SEARCH FOR VERY HIGH ENERGY NEUTRINOS WITH BAIKAL UNDERWATER DETECTOR

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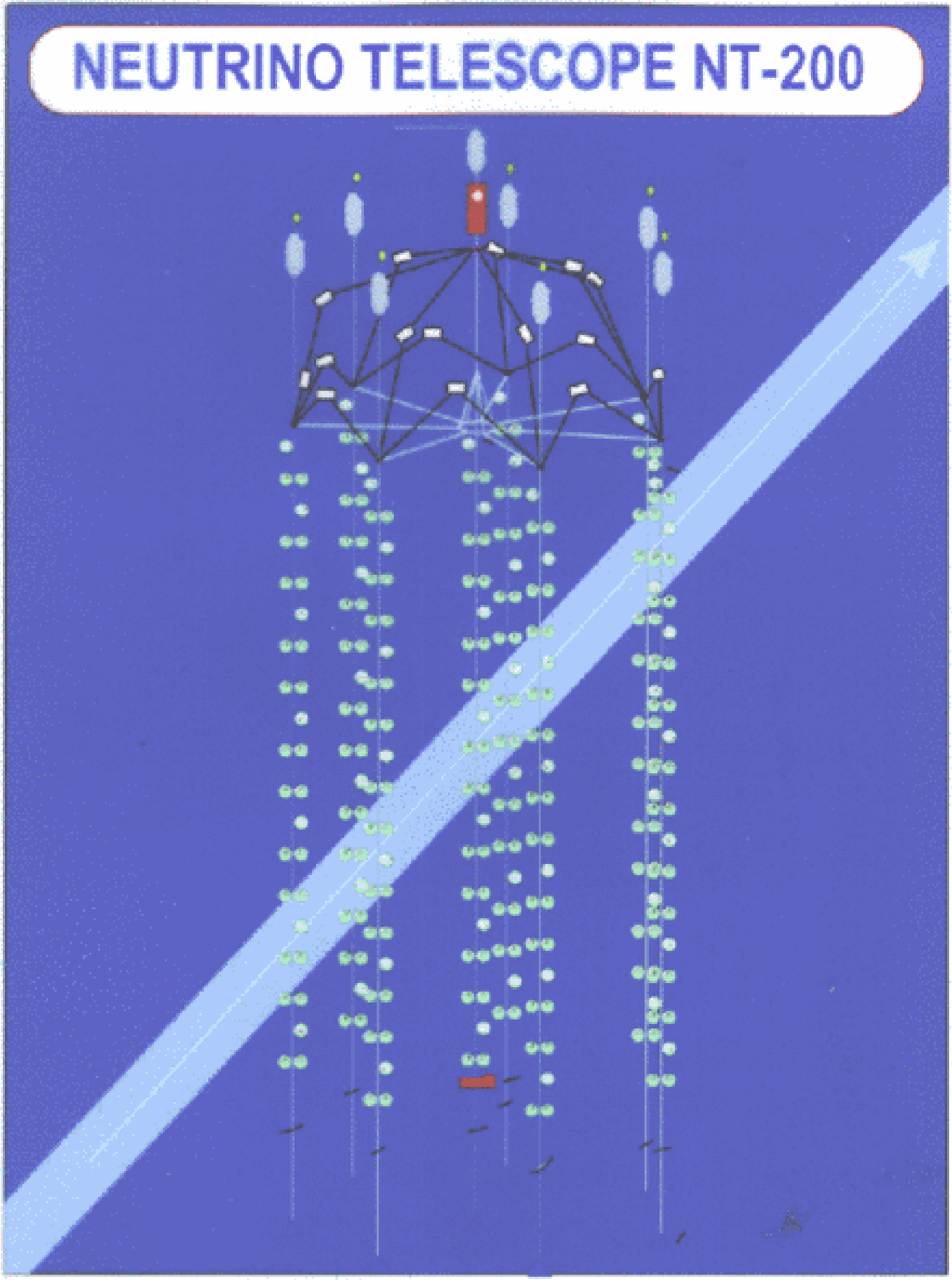
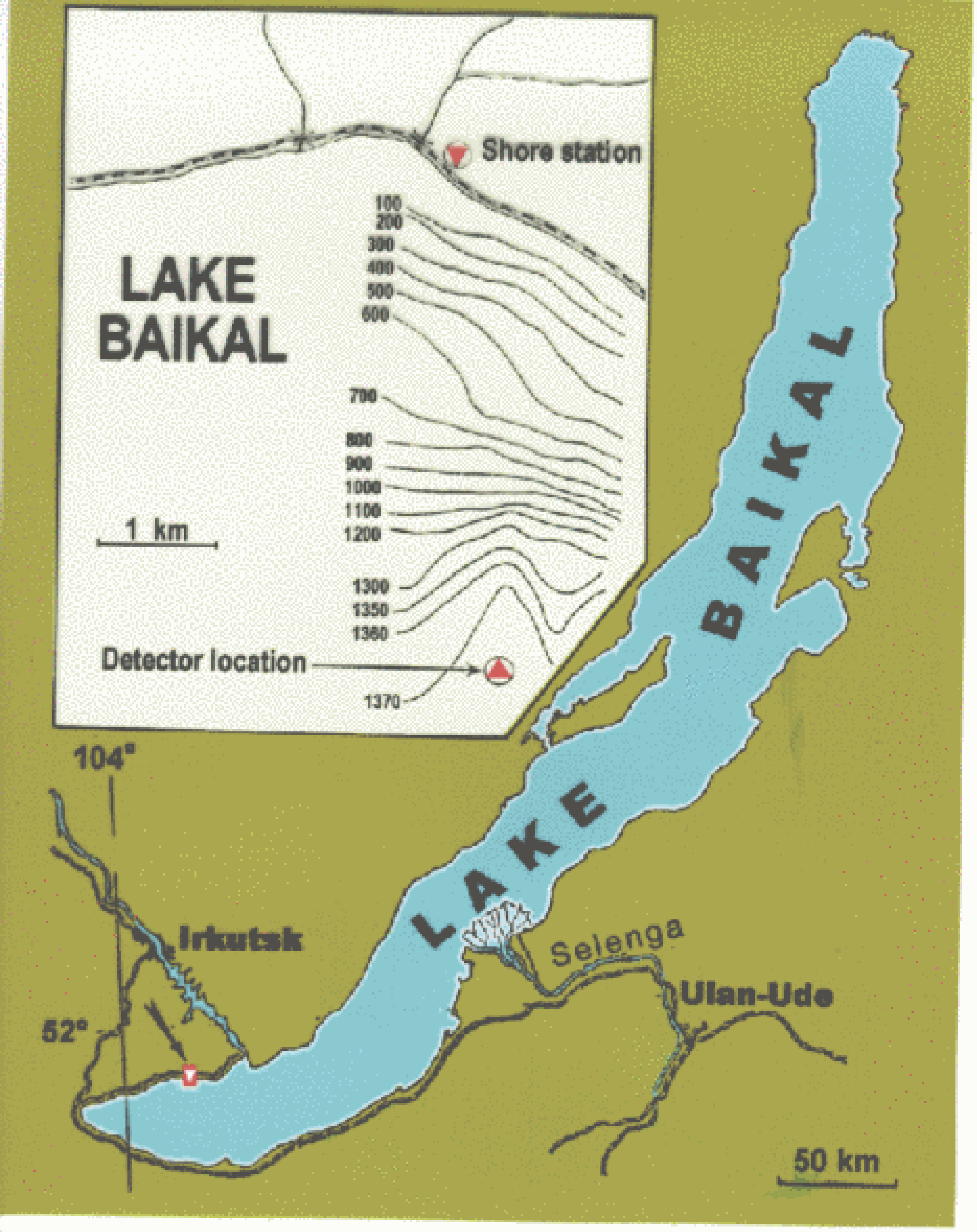
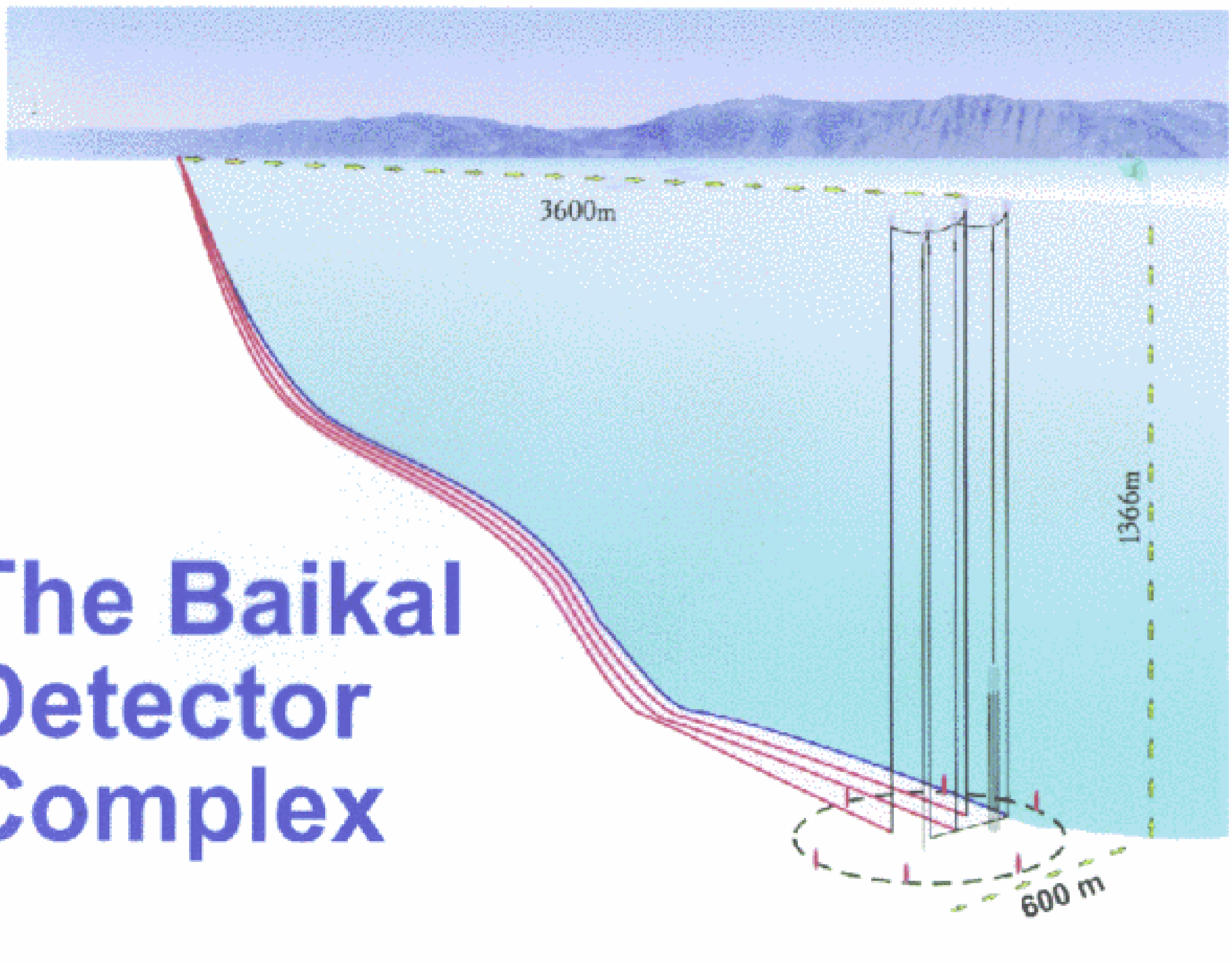

NEUTRINO TELESCOPE NT-200

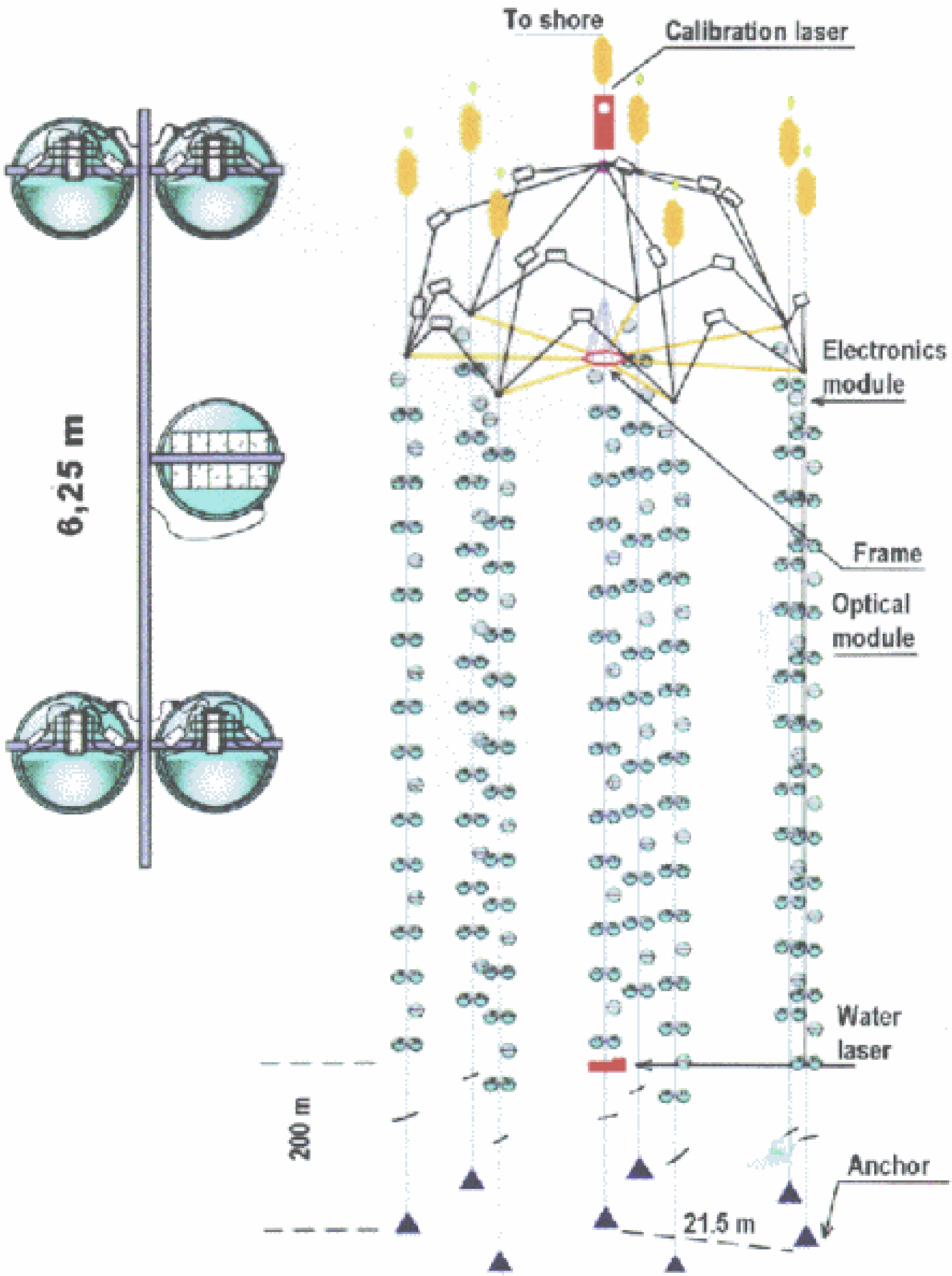


Shore station
LAKE BAIKAL
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1350
1360
1370
1 km
Detector location
104°
Irkutsk
Selenga
Ulan-Ude
52°
LAKE BAIKAL
50 km

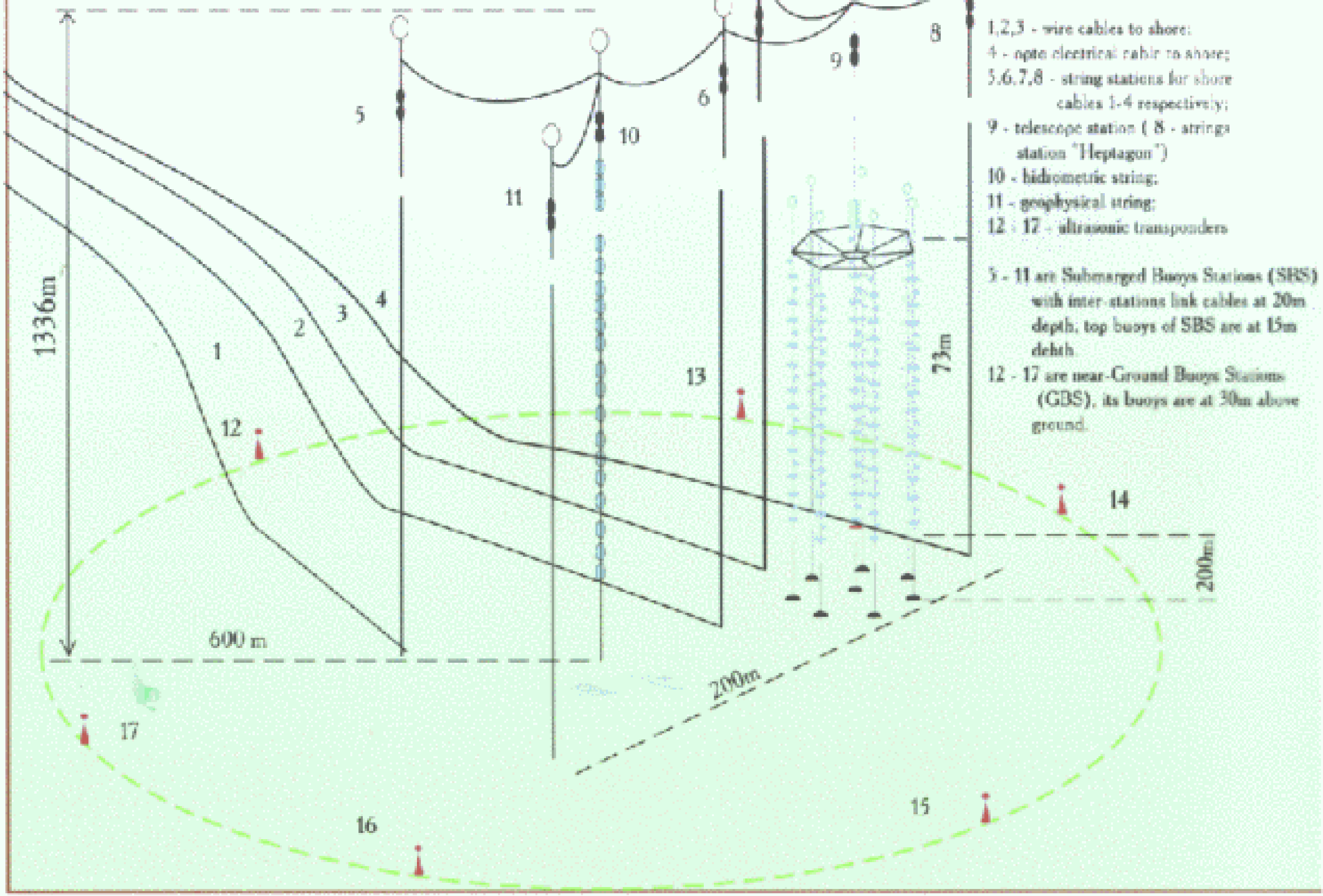
The Baikal Detector Complex



NEUTRINO TELESCOPE NT-200



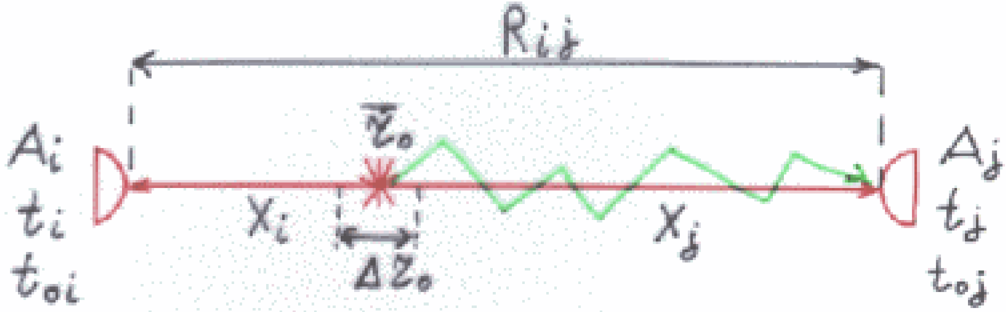
The Baikal Detector Complex (2000)



NT-200 STAGES

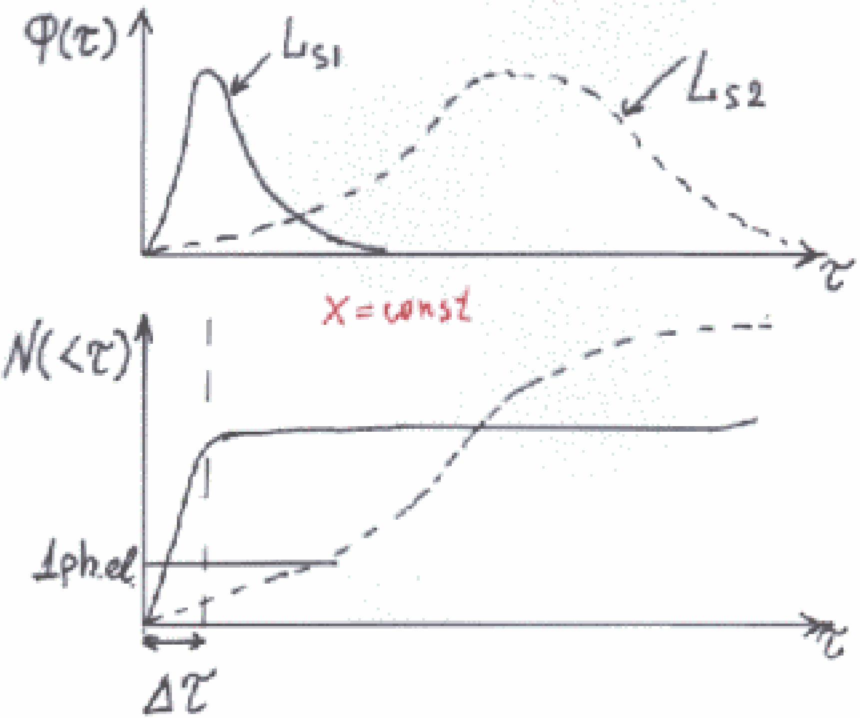
Years →	97-98 (NT-144)	98-99	99-00	00-01
T_{data}(days)	140	234.6	236	245
T_{data}/T_{tot}	70%	73%	75%	79%
$N_{ev}(4/1)/10^6$	133	197	191	233
$N_{ev}(6/3)/10^6$	44	67	65	82
$\bar{N}_{op}/N_{tot}$	83%	71%	76%	81%
$T_{data}(4/1)$ ($\frac{N_{op}}{N_{tot}}$ >85%)	90	8	61	120

(4/1) - $\geq$ 4 hit channels on $\geq$ 1 strings (*muon trigger*)
(6/3) - $\geq$ 6 hit channels on $\geq$ 3 strings (*off-line trigger allowing track reconstruction*)
$\bar{N}_{op}$ - mean number of operating channels
N_{tot} =96 (72 for NT-144)



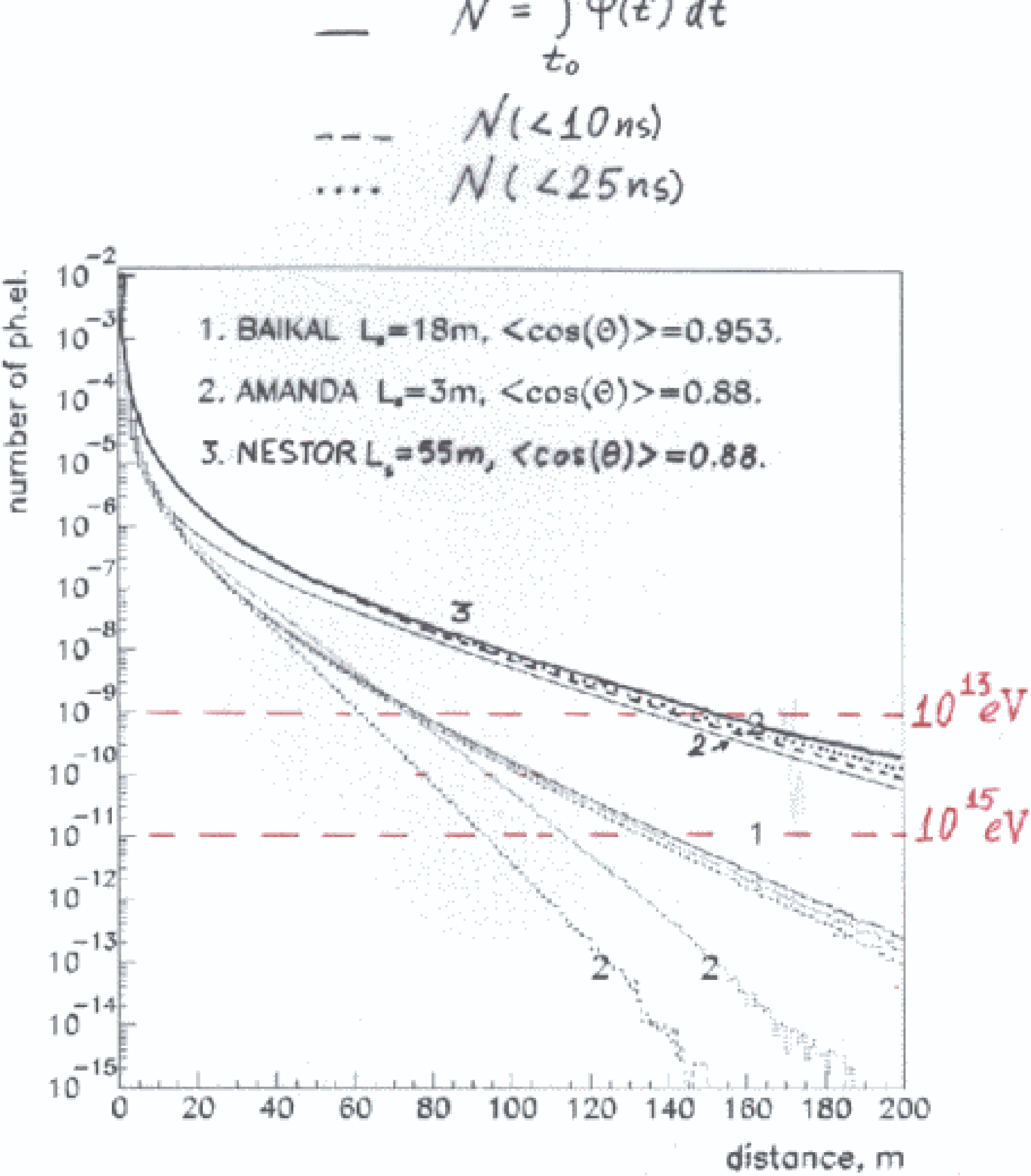
$$t_0 = X/V_\gamma , \quad \tau = t - t_0$$

$$\boxed{\Delta\bar{\tau}_0 = f(\Delta\tau)}$$



$L_{s1} \gg L_{s2}$

$$N(<\tau) = \int_0^{\tau} \varphi(\tau')\, d\tau'$$



— $N = \int_{t_0} \varphi(t)\,dt$
--- N(<10ns)
.... N(<25ns)
number of ph.el.
1. BAIKAL L_s=18m, <cos(θ)>=0.953.
2. AMANDA L_s=3m, <cos(θ)>=0.88.
3. NESTOR L_s=55m, <cos(θ)>=0.88.
10^{13}eV
10^{15}eV
distance, m

ELECTROMAGNETIC AND HADRONIC SHOWERS

$N_\gamma = 10^5 E_{sh}(\mathrm{GeV})$ - Cherenkov photons

NEUTRINO-NUCLEON SCATTERING

$$\nu_l(\bar{\nu}_l) + N \xrightarrow{CC} l^-(l^+) + \text{hadrons},$$

$$\nu_l(\bar{\nu}_l) + N \xrightarrow{NC} \nu_l(\bar{\nu}_l) + \text{hadrons},$$

$$l = e,\ \mu,\ \tau$$

W - RESONANCE

$$\bar{\nu}_e + e^- \to W^- \to \text{anything}$$

resonant energy - $6.3 \cdot 10^6$ GeV,
resonant cross section - $5.02 \cdot 10^{-31} \mathrm{cm}^2$.

NT-200(1998) - RESULTS

- upward going atmospheric neutrinos

- WIMPs - search for excess of muons from the center of the Earth

- relativistic magnetic monopole ($\beta \geq 0.8$)

- diffuse flux of high energy neutrinos ($E_\nu > 10$ TeV)

SEARCH STRATEGY
($E_\nu > 10$ TeV)

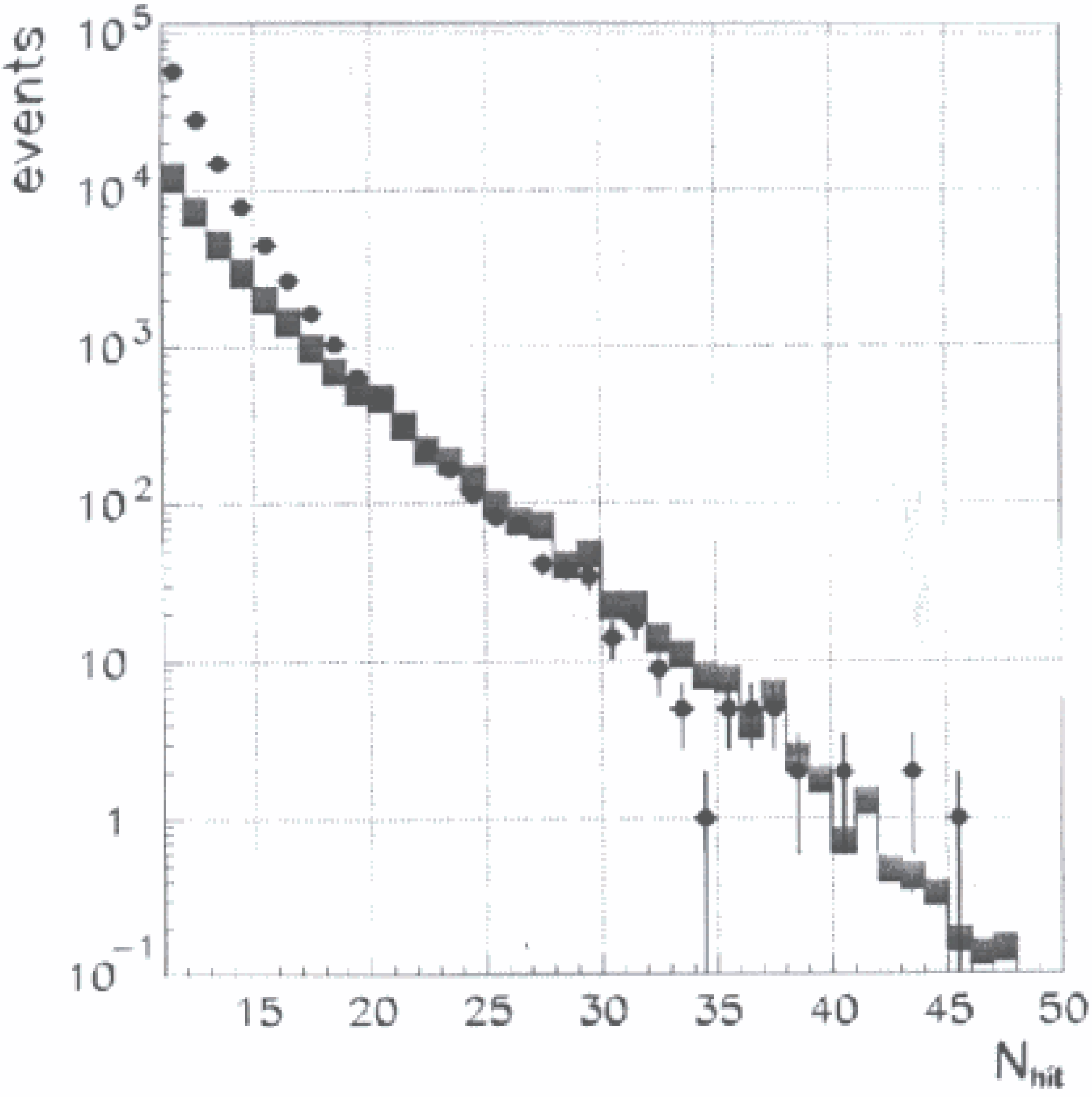
Detection of the Cherenkov light emitted by the electromagnetic and (or) hadronic cascades and high energy muons produced at the neutrino interaction vertex in a large volume around the Neutrino Telescope.

- $N_{hit}(E_\nu) > 10$ - events with high multiplicity of hit channels

- $(t_i - t_j) > -10$ ns, $(j > i)$ - for every pair of hit channels on every hit string (neutrino interaction vertex is *below* the detector)

BACKGROUND

- showers produced by atmospheric muons at the bremsstrahlung and photonuclear interactions ($E_{sh} \approx 0.5 - 2$ TeV)



events
10^5
10^4
10^3
10^2
10
1
10^{-1}
15
20
25
30
35
40
45
50
N_{hit}

MC-SIGNAL

- $E_\nu \to 10$ TeV $\div$ 10^4 TeV

- $\Phi_\nu(E)dE = A_\nu E^{-\gamma} dE$ - isotropic flux

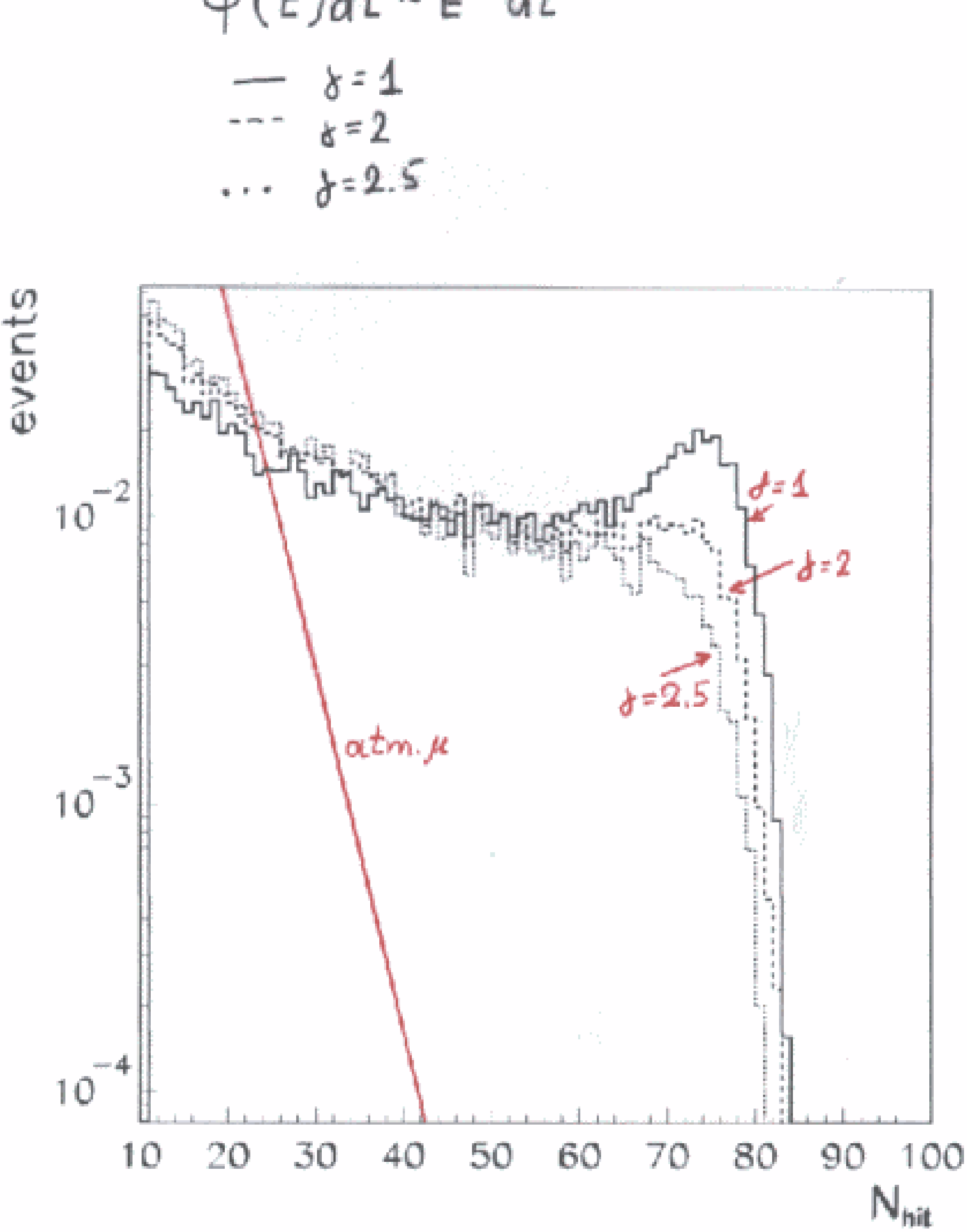
- Σ_ν - cross-sections (R.Gandhi et al.(98))

- absorption in the Earth - $\exp(-l(\theta)/l_{int})$

- hit channels multiplicity

Conf.1 - $N_{hit} > 50$
Conf.2 - $N_{hit} > 39$
Conf.3 - $N_{hit} > 26$

$$N_{ev} = A_\nu T \int E_\nu^{-\gamma} \Sigma_\nu V_{eff} \exp(-l/l_{int}) dE_\nu d\Omega$$



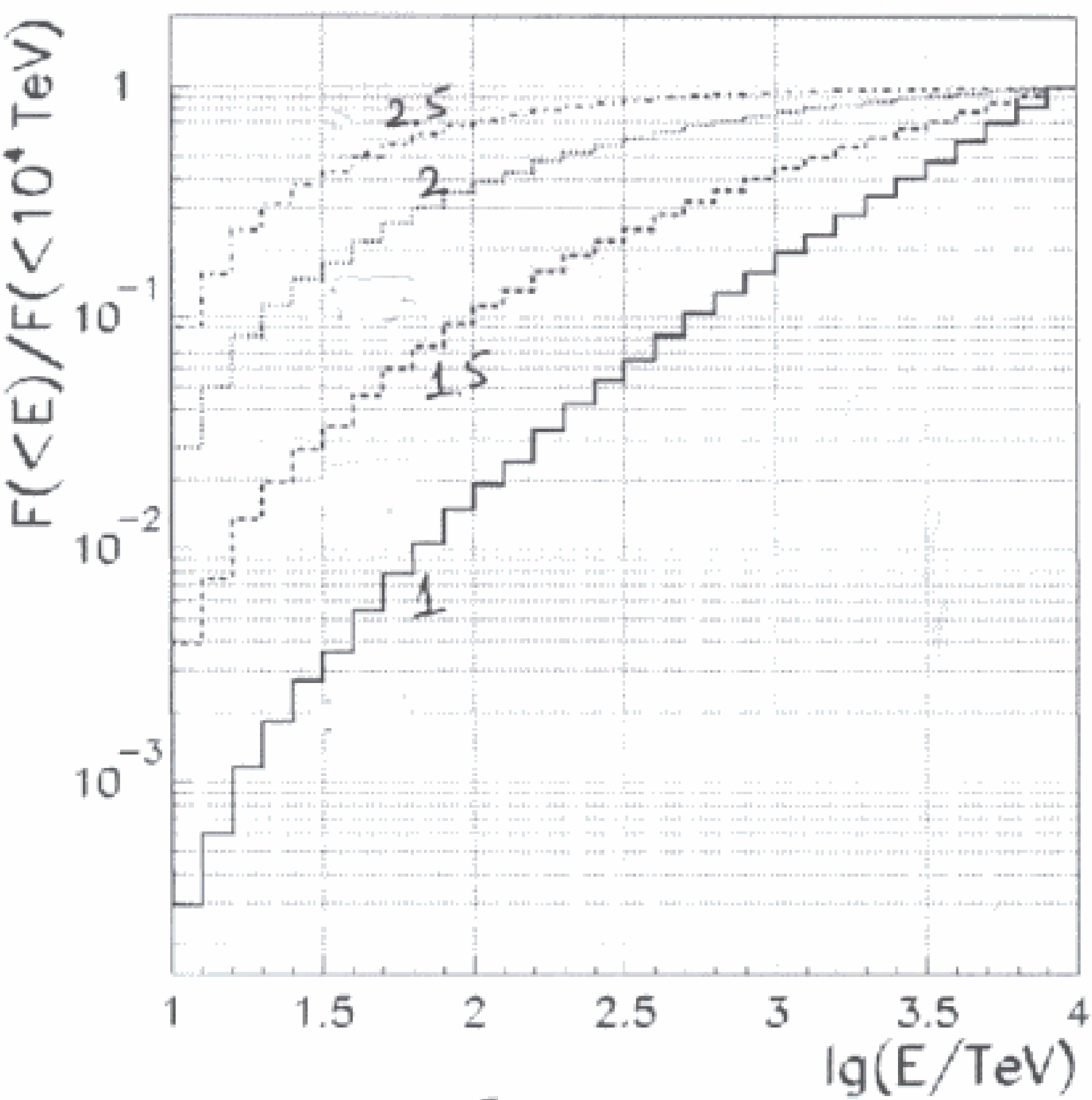
γ=1
γ=2
γ=2.5
events
atm. μ
γ=1
γ=2
γ=2.5
10^{-2}
10^{-3}
10^{-4}
10 20 30 40 50 60 70 80 90 100
N_{hit}

1 - $6 \cdot 10^2$ TeV →

1.5 - 100 →

2 - $10 \div 10^4$

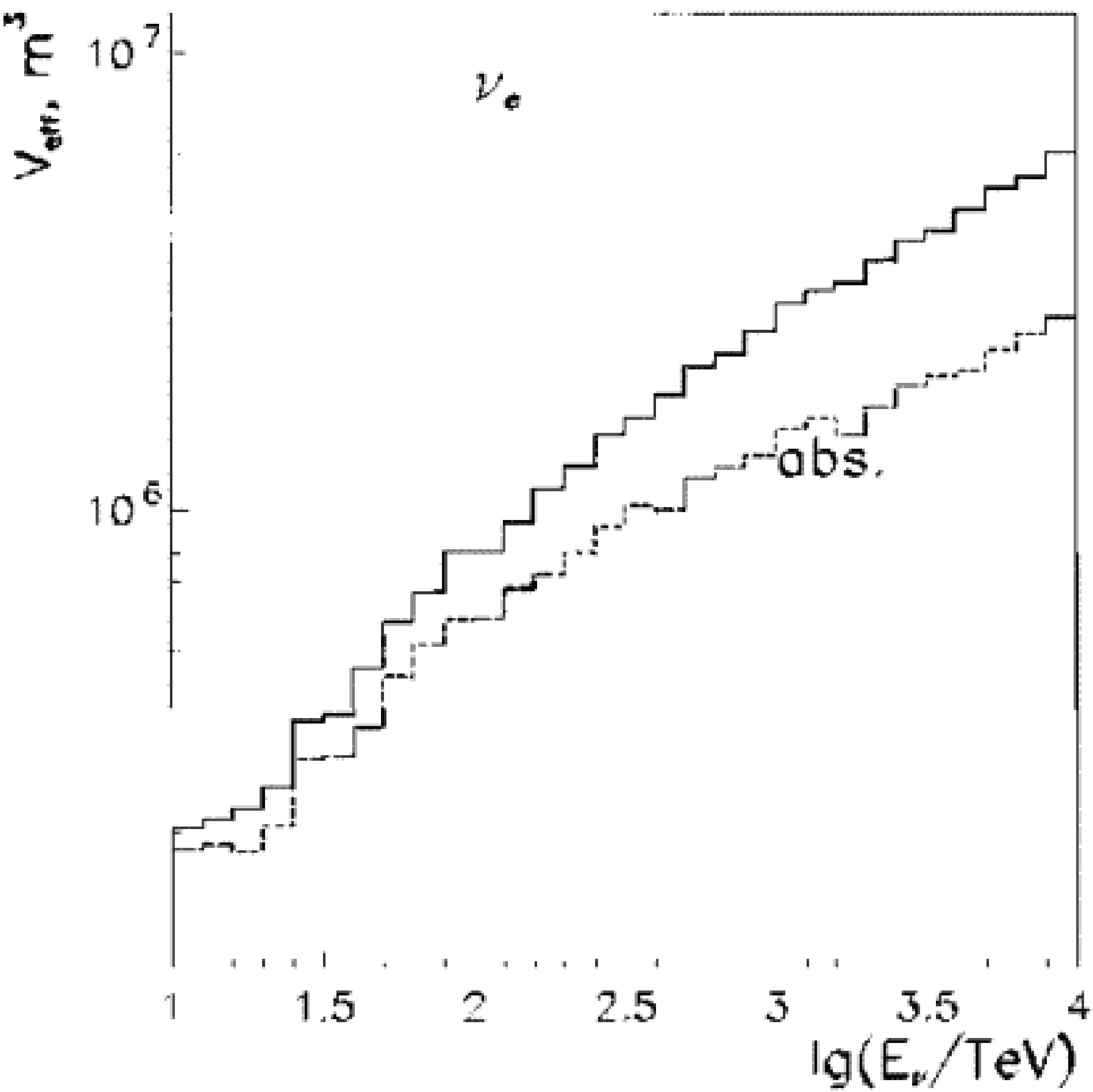
2.5 - $10 \div 3 \cdot 10^2$ TeV

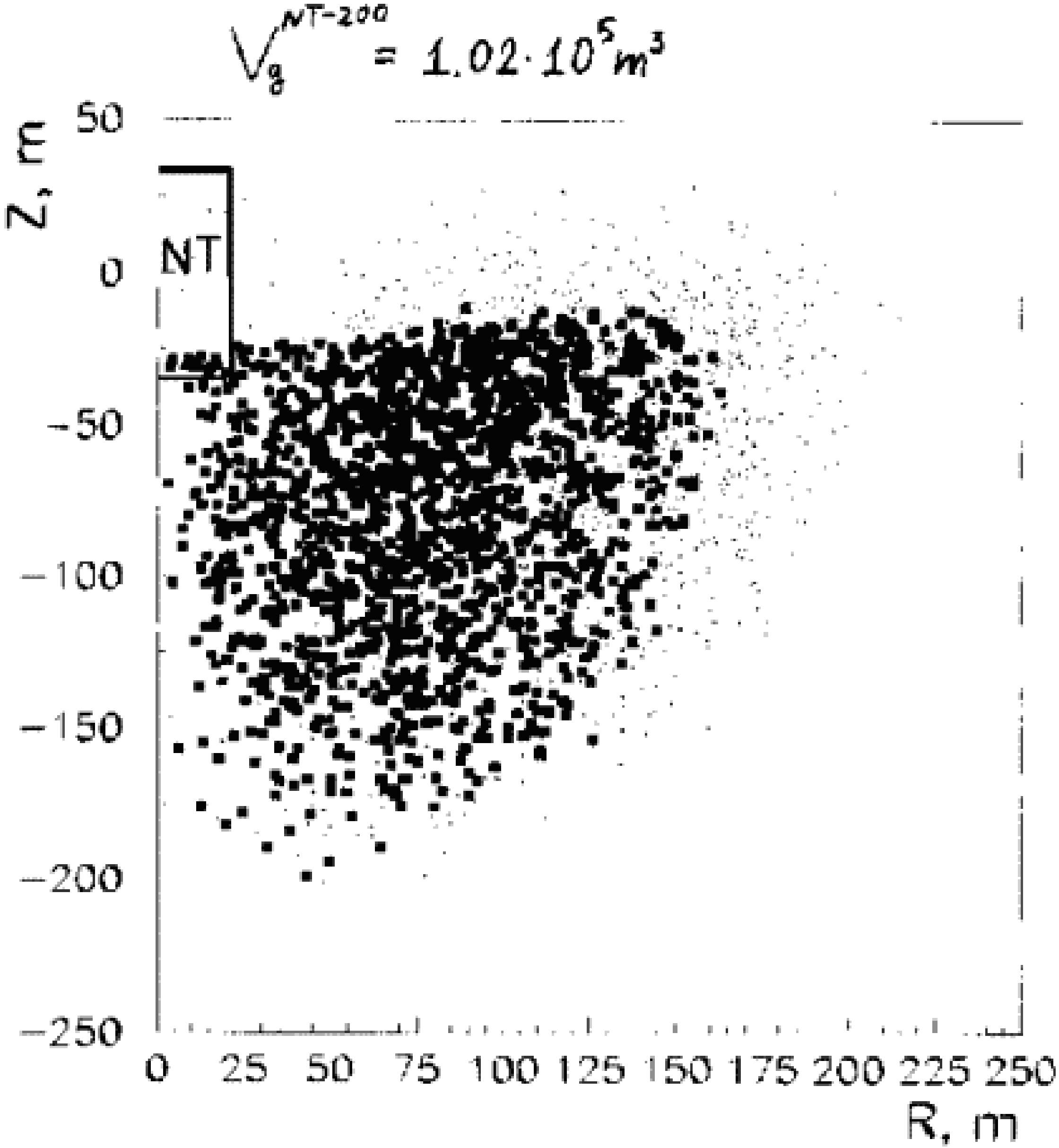


$$F(<E) = \int_{10\,TeV}^{E} N(E')\,dE'$$

$10\,TeV < E_{\nu_e} < 10^4\,TeV$

$0.2\,Mton < V_{ef} < 7\,Mton$




$V_g^{NT-200} = 1.02 \cdot 10^5 m^3$
Z, m
NT
R, m
50
0
-50
-100
-150
-200
-250
0
25
50
75
100
125
150
175
200
225
250

THE 90 % C.L. LIMITS OBTAINED WITH NT-96(70 days) + NT-200(234.6 days)

DIFFUSE NEUTRINO FLUX
($\Phi_\nu \sim E^{-2}$, 10 TeV < E < 10^4 TeV)

$$(\nu_e + \tilde{\nu}_e) : (\nu_\mu + \tilde{\nu}_\mu) = 1:2$$

$$\Phi_\nu = E^{-2}(A_{\nu_e} + A_{\nu_\mu}) = A_{\nu_e}E^{-2}(1+2)$$

$$E^2\Phi_{\nu_e+\tilde{\nu}_e} < (1.3 \div 1.9) \cdot 10^{-6} \frac{\text{GeV}}{\text{cm}^2 \cdot \text{s} \cdot \text{sr}}$$

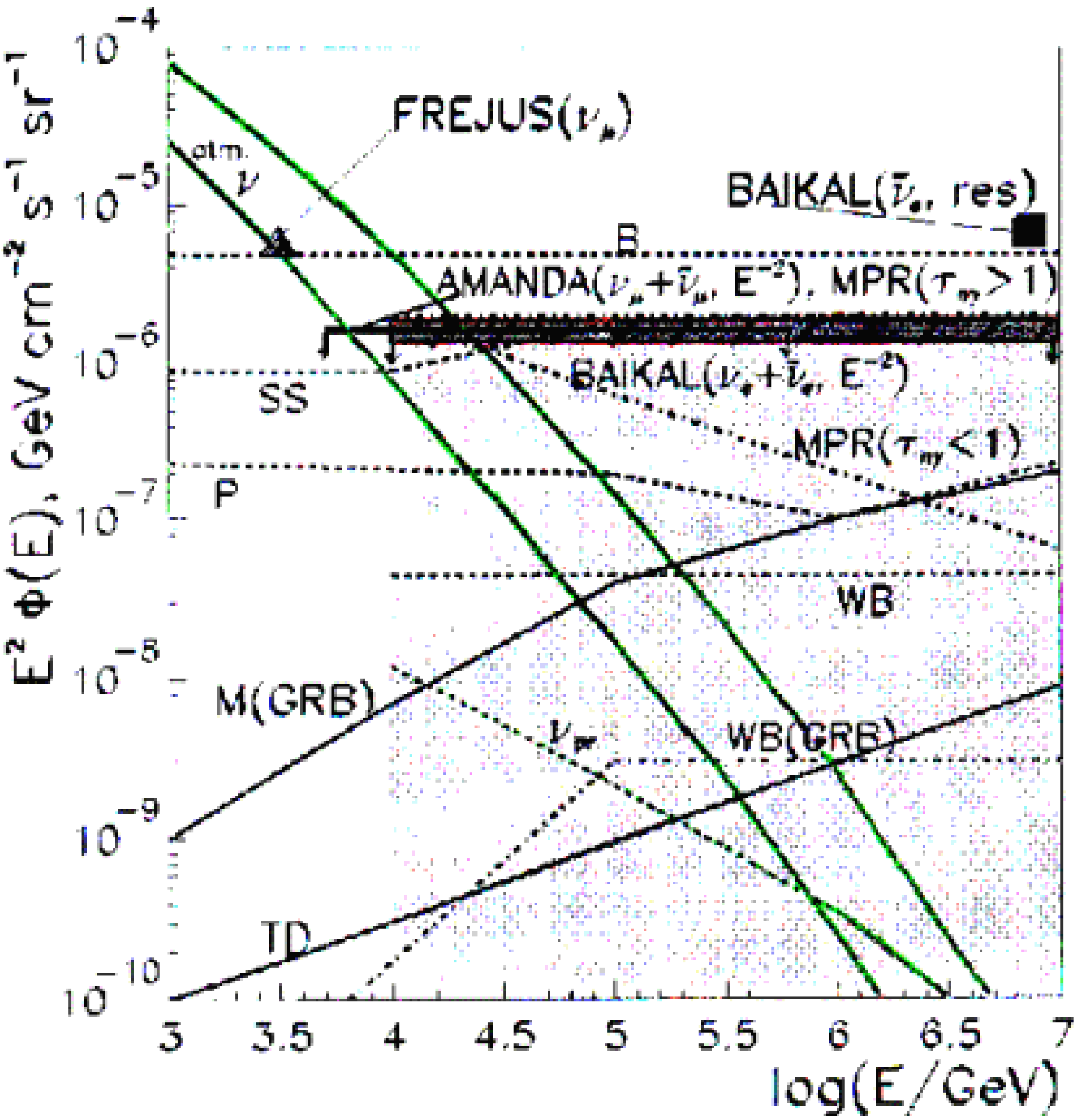
W-RESONANCE

$E_{res} = 6.3$ PeV

$\Delta E = \frac{(M_W+2\Gamma)^2}{2m_e} - \frac{(M_W-2\Gamma)^2}{2m_e} = 1.3$ PeV

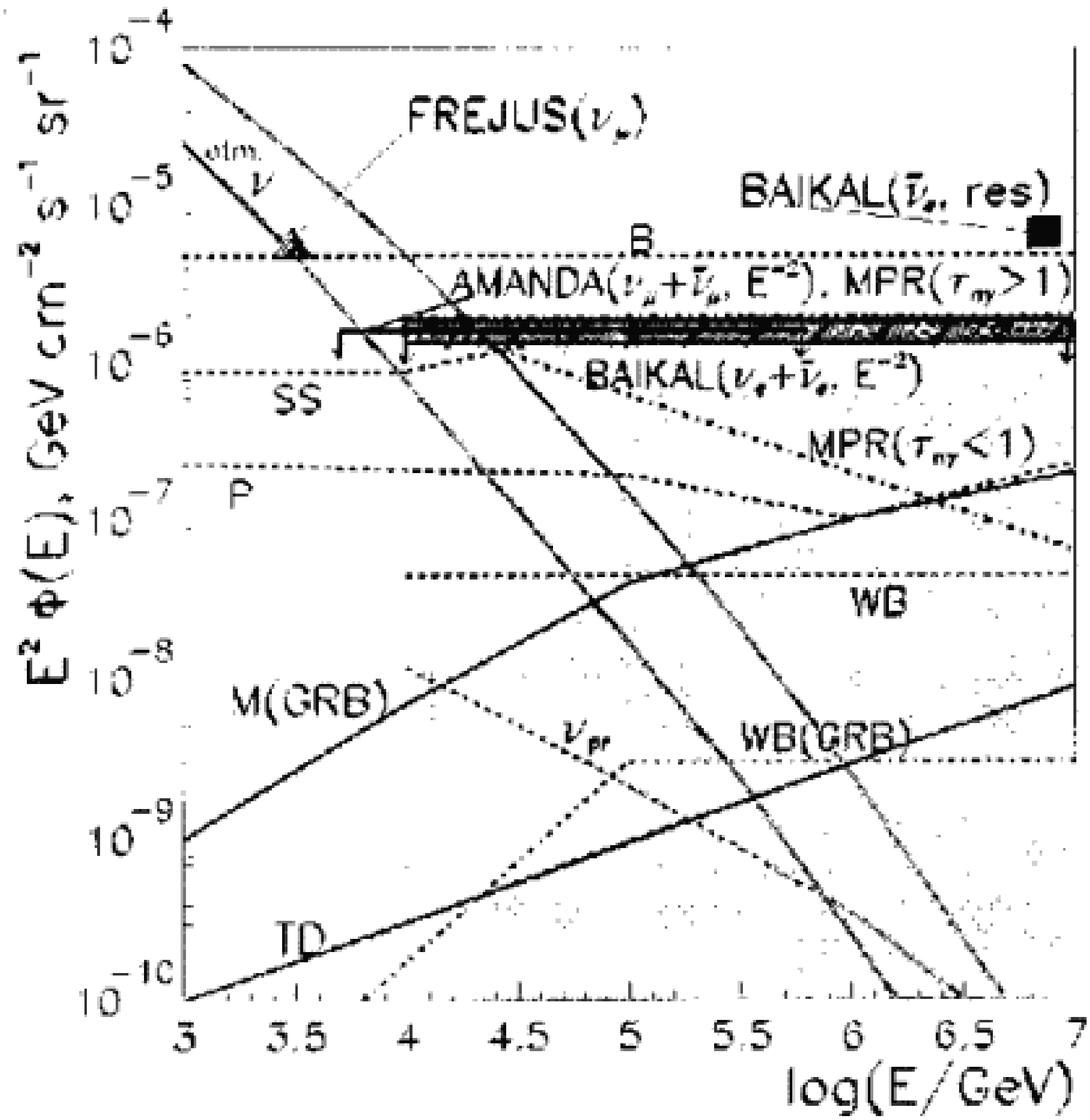
$\bar{\sigma} = 1.12 \cdot 10^{-31} \text{cm}^{-2}$ - mean cross-section (with shower in final state)

$$\Phi_{\tilde{\nu}_e} < (1.4 \div 1.9) \cdot 10^{-19} (\text{cm}^2 \cdot \text{s} \cdot \text{sr} \cdot \text{GeV})^{-1}$$



BAIKAL($\tilde{\nu}_e$, res): $(1.4 \div 1.9)\cdot 10^{-19} \frac{1}{cm^2\, s\, sr\, GeV}$

E = 6.3 PeV



BAIKAL($\tilde{\nu}_e$, res): $(1{,}4 \div 1.9)\cdot 10^{-19}\,\frac{1}{cm^2\,s\,sr\,GeV}$

E = 6.3 PeV

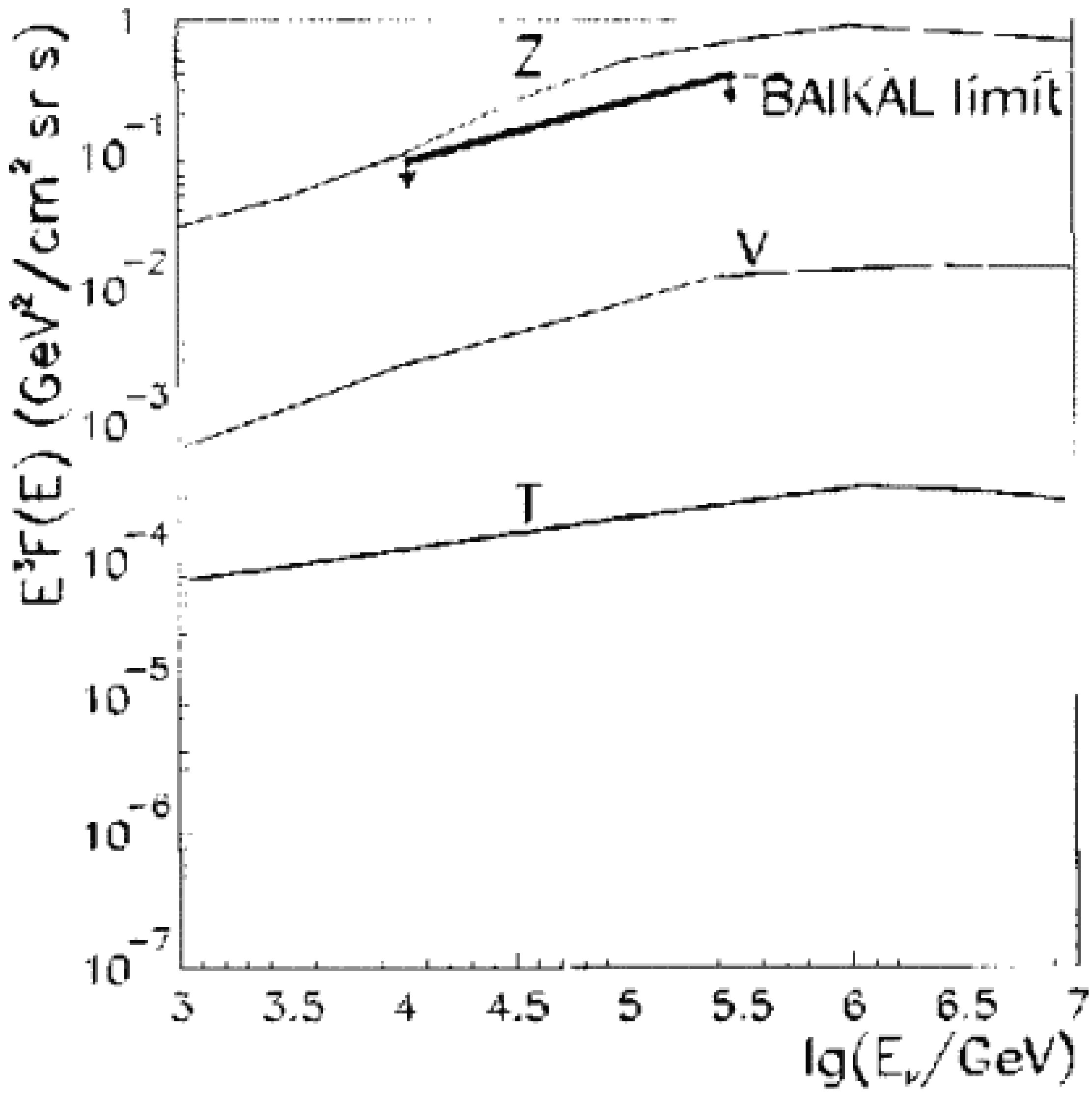
SUMMARY

- DATA TAKING, KEEPING FULL DETECTOR ON
- DATA ANALYSIS - ν_{atm}, WIMP, VERY HIGH ENERGY NEUTRINO, MONOPOLE
- ENVIRONMENT STUDIES

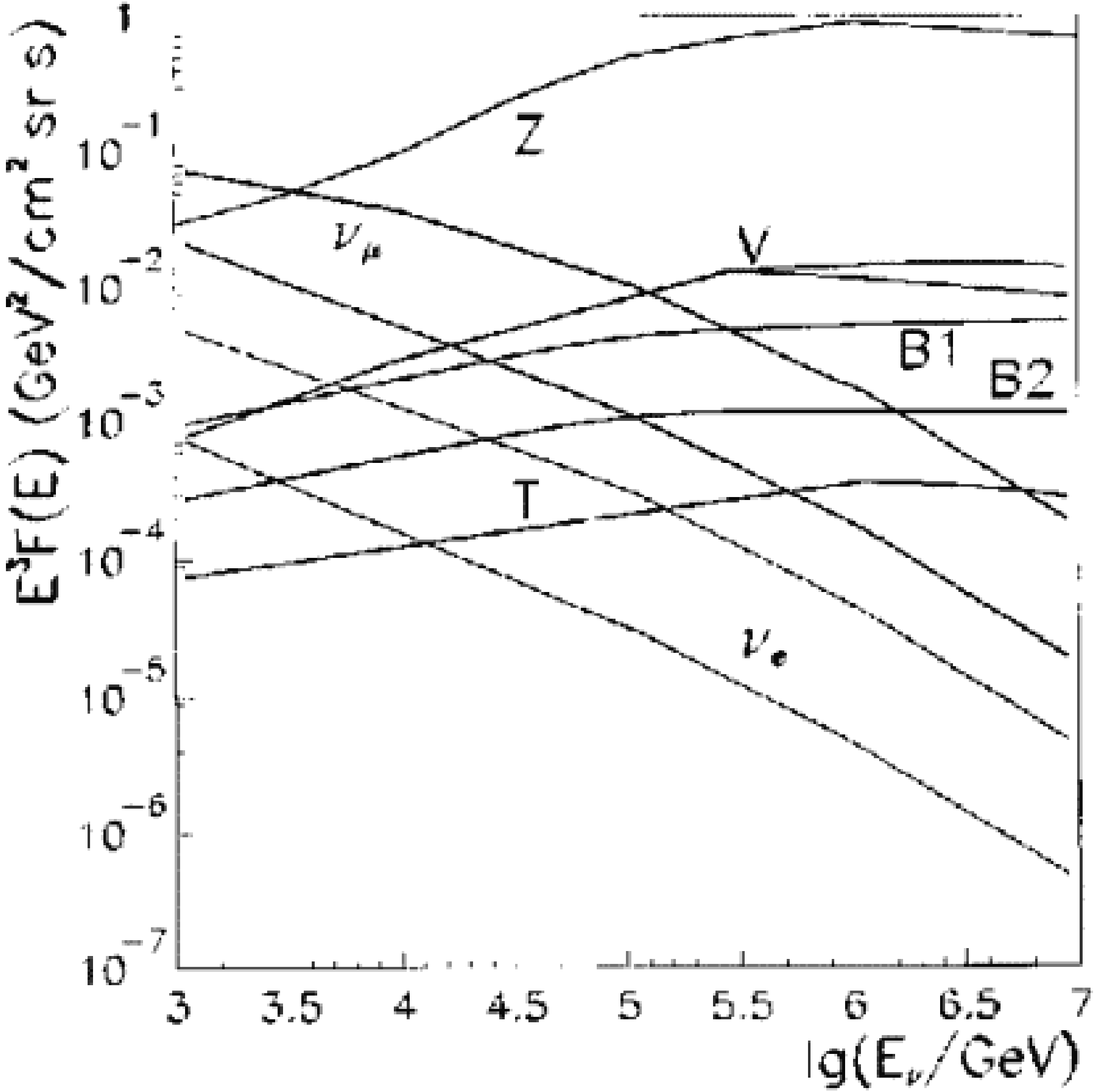
R&D

- ACOUSTIC SIGNAL DETECTION FROM VERY HIGH ENERGY NEUTRINO INTERACTIONS
- NEW VERSIONS OF OPTICAL MODULES UNDERWATER ELECTRONICS, DATA TAKING SYSTEM (FIBER OPTIC)
- MORE LARGE-SCALE NEUTRINO DETECTOR

90% C.L. BAIKAL limit on the flux of promt neutrinos



Promt atmospheric neutrino fluxes



T - M. Thunman et al. (96)

V - L. Volkova, G. Zatsepin (99)

B - E. Bugaev et al. (87)

Z - E. Zas, F. Halzen (93)