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Neutrino physics with the Baksan Underground Scintillation Telescope

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Summary. — The neutrino experiment at the Baksan Underground Scintillation Telescope is operating for 35 years. We present an updated analysis of observed upward through-going muons in searches for a signal from dark matter annihilations in the Sun and the astrophysical local sources.

First neutrino events was detected at the Baksan Underground Scintillation Telescope (BUST) in December of 1978 [1]. Since then and up to now the neutrino experiment keeps on working. The telescope is located in the Baksan valley of the North Caucasus at an altitude 1700 m above see level and at the depth 850 hg/cm^2 under the mountain Andyrchi where flux of atmospheric muons yet exceeds upward going muons by six orders of magnitude. Separation of arrival direction of muons between up and down hemispheres is performed by the time-of-flight method with time resolution 5 ns [2]. Parameters of the BUST and neutrino selection criteria was presented elsewhere and recently in Refs. [3]. The BUST is made of 3150 liquid scintillator counters of ($70 \times 70 \times 30$ cm^3) which are arranged in four-storey building of $17 \times 17 \times 11$ m^3. The results of multi-year monitoring of the time off-set distribution of each tank in terms of their mean values and sigmas averaged over all detectors per year till January of 2013 are shown in Fig. 1 (left). The plot illustrates a good level of stability of the BUST measurements.

The rate of the general trigger of events at the telescope is 17 Hz, while the measured neutrino rates is ~50 events per year. Totally 1255 upward through-going muons survive all selection cuts for 24.12 years of live time till November of 2009.

The telescope configuration provides muon angular resolution $\sim 1.5°$ for reconstructed trajectories longer than 7 meters, while the energy threshold for upward-going muons is about 1 GeV. This makes the BUST sensitive to a signal from dark matter annihilations (DMA) even for light dark matter particles (up to several GeV). In case of neutrinos from DMA in the Sun we look for an excess of events observed in the direction toward the Sun over background of neutrinos of atmospheric origin. Both distributions are compatible as it seen in Fig. 1 (right) and shown are the obtained 90% c.l. upper limits (UpL) on signal events in assumption of Poisson statistics law. The analysis is optimized with respect to sizes of search cones γ around the direction towards the Sun [3].

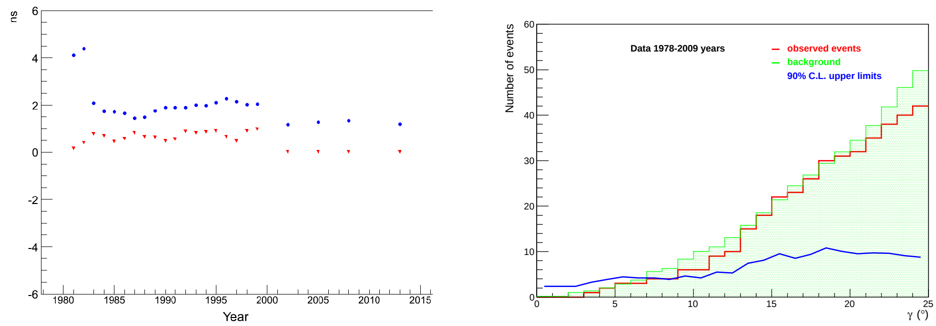

Fig. 1. – Left: measured mean (red) and sigma (blue) values of PMTs time off-set distributions over all 3150 counters of the BUST since December of 1978 till January of 2013. Right: the 90% C.L. upper limits on signal events in the direction toward the Sun (blue) in cone half-angle γ. Measured (red) and background (green) events are also shown depending on the value of γ.

Performing simulations of transport of high energy oscillating neutrinos from the center of the Sun to observer we translate the UpL on events into neutrino and muon fluxes and DMA rate for different dark matter masses and annihilation channels $b\bar{b}$, WW and $\tau\tau$. Experimental systematic error of observed number of events is estimated [4] to be around 8%. Theoretical systematic errors resulting mainly from uncertainties in neutrino oscillation parameters and neutrino-nucleon cross section are found to be from 7% to 50% depending on the mass of dark matter and annihilation channel [3]. Assuming equilibrium between capture and annihilation processes the UpL on DMA rate are recalculated into 90% c.l. UpL on spin-dependent cross sections (SD) shown in Fig. 2 (left) in comparison with the results of other experiments. For the DM mass range 10÷50 GeV the Baksan limits on SD (also SI [3]) cross section in the case of $\tau\tau$ annihilation channel are one of the most stringent to date among the results obtained by neutrino telescopes.

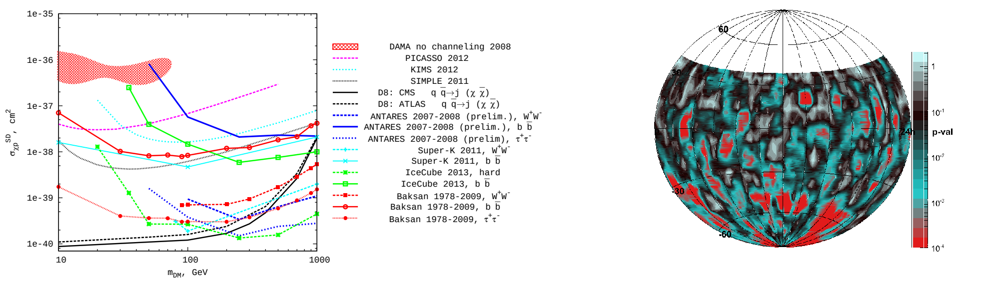

Fig. 2. – Left: Baksan upper limits (all red lines) on SD elastic cross section of dark matter on proton in comparison with other results (see Ref. [3] for details). Right: skymap with p-values of arrival directions of the BUST neutrino events for 24.12 years l.t..

No hints on excess were found anywhere in the visible part of the sky at the Baksan location place (43.16° N and 42.41° E) by scanning it with 3° and a size of cone 5° in a signal search. The Bayesian approach in unbinned method of analysis were applied to optimize a log likelihood "S/B" ratio. The expected background was obtained by swapping the event time and event direction randomly. Numerical optimization resulted in p-values shown in Fig. 2 (right) in equatorial coordinates and as it can be seen without directional features.

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