The ALICE Experiment, NRNU MEPHI a Two-way Road

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Abstract. ALICE is one of four main experiments at the Large Hadron Collider (CERN, Geneva). MEPHI is the member of the ALICE collaboration since 1996 year. Participation of the university professors in the international experiments of the highest level provides for their high scientific and knowledge level and therefore the level of their students and post-graduate students. Thus the students enter into scientific researches quite easily providing for the participation of Russian scientists in a large number of other international experiments.

1. The ALICE experiment

The Large Hadron Collider (LHC) at CERN gives the possibility to study the processes of collision of protons and more heavy particles up to lead and also the combination of the collisions of different particles up to the energies about 7 TeV per nucleon. In four crossing points of the two accelerated beams were build four large detectors of the secondary particles created in the collisions, one of them namely ALICE [1] is dedicated to the studies of ion-ion (led-led) collisions. The goal of the ALICE experiment is the study of the new state of matter – so-called quark-gluon plasma (QGP). The formation of the QGP manifests itself in various effects the study of which is the purpose of the ALICE detector system. The most important task of the detector system is registration and identification of all particles born in collisions as well as the particles – spectators. The ALICE experiment is dedicated to clarify the most fundamental problems:

- What happens with the matter when heated up to the temperature 100 000 times more than at the center of the Sun?
- Why protons and neutrons are 100 times heavier than the quarks of which they consist?
- Is it possible to make quarks free inside the dense nucleon matter?

The artistic view of the ALICE detector is shown in Figure 1. The detector was put into operation in 2008 year and participated in the first and the second runs of the LHC. The main results were obtained during Pb-Pb runs in 2010 and 2011 years at the energy in the center of masses 2.76 TeV per nucleon and also in 2015 and 2016 years at the energy 5.02 TeV per nucleon. Besides that in 2012, 2013 and 2016 years three special runs with proton-led collisions were carried out at the energies 2.76 … 8.16 TeV per nucleon.

For the illustration of the complexity in analysis a result of a Pb-Pb collision as seen in the Time Projection Chamber is shown in Figure 2. The detector system should trace and identify up to 10 000 secondary particles.

One of the important conditions of all experiments at CERN is a broad international cooperation. Namely in ALICE are working about 1500 scientists, engineers and technicians including about 350 post-graduate students representing 154 scientific centers from 37 countries.

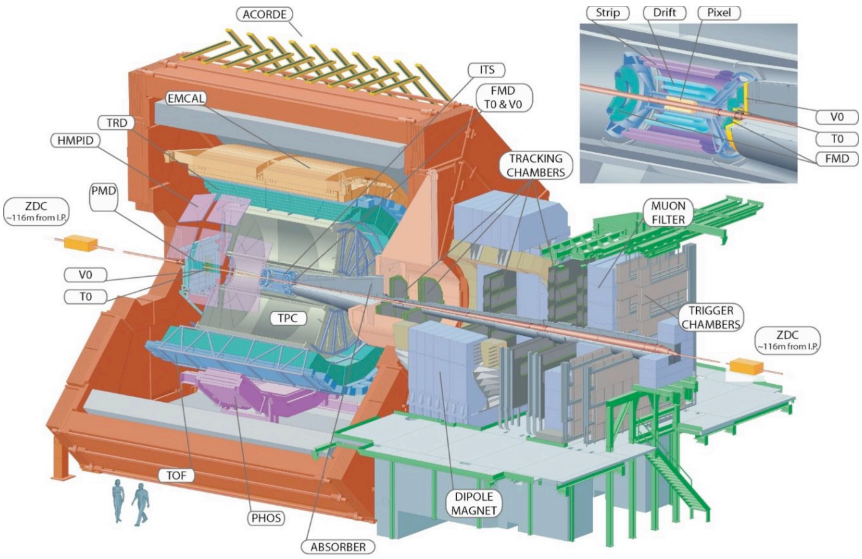

Figure 1. The artistic view of the ALICE detector.

For the moment the LHC program is fixed up to year 2029, further on a new run with the ten times increased luminosity is foreseen. For the future are considered the possibilities to build a collider LHC –hh with a ten times higher energy (about 100 km long), or a linear electron-positron collider (40 km long), or a muon collider. This program has been considered up to 2090 year, so the preparation of physicists for large experiments can be planned for the whole century.

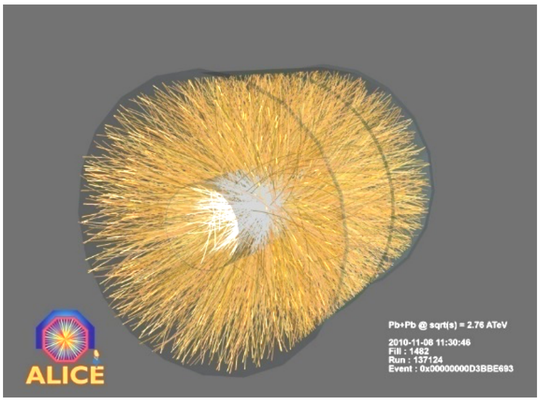

Figure 2. A result of a Pb-Pb collision as seen in the Time Projection Chamber.

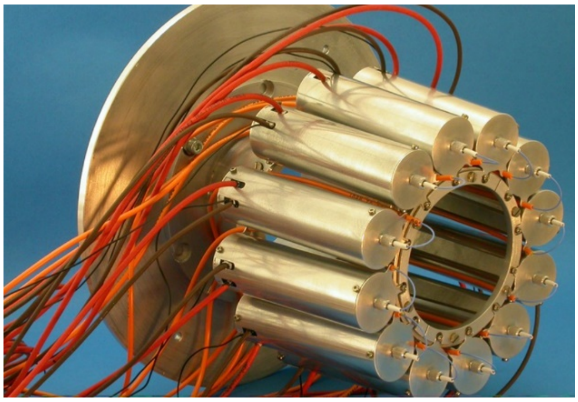

Figure 3. An assembly of Cherenkov counters (T0 detector).

2. Participation of NRNU MEPHI

2.1. Pestov spark chamber counters

At the beginning of 1996 year the MEPHI group joined the development of the time-of-flight system (TOF) of the particle identification based on the Pestov spark counters, at that time considered as the main option of TOF. The work was conducted at GSI (Darmstadt, Germany). The inventor of the counters Yu. Pestov was invited to GSI and in fact headed the job. He suggested us to develop the multichannel front-end electronics for amplitude measurements of the signals of Pestov counters. The work went on very actively, a lot of technical problems were solved, and the prototypes of the modules were produced and tested during a real experiment at CERN. Yu. Pestov achieved the best in the world time resolution for gas filled detectors better that 30 picoseconds [2].

Still when the Pestov option was considered in the ALICE collaboration, it was rejected because of numerous practical difficulties, very high price and some problems with safety of gas mixtures. Another option of TOF based on parallel plate resistive proportional counters using the same Pestov idea of discharge area limitation by resistive electrodes suggested by Italian group was finally accepted.

2.2. Development, production and running the start trigger detector T0

The idea of the T0 detector was based on our experience of the development of Russian photomultiplier tube with fine-mesh dynodes which can be operated in high magnetic field. The work was carried out in collaboration with MELZ, St-Ptb Nuclear Physics Institute and St-Ptb enterprise "Electron". The final option produced by "Electron" was labeled as FEU-187.

The T0 start trigger detector was proposed by the group MEPHI-INR (team leader prof. V. Grigoryev) as by the end of the nineties it became clear that the main option of the ALICE start detector based on microchannel plates cannot be realized in time if ever. So the ALICE collaboration accepted our proposal and the project was carried out by the international collaboration consisting of MEPHI, INR (Moscow), Kurchatov Institute and Uvaskula university (Finland) headed by docent W. Trzaska. The most part of the work including putting the detector into operation was fulfilled by the Russian participants.

The particle detection part of the detector [3] consists of two arrays (T0-A and T0-C) of Cherenkov counters based on PM tubes FEU-187 and quarts radiators. Figure 3 shows one of the arrays consisting of 12 Cherenkov counters. The nominal center of collisions lies between T0-A and T0-C. This geometry permits to determine the collision point by the time difference between signals from the two arrays. As the time resolution of the arrays is better than 50 picoseconds, the point can be determined with the uncertainty about 1 cm. The absolute time of the collision determined by the arrays gives a start signal for the time-of-flight detector system of the ALICE. T0 detector system also includes a unique laser calibration system based on a semiconductor laser with a pulse duration 30 picoseconds. A corresponding electronic system for generation of the trigger signals and also measurements of time and amplitude pulse parameters for each counter was also developed and produced.

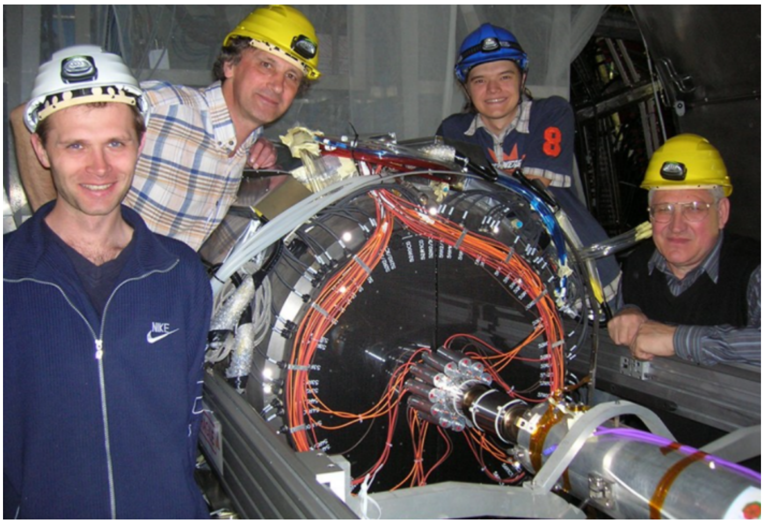

Figure 4. The process of assembling the T0-C in the ALICE magnet.

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Figure 4 shows the process of assembling the T0-C in ALICE magnet in the cavern. The detector was installed into ALICE in year 2007, in 2008 the work of the collider started. The long experience of running the detector from 2008 up to 2019 years showed that the detector was designed correctly from both technical and methodical points of view. As the T0-C was placed behind other detectors inside the magnet we had no access to it during the whole period of work. Nevertheless, all PM tubes were in good state with minimal deviations from their initial characteristics. As a whole the detector operated 10 years without significant changes of the parameters. For the moment the detector is disassembled and in year 2021 with the beginning of a new cycle of the LHC operation a new detector FIT (Fast Interaction Trigger) will substitute T0. An updated and broader collaboration is developing this new detector.

2.3. Development of the Fast Interaction Trigger (FIT)

The new detector [4] should be more efficient for the low multiplicity events and at the same time more compact compared with the T0 detector. Due to the additional muon detector practically at the same place only 9 cm in length along the beam pipe are left for the start trigger detector. Only plane PMTs based on microchannel plates could be used in this case.

For the moment there are about 40 members of the new FIT collaboration representing 19 institutes from 9 countries. Still the main works in the FIT collaboration as in T0 are conducted by MEPHI, INR and Jyvaskyla University.

The layout of the FIT detector is shown in figure 5.

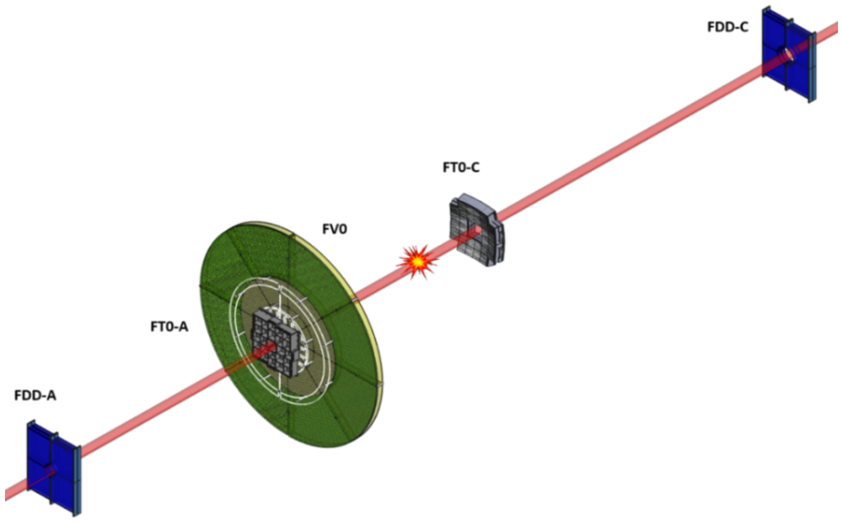

Figure 5. The layout of the FIT detector.

MEPHI is now developing the detectors FT0-A and FT0-C. The scientists from MEPHI have made practically all necessary investigation of different PMTs for these detectors and also the detailed studies of the physical characteristics of the proper PMT. Very good time resolution (better than 50 picoseconds) needed for the start trigger detector is mainly determined by the characteristics of the photomultiplier chosen. The PMT XP85012 which we chose after tests of different PMTs in principle meets the demands of the FT0 detectors. Still after the detailed studies of the PMT properties we found the way for their further improvements which gave the possibility to decrease the crosstalks between channels and also to get better results when registering single particles. As a result of discussion with a producer the upgrade brought to a new option of the PMT XP85002-FIT/Q. Figure 6 shows the PMT together with Cherenkov radiators, the PMT signals being subdivided into 4 parts for better granularity of the detector for multiplicity measurements. The new PMT demanded detailed measurements of the characteristics of the first samples and input control of all other PMTs. For the moment the first detector FT0-C is assembled, tested and ready for installation in ALICE. Figure 7 shows a half of the FITT0-C detector in the process of assembling. The beam tests gave the time resolution of the detector equal to 13 picoseconds – a record for large area Cherenkov detectors.

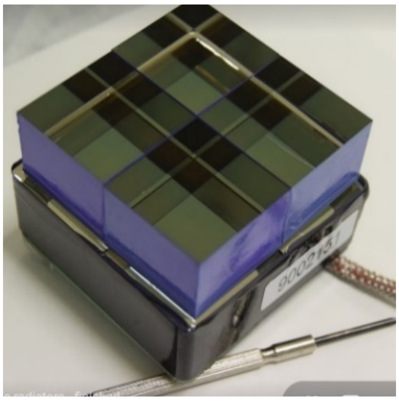

Figure 6. The PMT together with Cherenkov radiators.

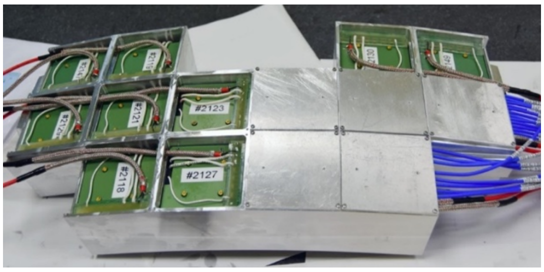

Figure 7. An assembly of Cherenkov counters (T0 detector).

3. The organization of works in international projects

Conclusions that we can make from our participation in a large international experiment. To become a member of the international collaboration one needs:

- Money for work at home and for the input to a common collaboration fund;
- High qualification adequate to the problem;
- A properly equipped home laboratory;
- Knowledge of the English language.

A properly equipped home laboratory together with regular visits to the best laboratories abroad provides for a proper training of the students and their readiness to work in mega projects. An active participation of the university professors in the projects is essential – otherwise how can they teach the students? Knowledge and experience go in both directions – this is a two-way road.

Unfortunately, too little number of Russian universities participates in the large experiments. In ALICE there are only two of them, same in other CERN experiments. A strong support of the Russian government is really needed.

Acknowledgements

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