union. These activities are focused on the requirements imposed to the TRD and TOF subsystems of the CBM (Compressed Baryonic Matter) experiment at FAIR, Darmstadt. Due to the high interaction rates at which the experiment is designed to run, up to $10^7$ interactions$\cdot$s$^{-1}$, in the innermost part the detectors of the experimental setup will be exposed to high counting rate and multiplicity environment.

The CBM experiment includes a transition radiation detector (TRD) for identification of high-momentum electrons with a pion discrimination efficiency better than 1% for 90% electron efficiency. At the same time it will perform intermediate tracking with a position resolution of 200 $\mu$m - 400 $\mu$m in order to match tracks reconstructed in the silicon tracking system (STS) to the time-of-flight (TOF) system. Being a fixed target experiment, the most forward angles of CBM-TRD have to cope with counting rates up to 100 kHz/cm$^2$. Therefore a fast detector is required.

The RPC counters of the inner zone of the CBM - TOF wall should provide a system time resolution of 80 ps and an efficiency beter than 95% being exposed to a particle flux up to 25 kHz/cm$^2$. However, a RPC by construction is limited in rate capability due to the resistivity of the material used for resistive plates. The optimal way to increase the rate capability of this counters is to use for resistive electrodes materials with lower resistivity than float glass (currently used in the RPC construction).

The goal of SIDDHARTA-2 experiment from INFN-LNF is to measure for the first time the X-ray emmision in the kaon transition from 2p$\rightarrow$1s using an upgraded version of SIDDHARTA experimental setup. The IFIN-HH proposal for upgrading the kaon subsystem is to built a detector based on 10 plastic scintillator barrel with a cross-section of 1 cm x 1 cm coupled at both ends with SiPM. This solution allows reconstruction of the trajectory of the two charged kaons rezulted from the decay of the $\Phi(1020)$ meson. The digitization of the signals delivered by SiPM is performed by FPGA based convertors. The R&D activities for upgrade of the SIDDHARTA experiment were developed within the frame of HP3/WP24 şi HP3/WP28 of FP7 Program of European Union.

The RPC and TRD prototyopes developed in Hadron Physics Department (HPD) of IFIN-HH where tested in-beam at international accelerating facilities.

The TRD detector prototypes developed in HPD were tested with a mixed electron/pion beam of 1-5 GeV/c momenta at T10 beam line of the CERN PS accelerator.

In order to perform the in-beam test of the detector, in addition of the design, construction and preliminary tests of the prototypes, it was necessary to design and manufacture the mechanical components needed for mounting and align the detectors in the beam line, to perform a proper configuration of the MBS acquisition system on both hardware and software sides, to develope software for on-line data monitoring and calibration.

The original TRD architecture, proposed by our group from HPD for electron discrimination in a high counting rate environment, is based on two multiwire proportional chambers with a common double-sided pad structure read-out electrode. The detector maintains the timing properties of a single multiwire proportional chambers (MWPC) while the gas thickness for transition radiation (TR) absorption is doubled. The design based on two MWPC readout by a common pad plane electrode with a negligible absorption of TR improves the rejection power of a single TRD layer while conserving the timing properties of a single MWPC with the same anode-cathode distance. The readout electrode with triangular shaped pads allows for position determination in two directions, along and across the pads with a single TRD layer. An excellent pion efficiency of 0.5 % for a 6 TRD layers configuration was obtained for a 80%/20% Xe/$CO_2$ gas mixture. The results obtained in-beam demonstrate that a TRD detector with 6 layers of such architecture fulfills the required electron/pion discrimination performance of CBM experiment. The TRD prototype based on a single multiwire proportional chamber coupled with a small drift region fulfills the requirement of high geometrical efficiency of CBM-TRD stations. A good pion misidentification probability of 1.18% was obtained for a six TRD layer configuration, but this performance could still be improved by increasing the FASP-V02 shaping time to 100 ns, as it was shown by the performed simulations.

In order to fullfil the counting rate requirements of the inner zone of the CBM-TOF wall, our group from HPD/IFIN-HH has developed prototypes based on low resistivity glass. The prototype has as strip sizes, 7.1 mm pitch (5.6 mm width and 1.5 mm gap) and 96 mm length. The active area of 96 x 280 $mm^2$ is covered by 40 strips. Two identical counters with low-resistive glass electrodes of 0.7 mm thickness and 2 x 5 gaps of 140 $\mu$m are mounted in a common gas box in a staggered way (with an overlap of 6 mm along the strips) in order to start to develop a basic architecture for covering the inner zone with a more complex configuration in which the counters will be assembled, called module. High count rate tests were performed at COSY/Jülich with a proton beam of 2.5 GeV/c, exposing the counter on an area limited to the beam spot sizes. A time resolution better than 70 ps was obtained at 100 kHz/$cm^2$ and an efficiency better than 90% at this counting rate.

The results obtained during the project period were reported in:

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  e/$\pi$ identification and position resolution of high granularity single sided TRD prototype
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  Electron/pion rejection performance and systematic studies of position resolution of Bucharest TRD prototype
  $20^{th}$ CBM Collaboration Meeting, Kolkata, India, 24 - 28 September, 2012

- M. Petriş, M. Petrovici, V. Cătănescu, V. Simion, D. Bartoş, I. Berceanu, A. Bercuci, G. Caragheorgheopol, F. Constantin, M. Târzila, C. Bergmann, D. Emschermann, S. Linev, W.F.J. Mueller, J.P. Wessels
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- Mariana Petriş and Mihai Petrovici
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