Project submitted for the base funding of Alikhanyan National Scientific Laboratory

TITLE: THE STUDY OF THE PARTICLE PRODUCTION MECHANISMS IN HIGH-ENERGY NUCLEAR INTERACTIONS

Principal Investigator: Gulkanyan Hrant

Division, group: Experimental Division, groups 143, 144 and 124.

The Project will be performed in collaboration with the CERN (the ALICE experiment), JINR (the BECQUEREL experiment) and IHEP (the SKAT experiment).

DURATION: 3 years

Estimated Project Costs

Estimated total cost of the project (US $)	150000

Including:

Payments to Individual Participants	144000
Equipment	1400
Materials	400
Other Direct Costs	
Travel	4200

PROBLEMS:

The proposed investigations concern the following problems in the field of high-energy physics:

1. The looking for and the study of properties of a new state of the matter composed of free quarks and gluons – the quark-gluon plasma (QGP) – the primordial matter which presumably filled the Universe a few microseconds after Big Bang.
2. The experimental study of the cluster structure of light nuclei (including radioactive ones) aimed at gaining deeper insight into the properties of the nuclear forces and the mechanisms of cosmic nucleosynthesis.
3. The experimental study of the neutrinoproducttion of hadronic resonances and mutihadron systems on nuclear targets, providing unique information on the space-time structure of the quark string fragmentation and hadron formation.

OBJECTIVES

1.The ALICE detector of the experimental programme of CERN is designed to study the properties of the extremely hot and dense strong interacting primordial matter, Quark-Gluon Plasma (QGP), produced in the heavy-ion collisions at the ultrahigh energy provided by the LHC accelerator. The members of ANSL group have been participating in the ALICE collaboration works since 1994, making contribution to the design, development, construction (with particular emphases to the Muon Spectrometer and ALICE Grid Infrastructure), installation and maintenance of different components of ALICE detector. Besides, the group has deployed in ANSL an ALICE site of the LHC worldwide Grid infrastructure, called WLCG. Within its commitments as ALICE collaboration member, the group will continue in 2011-2013 the works on data analysis, software and Grid middleware development and maintenance.

- analysis of anomalous suppression of the yield of heavy quarkonium states (J/ψ, ψ', Υ, Υ', Υ'') in the $\mu^+ \mu^-$ channel.
- Study of the multiparticle production in the Pb-Pb collisions: the hadron multiplicities, yield of resonances, femtoscopy

2.The cluster structure of light nuclei and they excited states will be studied in the dissociation processes of relativistic nuclei in a nuclear track emulsion, at energies of the Dubna Nuclotron (a few GeV per nucleon). The nuclear emulsion method provides an unique possibility to observe excitations close to the few-body decay threshold related to the inverse, few-body fusion processes which can play an important role in the cosmic nucleosynthesis.

3.The data obtained with the help of the SKAT bubble chamber exposed to the Serpukhov accelerator neutrino beam with energies $3 < E_\upsilon < 30$ GeV will be analyzed. For the first time, the nuclear effects in the inclusive production of hadronic resonances and three hadron systems in leptonuclear reactions will be studied, providing new, valuable information in the space-time pattern of the quark string fragmentation and hadron formation.

TASK 1:

Task description and milestones	Participating Institutions
Task 1.1 Participation in the ALICE experimental runs and detector maintenance works	CERN, ANSL
Task 1.2 Development of the software for Geometry Monitoring System (GMS) of the ALICE Muon Spectrometer (2011)	ANSL, IPNL(Lyon)

Task 1.3 Investigation of multiparticle processes in Pb-Pb collisions at the LHC energies: multiplicities, resonances production, femtoscopic measurements of the interaction volume (2011-2013)	CERN, ANSL
Task 1.4 Investigation of charmonium and bottonium production in Pb-Pb and p-p collisions. Development of simulation and ALICE data analysis codes (2011-2013)	CERN, ANSL, JINR
Task 1.5 Study of spectral functions of light mesons (ρ, ω and φ) produced in e^+e^- and $\mu^+\mu^-$ channels. Development of the simulation and data analysis codes (2012-2013)	CERN, ANSL, IPNL (Lyon)
Task 1.6 Development of the components of the ALICE data accumulation, distribution and analysis environment, including the middleware of ALICE Grid infrastructure, AliEn, user documentation and user interfaces (2011-2013)	CERN, ANSL
Task 1.7 Administration and maintenance of the CERN ALICE Analysis Facility (2011-2013)	CERN,ANSL
Task 1.8 Administration and maintenance of the WLCG/ALICE cluster of ANSL (2011-2013)	ANSL
Task 1.9 Work of one master study and two bachelor study students on their theses, within the Tasks 1.5 and 1.6 (2011-2013)	ANSL

Description of deliverables	
	Publications, presentations at the ALICE and ANSL meetings and seminars, diploma theses, annual and final reports

TASK 2:

Task description and main milestones	Participating Institutions
Task 2.1 Data handling on interactions of relativistic nuclei in photoemulsions (2011)	ANSL, JINR
Task 2.2 Data handling on dissociation of relativistic nuclei in photoemulsions. A study of the cluster structure of isotopes of lightest nuclei (Be, B, C, N) (2012)	ANSL, JINR
Task 2.3 Data handling on dissociation of relativistic nuclei in photoemulsions. A study of the cluster structure of isotopes of lightest nuclei (Be, B, C, N) . A study of the α – clusterization	ANSL, JINR

of light nuclei (^{28}Si and ^{32}S). (2013)	

Description of deliverables	
2	Annual reports, publications, the final report

TASK 3:

Task description and main milestones	Participating Institutions
Task 3.1 A study of the inclusive neutrinoproduction of $\Delta^{++}(1236)$ on protons and neutrons (2011)	ANSL, IHEP
Task 3.2 A study of the nuclear attenuation of three-hadron systems (2012)	ANSL, IHEP
Task 3.3 A study of the inclusive production of $\Delta^{++}(1236)$, $\Delta^{+}(1236)$ and $\Delta^{0}(1236)$ in neutrinonuclear interactions (2013)	ANSL, IHEP

Description of deliverables	
3	Annual reports, publications, the final report

IMPACT:

1. The heavy-ion collisions at the CERN LHC (up to lead-lead collisions with the energy of 287 TeV per beam) are expected to reproduce the strong interacting matter composed of free quarks and gluons (QGP) which filled the Universe a few microseconds after the Big Bang. Although some indications on the QGP formation were observed earlier at lower energy range at the RHIC and the CERN SPS, in particular, in the CERN NA50 and NA60 experiments (see, e.g., references [1-4] with the authorship of the participants of this Proposal), more conclusive and reliable data will be provided by the ALICE experiment since the temperature and density of the matter created at the Pb-Pb collisions at LHC will largely exceed those necessary for QGP formation.
2. The unprecedented spatial resolution (0.5 μm) in the method of nuclear track emulsion opens a unique possibility to study the multi-cluster structure and low-laying excitations of nuclei which can be observed in the coherent dissociation of relativistic nuclei in photoemulsions (see, e.g., references [5-8] with the authorship of the participants of this Proposal). The scale of the measured excitation energies can be as small as that typical for their inverse reactions – multiparticle fusion processes occurring in the stellar environment. The experimental study of the coherent dissociation processes can, therefore, have important astrophysical applications.
3. The total yields and differential spectra of hadrons in leptonuclear reactions reflect the space-time structure of the quark string fragmentation and the formation of hadrons, both produced directly or as a result of secondary intranuclear interactions or originate from the decay of resonances. The latter play a significant role in the production of stable hadrons. Hence, the space-time pattern of the leptoproduced quark-string fragmentation and the formation of hadrons would be rather incomplete

without discerning to what extent the hadrons detected in a given phase-space domain originate directly from the string fragmentation and to what they are decay products of other, higher mass string fragments – resonances. Up to now, the experimental data are obtained, only for the leptoproduction of light meson resonances (see, e.g., the references [9-11] with the authorship of the participants of this Proposal), while the first data on the inclusive production of nucleonic resonances will be obtained in the framework of this Proposal. It is also foreseen to obtain the first experimental data on the leptoproduction of trihadron systems, in addition to those obtained earlier for the dihadron [12].

References:

[1] M. C. Abreu et al. (NA50 Coll.), Eur. Phys. J. C 39 (2005) 335
"A new measurement of J/ψ suppression in Pb-Pb collisions at 158 GeV per nucleon"

[2] R. Arnaldi et al. (NA60 Coll.), Phys. Rev. Lett. 96 (2006) 162302
"First measurement of the ρ spectral function in high-energy nuclear collisions"

[3] R. Arnaldi et al. (NA60 Coll.), Phys. Rev. Lett. 100 (2008) 022302
"Evidence for radial flow of thermal dileptons in high-energy nuclear collisions"

[4] R. Arnaldi et al. (NA60 Coll.), J. Phys. G 37 (2010) 094030
"Φ production in In-In collision at 158 A GeV"

[5] D.O. Krivenkov et al., Phys. Atom. Nucl. 73 (2010) 2103
"Coherent dissociation of relativistic ^{9} C nuclei"

[6] D. A. Artemenkov et al., Phys. Atom. Nucl. 71 (2008) 1565
"Fragmentation of relativistic nuclei in peripheral interactions in nuclear track emulsion"

[7] N. P. Andreeva et al., Phys. Atom. Nucl. 68 (2005) 455
"Topology of "white stars" in relativistic fragmentation of light nuclei"

[8] F. A. Avetyan et al., Yad. Fiz. 59 (1996) 110
"Coherent dissociation ^{16} O $\rightarrow 4\alpha$ in emulsion at 4.5 GeV/c per nucleon"

[9] N. M. Agababyan et al., Phys. Atom. Nucl. 70 (2007) 1898
"A study of the nuclear-medium influence on ρ^0 neutrinoproduction"

[10] N. M. Agababyan et al., Yad. Fiz. 74 (2011) 246; IHEP Preprint 2010-4, Protvino, 2010
"The yields of light meson resonances in neutrino-nucleus interactions at $< E_\upsilon > \approx 10$ GeV"

[11] N. M. Agababyan et al., Yad. Fiz. 74 (2011) 256; IHEP Preprint 2010-5, Protvino, 2010
"A study of the neutrino production of Φ and D_s^+ mesons"

[12] N. M. Agababyan et al., Yad. Fiz. 74 (2011) 264; IHEP Preprint 2010-8, Protvino, 2010
"A study of the double hadron neutrinoproduction on nuclei"

Personnel Commitments

N	Name	Position	Staff	Task participation
1	Abramyan Armenuhi	Bachelor student, Engineer-programmer at ANSL	0.5	Task 1
2	Grigoryan Smbat	Senior scient. research.	1	Task 1
3	Harutyunyan Artem	Senior laboratorian	1	Task 1
4	Hayrapetyan Arsen	Minor scient. research.	1	Task 1
5	Kakoyan Vanik	Senior scient. research.	1	Task 1
6	Manukyan Narine	Bachelor student, Programmer at ANSL	0.5	Task 1
7	Papikyan Vardanush	Master study student, Engineer- programmer at ANSL	0.5	Task 1
8	Avetyan Fira	Engineer	1	Task 2
9	Hovnanyan Knarik	Engineer	1	Task 2
10	Moiseenko Aza	Minor scient. research.	1	Task 2
11	Sarkisyan Victoria	Group leader	1	Task 2
12	Torosyan Hrach	Senior scient. research.	1	Task 2
13	Amirjanyan Armik	Laboratorian	1	Task 3
14	Grigoryan Natella	Minor scient. research.	1	Task 3
15	Gulkanyan Hrant	Leading scient. research. Group leader	1	Task 3
16	Karamyan Zhanna	Senior scient. research.	1	Task 3

The mean age of participants: 52
The number of participants younger than 35 year: 5
The number of participants of pension age: 5

Equipment (www.Lans.am)

Equipment description	Quantity	Cost (US $)
PC (Pentium-4)	1	620
PC Monitor	3	600
Keyboard	6	90
Mouse	6	90
Total		1400

Materials

Materials description	Quantity	Cost (US $)
Cartridge	3	300
Paper		100
Total		400

Other Direct Costs

Direct costs description	Cost (US $)
—	—

Travel costs (US $)

CIS travel	International travel	Total
4200		4200

Technical Approach and Methodology

1. The dimuon production in nuclear collisions in the ALICE experiment

One of the most powerful tools in investigations of properties of the hot, dense matter (in particular, the QGP) created in high-energy heavy ion collisions are the processes of the heavy quarkonium production. The vector states of the quarkonium (J/ψ, ψ', Y, Y', Y") can be properly registered via their dimuon decays. One of the largest subdetectors of ALICE, the Muon Spectrometer (MS), is dedicated to the detection of muons (see [1.1] and references therein). The MS consists of 10 big tracking chambers (TC) used for reconstruction of muon trajectories. The proper reconstruction of the quarkonium mass (with the accuracy of 100 MeV for bottomium states) requires about 40 μm precision in the knowledge of the TC's relative positions. This task will be achieved by the Geometry Monitoring System (GMS) designed and constructed with the involvement of the participants of this Proposal (see [1.2-1.7] and references therein). The GMS represents a network of 460 optical sensors which are installed on platforms placed at each corners of the TC's. The analysis of the data from the optical sensors provides a measurement of the TC's relative displacements during the physical runs. Further works are foreseen to improve the analysis algorithm and to achieve the maximal accuracy and the reliability of the GMS performance.

The huge volume of information recorded from the ALICE subdetectors requires

the development of advanced tools for the data acquisition, accumulation, analysis and visualizations. These tasks will be achieved on the base of the ALICE Grid information infrastructure (AliEn). The further development of the ALICE software is foreseen in this Proposal, as a continuation of resent investigations performed by its participants (see, for example, [1.8-1.15]).

It is foreseen to continue the works started by participations of this Proposal (see, for example, references [1.16-1.19]), on the detailed simulations of the dimuon production in nucleus-nucleus, proton-nucleus and proton-proton collisions. The simulation results will be used in the analysis and interpretation of experimental data on the production of vector mesons.

[1.1] G. Dellacasa et al., CERN/LHCC 2000-46, 2000
[1.2] R. Tieulent et. al., ALICE Internal Note ALICE-INT-2005-009
[1.3] P. Pillot et al., ALICE Internal Note ALICE-INT-2005-020
[1.4] R. Tieulent et. al., ALICE Internal Note ALICE-INT-2007-010
[1.5] V. Kakoyan, ALICE Internal Note ALICE-INT-2007-028
[1.6] V. Kakoyan, ALICE Internal Note ALICE-INT-2009-004
[1.7] R. Tieulent et. al., ALICE Internal Note ALICE-INT-2010-010
[1.8] A. T. Harutyunyan, A. R. Hayrapetyan, Proc. of 1st Int. Conf. “Distributed Computing and Grid-Technologies in Science and Education”, 2004, 29 June-2 July, Dubna, Russia
[1.9] A. A. Grigoryan, A. T. Harutyunyan, A. R. Hayrapetyan, Proc. of 2nd Int. Conf. “Distributed Computing and Grid-Technologies in Science and Education”, 2006, 26-30, Dubna, Russia
[1.10] A. Harutyunyan, Proc. at 3rd Int. Conf. “Distributed Cmputing and Grid-Technologies in Science and Education”, 2008, June 30-July 4, Dubna, Russia
[1.11] A. Hayrapetyan, Proc. at 3rd Int. Conf. “Distributed Cmputing and Grid-Technologies in Science and Education”, 2008, June 30-July 4, Dubna, Russia
[1.12] A. Harutyunyan, A. Hayrapetyan, Proc. at 3rd Int. Conf. “Distributed Cmputing and Grid-Technologies in Science and Education”, 2008, June 30-July 4, Dubna, Russia
[1.13] B. Segal et al., Proc. of Latin American Conference on High Performance Computing, 2009, Merida, Venezuela
[1.14] P. Buncic et al., J. Phys: Conf. Ser. 219042003 (2010)
[1.15] A. Harutyunyan et al., Proc. of CHEP 2009 Conference, Prague, Gzech Republic, 21-27 March 2010
[1.16] S. Grigoryan and A. De Falco, ALICE Internal Note ALICE-INT-2008-16
[1.17] L. Aphecetche et al., ALICE Internal Note ALICE-INT-2010-015
[1.18] L. Manceau et al., ALICE Internal Note ALICE-INT-2010-004
[1.19] X. Zhang et al., J. Chines Physics C 34 (09) 1538, 2010

2. The dissociation of relativistic nuclei in photoemulsion

The dissociation of relativistic nuclei in photoemulsion provides a powerful tool to study the cluster structure and the excitations of nuclei (including the exotic ones). The unprecedented spatial resolution (0.5 μm), the ionization and multiple scattering measurements in the method of nuclear track emulsion provide a unique possibility to detect and identify the fragments emitted in a narrow cone (around the projectile), as well as to reconstruct the effective masses of the fragment systems. The corresponding excitation energies can reach rather low values – up to a few tens KeV – a scale typical for multiparticle fusion processes occurring in the stellar environment.

The aforementioned advantages of the method of nuclear track emulsion allowed the BECQUEREL collaboration [2.1] to reveal the peculiarities of clustering in a number of light nuclei, including the radioactive isotopes of beryllium, boron and carbon (see, for example, [2.2-2.5] and references therein). More detailed and precise data on this topic are foreseen to obtain, in the basis of extended statistics, during next years.

[2.1] http:/becquerel.jinr.ru
[2.2] D. O. Krivenkov et al., Phys. Atom. Nucl. 73 (2010) 2103
[2.3] D. A. Artemenkov et. al., Phys. Atom. Nucl. 71 (2008) 1565
[2.4] N. P. Andreeva et. al., Eur. Phys. J. A 27 (2006) 295

3. Nuclear effects in the neutrinoproduction of resonances and multi-hadron systems

The planned investigations are based on the data collected with the SKAT bubble chamber [3.1] filled with a propane-freon mixture and exposed to a wideband neutrino beam with energies $3 < E_\nu < 30$ GeV. The chamber enables the registration of practically all neutrinoproduced charged particles, the most part of decay gammas and a significant fraction of the decays of neutral strange particles. Moreover, the method developed in [3.2-3.3] allows one to disentangle the neutrino-nucleon and neutrino-nucleus interactions and study the nuclear medium influence on the production of hadrons [3.1-3.5], light-meson resonances [3.6] and two-hadron systems [3.7]. It is foreseen to extend the investigations to baryon resonances and three or more hadron systems.

[3.1] N. M. Agababyan et. al., YerPhI Preprint-1578, 2002, Yerevan
[3.2] N. M. Agababyan et. al., Phys. Atom. Nucl. 66 (2003) 1310
[3.3] N. M. Agababyan et. al., Phys. Atom. Nucl. 68 (2005) 1160

[3.4] N. M. Agababyan et. al., Phys. Atom. Nucl. 69 (2006) 35
[3.5] N. M. Agababyan et. al., Phys. Atom. Nucl. 70 (2007) 1731
[3.6] N. M. Agababyan et. al., Phys. Atom. Nucl. 70 (2007) 1898
[3.7] N. M. Agababyan et. al., Yad. Fiz. 74 (2011) 264