1. Hello everybody!

My name is Vladislav Oleynikov.

I am PhD student in Budker Institute of Nuclear Physics.

The theme of my presentation is “Measurement of ionization yields of nuclear recoils in liquid argon using two-phase detector”

0:00 – 0:15

1. I have divided talk into 5 parts.

First of all I’ll tell you about Our global objectives and current activity.

Then I’ll describe a two-phase Cryogenic Avalanche Detector

In the third part I’ll present our recent results on Ionization yields in LAr.

After this I’ll tell about our Future plans, in particular about S1/S2 selection technique and Neutron double-scattering

And, finally, I’ll give summary of presentation.

0:15 – 1:00

1. Our global objectives are

Development of liquid Ar detectors of ultimate sensitivity for dark matter search and coherent neutrino nucleus scattering experiments and their energy calibration.

Our group is currently conducting researches in the following directions, in the frame of Laboratory of Cosmology and Elementary Particles (located at the NSU and the BINP) and DarkSide experiment.

* Measurement of electroluminescence (EL) yields in two-phase Ar using a 9-liter detector.
* Problem of Ar doping with Xe and N2.
* Measurement of ionization yields of nuclear recoils in liquid Ar using neutron scattering technique.
* Development of new readout technique in two-phase Ar detectors using SiPM-matrices.

1:00 – 2:00

4) Our Experimental setup comprises a vacuum-insulated 9 liters two-phase cryogenic chamber filled with 2.5 liters of liquid Ar.

During each cooling procedure Ar was purified from electronegative impurities by Oxisorb filter, providing electron lifetime in the liquid >70 us. (откуда это число?)

2:00 – 3:00

5) The cryogenic chamber included a cathode electrode, two field-shaping electrodes, a THGEM0, immersed in liquid Ar layer and a double-THGEM assembly, consisting of a THGEM1 and THGEM2, placed in the gas phase above the liquid.

The EL region was formed by the liquid surface and the THGEM1 plate.

There were two ways of optical readout of the EL gap.

Firstly, the gap was viewed by four compact cryogenic PMT, located on the perimeter of the gap.

Secondly, the scintillation in the spectral range other that VUV (NIR, for example) could be recorded using 11 by 11 SiMP matrix.

2:30 – 4:30

6) To produce neutrons a specially designed neutron generator was used that continuously emitted monenergistic not collimated neutrons with a kinetic energy of 2.45 MeV obtained in the DD fusion reaction.

The Design parameters of neutron generator are:

* Neutron yield: 105 neutrons/s (ten to the fifth power)
* Rated current of ions: 50 uA (microamps)
* Operating voltage: 80 kV (kilovolts)
* Insulation: SF6, 8 atm (sulfur hexafluoride at eight atmospheres)

4:30 – 5:30

7) Study of proportional EL in two-phase Ar has been carried out.

The left picture shows the EL gap yield as a function of the electric field in the gap, measured using PMT signal.

The right picture shows the amplitude spectrum of the total PMT signal from the EL gap induced by X-ray from a mixture of the Cd and Am radioactive sources.

High EL gap yield: 15 pe/keV (1.4 pe/e) and good energy resolution: 22% at 60 keV have been reached at 7 kV/cm field in the EL gap.

5:30 – 6:30

8) Recently, we have presented a comprehensive analysis of photon emission and atomic collision processes in two-phase argon doped with xenon and nitrogen.

The problem is currently under study in our group.

You can find details in the article.

6:30 – 7:30

9) The experimental setup and its main parameters have been described previously and now we’ll discuss Measurement of the ionization yield.

A particle interaction in the liquid phase produces primary scintillation (S1) and ionization.

The electrons are drifted away from the interaction site by an electric field and extracted into the gas where they create secondary scintillation (S2).

The ionization yield is ratio of number of electrons escaping recombination with positive ions (ne) and the energy deposited by a nuclear recoil (E).

While for liquid Xe there are ample experimental data on such yields, little is known about it in liquid Ar.

Recently we have measured ionization yield of nuclear recoils in liquid argon at 80 and 233 keV (see the picture).

In present work the ionization yield of nuclear recoils in liquid Ar has been measured at high energy 233 keV for several eclectic fields.

7:30 – 10:00

10) The primary ionization charge in liquid Ar was produced by either 60 keV gamma from 241Am or 2.45 MeV neutron from DD-generator.

The left picture shows a typical oscillogram with a raw signal and integral spectrum for Am isotope.

The right picture shows the integral spectra for Am, neutron and background runs.

10:00 – 10:40

11) To measure ionization yield we subtracted the background-run contribution from the neutron run(see the top left picture).

After this we subtracted the gamma-ray contribution, resulted from a radiative capture in surrounding materials (see the bottom left picture).

Finally, the pulse integral was normalized to that of 60 keV peak and we found spectrum end-point in units of ne (number of electrons escaping recombination with positive ions unit.)

The theoretical spectrum (red curve on the right picture) was convolved with energy resolution function (the result of convolution is black curve).

The Ionization yield was calculated by dividing the end point of experimental spectrum to the theoretical one.

10:40 – 12:10

12) On the graph you can see the ionization yield as a function of electric field for two data sets:

Square for previous data obtained in 2014 and circles for current data.

Field dependence is well described by Jaffe model (red curve ).

Systematic error is dominant and occurs because of calibration using LAr ionization yield of electron recoil.

12:10 – 13:00

13) Previously we used spectra subtraction to reject background events, but also there is opportunity to use S2 S1 ratio as discriminator factor for nuclear and electron recoil.

We irradiated Cryogenic Avalanche Detector by sodium 22 isotope, which produce two gamma quanta.

One of them was detected by BGO counter and produced trigger and another one by CRAD.

The right picture shows typical signals from detectors.

Unfortunately, S1 signal is low, so we plan to install additional SiMP matrix on the detector bottom and improve light collection.

13:00 – 14:10

14) The double-scattering concept has been recently realized in LXe in LUX experiment .

The main idea of this experiment was to register scattered neutron again in the TPC.

We want to measure ionization yield in our experiment for LAr using Neutron double-scattering too.

The left picture shows a scheme of this experiment.

The right picture shows recoil energy dependence as a function of the neutron scattering angle.

Having high spatial resolution in detector, of 1 mm, we expect reaching accuracy of about 2o in scattering angle, corresponding to nuclear recoil energy as low as a few keV

14:10 – 16:00

15) To sum up,

- We have measured the ionization yields of nuclear recoils in liquid Ar using neutron scattering technique, in new ranges of energies and electric fields.

- Neutron double-scattering technique, for low-energy calibration of liquid Ar dark matter detectors, is in the course in our lab.

- We continue to study proportional electroluminescence in two-phase Ar. In particular, we are trying to resolve the problem of doping Ar with Xe and N2 in the two-phase mode.

- These studies are conducted in the frame of R&D program for the DarkSide dark matter search experiment.

16:00 – 17:00