Baikal-GVD – the Next Generation Neutrino Telescope in Lake Baikal

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on behalf of the Baikal Collaboration

Outline
- Baikal-GVD (Gigaton Volume Detector) Phase I allows to investigate
  - Galactic and extragalactic neutrino source points in TeV - PeV energy range
  - Diffuse neutrino flux – energy spectrum, local and global anisotropy, flavor content
  - Transient sources like GRBs etc.
  - Dark matter – indirect search
  - Exotic particles – monopoles, Q-balls, dark matter, ...
- The experiment looks like km$^2$ - scale 3D array of photo sensors located deep underground
- Flexible structure allows to rearrange of the main building blocks to change, for example, energy threshold
- High sensitivity and resolution of neutrino energy, direction and flavor content

Baikal-GVD Phase I Array:
- 2304 Optical Modules (OM) in GVD Phase I
- OM’s arranged in 8 Clusters with 8 strings each
- Depth is 750 – 1275 m (0.1 to above the bed)
- Distance between OM’s is a string
- 500 m between Clusters

Muon $\Delta t$ distribution:
- Hit time difference on adjacent OM’s
-Muon hit selection:
  - Causality criterion, 20 ns window
  - Three or more OM’s in a row must be hit
  - At least one OM of the three must have $\Delta t \geq 3$ p.c.
- Serves as a cross check of time calibration with 5 ns precision, OM sensitivities

Search for cascades in 2015 (41.6 live days)
- Reconstruction of coordinates (Q > 1.5)
- Energy resolution $\approx 30\%$ (averaged by $E_1 \nu_1$ spectrum)
- $\approx 6$ events/yr ($E_{\nu_1} > 100$ TeV, $N_{\text{OM}} = 200$)
- $\eta_{\text{hit}} = 0.00 - 0.11$, $\eta_{\text{hit}}$, $\eta_{\text{hit}}$ effect area
- Probability of $N_{\text{hit}} > 16$: 0.0947, 0.0015, 0.0026, 0.0041

Search for cascades in 2016 (182.0 live days)
- $E_{\text{hit}}$, $\delta_{\text{hit}}$, $\nu_{\text{hit}}$ & $\eta_{\text{hit}}$ (total)
- $E = 10^7$ TeV, $\delta = 58.0^\circ$, $\nu = 135.1^\circ$, $\phi = 0^\circ$, $\rho = 58^\circ$

Baikal-GVD Site Infrastructure:
- Baikal, Power station site
- The new data taking center at the array site has been installed in 2016.
- The new shore lab was created on the site during summer 2017.
- The building in Baikalik town is ready for the local lab and temporary OM’s storage for detector maintenance and upgrade.

The optical modules production facility in Dubna:
- The facility allows to produce and test up to 12 OM’s per season.
- We need to produce and send to the site 600 OM’s per season.

Search for muon neutrino in 2016 (13 live days)

Muon Neutrino Selection
- Polar angle distribution of muons selected with the requirement of at least 6 hits OM’s at 3 strings.
- Comparison of reconstructed events in obtained data and simulated atmospheric muon flux generated with CORSIKA.

Atmospheric background suppression
- After track reconstruction and cuts on energy variables have been done, Boosted decision tree (BDT) was used.
- BDT is trained on events reconstructed as upgoing with $0 < 0 < 90$ deg, $300$ GeV signal events
- $10^5$ background events
- BDT response cut:
  - $0.20$, $80\%$ signal efficiency
  - $0.25$, $65\%$
  - $0.30$, $40\%$

Result:
- Angular distribution for BDT > 0.2 cut
  - 22 events were selected in the signal region
  - 3 events – expected bg from atm. muons
  - 20 events – expected signal from atm. neutrinos

Search for high-energy neutrinos associated with the GW170817
- GW: 17.08.2017, 12:43:04 UTC $\rightarrow$ J0502396648.637649
- NS4993 at ~ 40 Mpc, equatorial coordinates $\alpha = 2000.0$ + 13h $\delta = +61.8$ $2017.08.17.000000.0000 - C / 222373 : 747$
- Zenith angle of the source at registration time: 90.3°
- No neutrino events associated with GW170817 using cascade mode within both a 500 sec and 14 days are observed.
- Assuming E$^2$ spectral behavior and equal fluence at all flavors the upper limits at 90% C.L. are obtained on the neutrino fluence.

Timeline

Baikal-GVD Site:
- Location NSI: 76°73’72” E104°41’50,42”
- Depth of 1186 m at only 3.6 km from shore
- High deep water transparency (22 m) and low light scattering (10-50 m)
- Fresh water (simple mechanical solutions, no background from radon)
- No bioluminescence
- The most northern location allows observing the Galactic Center 18 hours per day.
- Reliable ice cover (mid February – mid April) as an excellent platform for:
  - bed cabling laying
  - telescope deployment and maintenance

Cascade detection in one cluster
- Directional resolution $\approx 2^\circ$, $4^\circ$(median)
- Energy resolution $\Delta E/E = 30\%$ (averaged by $E_1 \nu_1$ spectrum)
- $\approx 6$ events/yr ($E_{\nu_1} > 100$ TeV, $N_{\text{OM}} = 200$)
- $\eta_{\text{hit}} = 0.00 - 0.11$, $\eta_{\text{hit}}$, $\eta_{\text{hit}}$ effect area
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