Project submitted for the base funding of Artem Alikhanyan National Laboratory (ANL)

TITLE: THE LOW BACKGROUND MEASUREMENTS
(presented by V.Poghosov)

Division, group: Experimental Physics Division, group 146.

The Project will be partially performed in collaboration with the JINR

DURATION: 3 years

Estimated Project Costs

Estimated total cost of the project (US $)	

Including:

Payments to Individual Participants	
Equipment	12900
Materials	6000
Other Direct Costs	1000
Travel	4200

PROBLEMS:

The main goal of proposed project is to develop underground laboratory to carry out competitive low-background experiments. It's also supposed to continue the investigation of bismuth nuclei fission processes we started before. The project includes the following problems:

1. The measurements of the propagation of radio waves in the rock of the Avan salt mine are proposed to perform for the determination of Askarian [1] method's applicability for high energy cosmic neutrino detection in Avan salt mine. It's known that an outer Galactic astrophysics in the region out of 100 Mps at the energies above 10^{16} eV could be studied by means of neutrinos only. One of the most promising approaches to the problem of detecting such neutrinos is to use Askarian method.

R&D works for other low background measurements in our underground laboratory.

2. In the frame of collaboration with JINR participation in the GEMMA experiment for the searching for the neutrino magnetic moment. This experiment [2] gives now the most stringent in the world an upper limit on its value which is $\mu_\nu / \mu_B \leq 3.2 * 10^{-11}$,

μ_B –Bohr magneton. It's supposed to increase the sensitivity of experimental setup. Participation in the others low-background experiments is also considered.

3. The investigation of bismuth nuclei fission into two and three fragments with comparable masses by GeV energy photons. In spite of the problem of heavy nuclei fission initiated by energetic particles has a more than three decade history it's actual up today. Moreover, photons in such kind of experiments were used only by us [3,4]. This task is out of the main direction of presented project, but we have included it because we have accumulated data, so only processing is needed.

OBJECTIVES

1. The measurements of the attenuation lengths of radio waves in the Avan salt mine at the level of our underground laboratory are proposed to carry out. The Avan salt dome has a volume of several cubic kilometers and could be used as a target for high energy neutrino interactions if our salt rock has a sufficient transparency for radio waves. It's supposed to perform the measurements at the frequency region 50 – 1000 MHz. There is an empty area about square kilometer at the depth about of 660 m of water equivalent, were our laboratory is placed. Such an area allows to put a large array of receiving antennas. The positive results will make our mine attractive for international cooperation.

R&D works for future low background measurements in the underground laboratory will be carried out in two directions mainly. One of them is the continuation of investigation the possibility to decrease the energy threshold of NaI detector that is very important, for example, in dark matter searches experiments. We hope to achieve this aim using contemporary experience and applying some novelties. The other one is R&D the underground monitoring system for muons, which will be performed together with the Cosmic Ray Division.

2. The GEMMA collaboration develops now the experimental setup. Total mass of Germanium detector will be increased by factor four, the energy threshold will be decreased, the distance between active zone of reactor and detector will be decreased. It's very important to use in low background setups materials with lowest radioimpurities as possible. Materials which supposed to be used in constructive details in GEMMA-2 (as well as in other developing setups, which consider our participation) will be tested on the low-background setup in our underground laboratory.

3. The measurements were carried out by us in 90-th on the bremsstrahlung beams of Yerevan synchrotron at different maximal energies (2 GeV, 3 GeV, and 4.5 GeV) of photon spectrum. Nuclear photoemulsions, which were implanted by bismuth nuclei, were used. The data handling of the results of the experiment of bismuth nuclei fission into two and three fragments with comparable masses is performed now.

TASK 1:

Task description and main milestones	Participating Institutions
Task 1.1 Transmitting and receiving systems development. Radio waves propagation measurements. R&D NaI detector	

Task 1.2 Radio waves propagation measurements. R&D of NaI detector. R&D of muon monitor.	
Task 1.3 Radio waves propagation measurements. R&D of NaI detector. R&D of muon monitor.	

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

TASK 2:

Task description and main milestones	Participating Institutions
Task 2.1 GEMMA-1 data handling. (2011)	JINR, ITEP
Task 2.2 R&D GEMMA-2. Measurements of the level of radioimpurities in constructive details for GEMMA-2 and other low-background setups. These measurements will be carried out in our underground laboratory. (2012)	JINR, ITE P
Task 2.3 2 R&D GEMMA-2. Data handling GEMMA-2 and other low-background setups. (2013)	JINR, ITEP

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

TASK 3:

Task description and main milestones	Participating Institutions
Task 3.1 Data handling (2011)	
Task 3.2 Data handling (2012)	

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

IMPACT

1. The measurements of the propagation of radio waves in the rock of the Avan salt mine will determine possibilities of ultra high energy cosmic neutrino detection in our salt mine. Successive attempt to decrease the energy threshold of NaI detector will make possible to construct a setup for dark matter searching at higher

level of sensitivity than DAMA experiment [5] has and so to solve the puzzle of DAMA results. Muon monitoring system at the depth of our underground laboratory detects atmospheric muons with energies higher 150 GeV. This could be interesting, for example, for searching for high energy events from the Sun.

2. It's supposed that the second stage of GEMMA experiment will allow to decrease an upper limit for the value of neutrino magnetic moment up to $\mu_\nu / \mu_B \leq 1.5 * 10^{-11}$.

3. Heavy nuclei fission into two and three fragments with comparable masses initiating by intermediate energy particles were studied using proton and light nuclei beams. So the photon beams should give an additional information to understand these processes. Only our group used such beams [3,4].

BRIEF SURVEY OF THE WORLDWIDE RESEARCHES MADE ON THE PROJECT TOPIC, THE COMPETITIVENESS OF THE PROJECT, AND ACHIVEMENTS OF THE GROUP

1. There are several ultra high energy neutrino experiments, based on Askarian method, are planned. We should mention for example SalSA [6] collaboration that projects to perform such experiment also in salt. For these experiments need as large volume as possible, any additional experiment is desirable. It's important also to have independent measurements, especially in opposite points of Earth. Our activity in R&D NaI detector is determined mainly by following. There is the strong contradiction between DAMA experiment [5], which declared observation of season modulation effect in count (and so the existence of WIMPs with masses about 60 GeV), and the null - results of other experiments (for example, with results of CDMS collaboration [7], which is considered as much more sensitive). So it's very important to perform an experiment, which is able to find out the reason of this incompatibility. DAMA collaboration have used NaI(Tl) scintillation technique. We have some ideas to reduce the energy threshold of NaI detector which will substantially improve the sensitivity because of the quasi-exponentially decreasing signal rate as function of recoil energy (if an elastic WIMP - nucleus scattering is considered). This'll give us a possibility to perform the more sensitive experiment with the same nuclei as DAMA used.
The main goal of R&D muon monitoring setup is systematic monitoring of atmospheric muons with energies more than 150 GeV, including events initiating by particles coming from the Sun. There are no data at this energy threshold.

Our group has the experience in the field of low-background measurements. As an example we can mention the experiment, that had been performed in our underground laboratory together with ITEP (Moscow) in which the first observation of two-neutrino double beta decay of ^{76}Ge was made, and the most stringent limit (for that time) on half- life of neutrinoless double beta-decay in this germanium isotope was set 8]. It allowed us to estimate the lowest upper limit for Majorana mass of neutrino. This was the first experiment with enriched germanium detectors. Contemporary limit for Majorana mass was achieved in the experiments (IGEX [9, and Heidelberg- Moscow [10]) based on this technique. It should be mentioned also our participation in IGEX experiment.

We also performed preliminary measurements of radio waves attenuation in a local region in salt mine [11].

2. As it was mentioned above, the first stage of GEMMA experiment gives the best in the world limit on neutrino magnetic moment [2]. It’s considered substantially increase the sensitivity on the second stage.

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PERSONAL COMMITMENTS

N	Name	Position	Staff	Task participation
1	Aleksanyan Andranik	Engineer-physicist	1	Task 1,2
2	Galstyan Tigran	Senior scient. research.	0.5	Task 1
3	Kotanjyan Tigran	Senior laboratorian	0.5	Task 1,2
4	Poghosov Valeri	Leading researcher Group leader	1	Task 1,2,3
5	Poghosyan Levon	Minor scient. research.	1	Task 1,2
6	Pogosova Olga	Engineer-physicist	1	Task 2,3
7	Reymers Evgeniy	Engineer	1	Task 1
8	Tarverdyan Moris	Engineer	0.5	Task 1

The mean age of participants: 50.5 year
The number of participants younger than 35 year: 2
The number of participants of pension age: 2

Equipment

Equipment description	Quantity	Cost (US $)
PC (Pentium-4)	2	1400
PC Monitor	2	500
Multichannel ADC	2	6000
TRUMP-PCI-8K	1	5000
Total		12900

Materials

Materials description	Quantity	Cost (US $)
Liquid nitrogen	4000 L	4000
Radio components		1000
Other materials		1000
Total		6000

Other Direct Costs

Direct costs description	Cost (US $)
Payments for tender works in the mine	1000

Travel costs (US $)

CIS travel	International travel	Total
4200		4200

TECHNICAL APPROACH AND METHODOLOGY

The low-background laboratory of ANL is located at the depth of 660 m w.e. in Yerevan salt mine. Our laboratory has such an important advantage, compared to known underground laboratories, as it is located in precincts of large city (with corresponding infrastructure and communication system) and near to the known scientific center. This circumstance is very important for realization of the mutually-advantageous international cooperation. It should be mentioned also, that the natural conditions in the mine (the humidity is about 35%, temperature 20-21 C) are very comfortable both for people and electronic devices. It’s well known also, that the natural background in salt mines is exceptionally low (in harder rock the background is higher by several order of magnitude). So it reduces a cost of required passive and active shielding technique. The only disadvantage is a relatively low depth. Nevertheless such a depth is sufficient for many contemporary underground physics’ tasks. As an example we can mention above cited double beta decay experiment [9], which was carried out here.

All auxiliary low-background measurements, needed in the frame of this project, will be performed on our setup based on semiconductor germanium detectors.

ANL has a several hundred kilograms of NaI crystals. The measurements carried out on our low-background setup haven’t revealed the presence of radio-impurities in this crystal. For example, an upper limit for natural potassium doesn’t exceed 100 ppb. So it could be construct the large-scale setup for WIMPs searching if we’ll be able to decrease an energy threshold.