The Baikal Neutrino Telescope - Status and Plans

Outline:

- Detection Methods
- The Detectors: NT200 and NT200+
- Physics Results from NT200
  → Diffuse cosmic neutrino search
- The Km3 Baikal Detector Project
  ("Gigaton Volume Detector")

Ralf Wischnewski

DESY, Zeuthen

- for the Baikal Collaboration -

Poster:

- A prototype acoustic neutrino detector / 0639
- NT200 Physics Results / 1088

30th ICRC, Merida, Mexico, July 2007

The Baikal Collaboration

- Institute of Nuclear Research, Moscow
- Moscow State University
- DESY Zeuthen
- Irkutsk State University
- Nishni Novgorod State Techn. Univ.
- State Marine Techn. Univ. St.Petersburg
- Kurchatov Institute, Moscow
- JINR, Dubna

~45 authors

Project Milestones

>1983: Site / Water studies;
R&D: large area PMT, underwater technology,
Physics small setups (exotics search)

1991: Project NT200 submitted

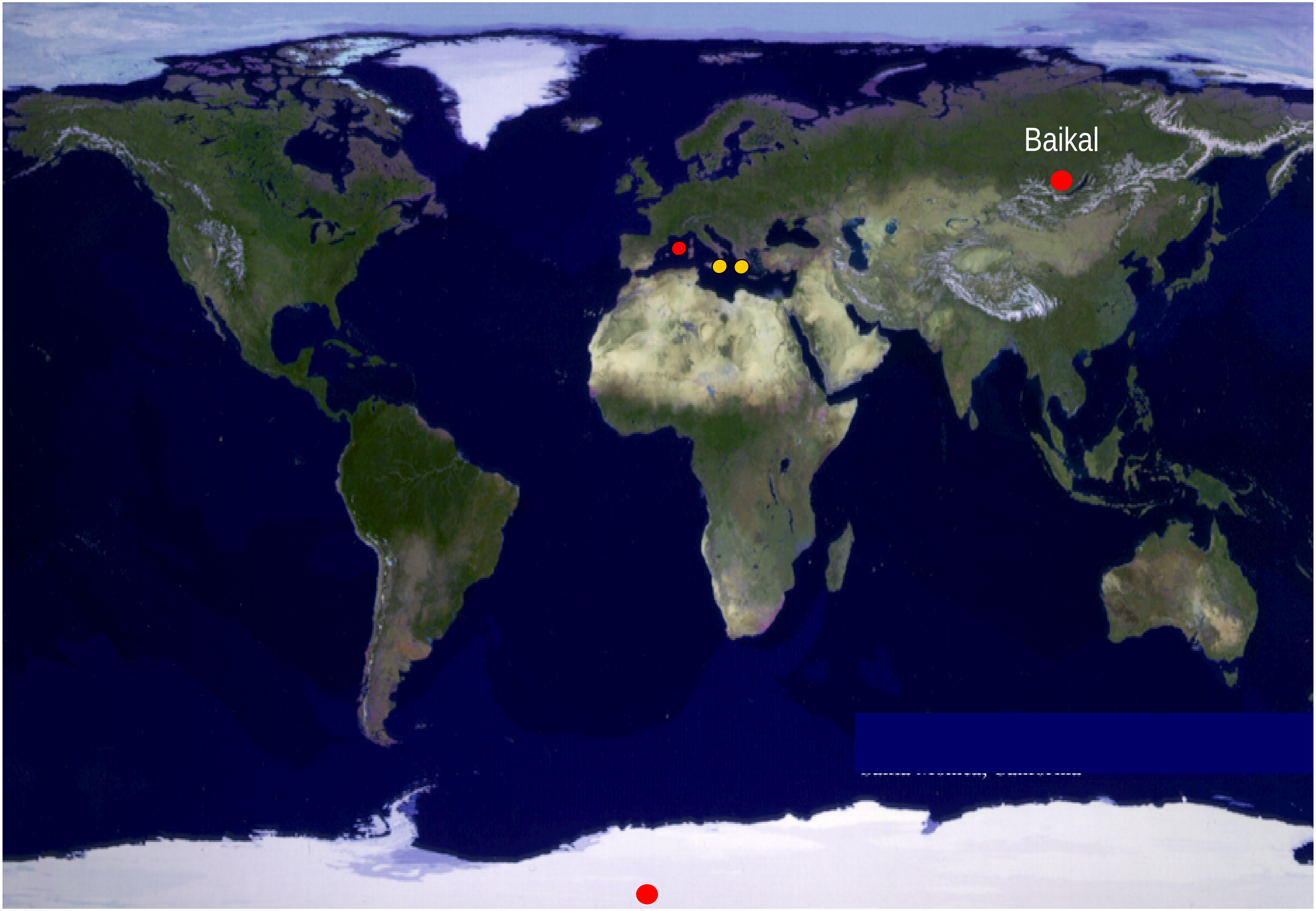
1993: NT36 – the first underwater array operates

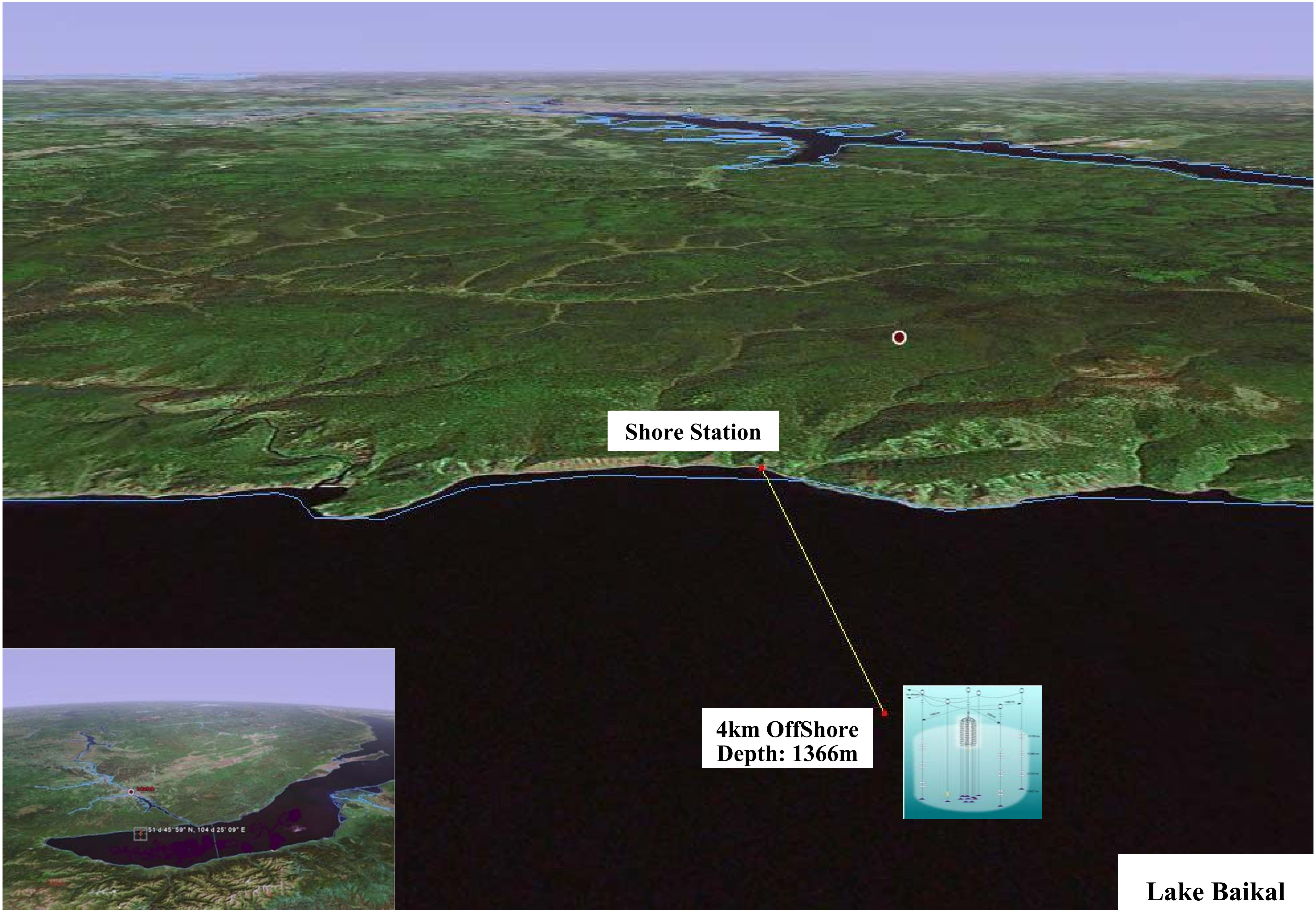
1998: NT200 commissioned

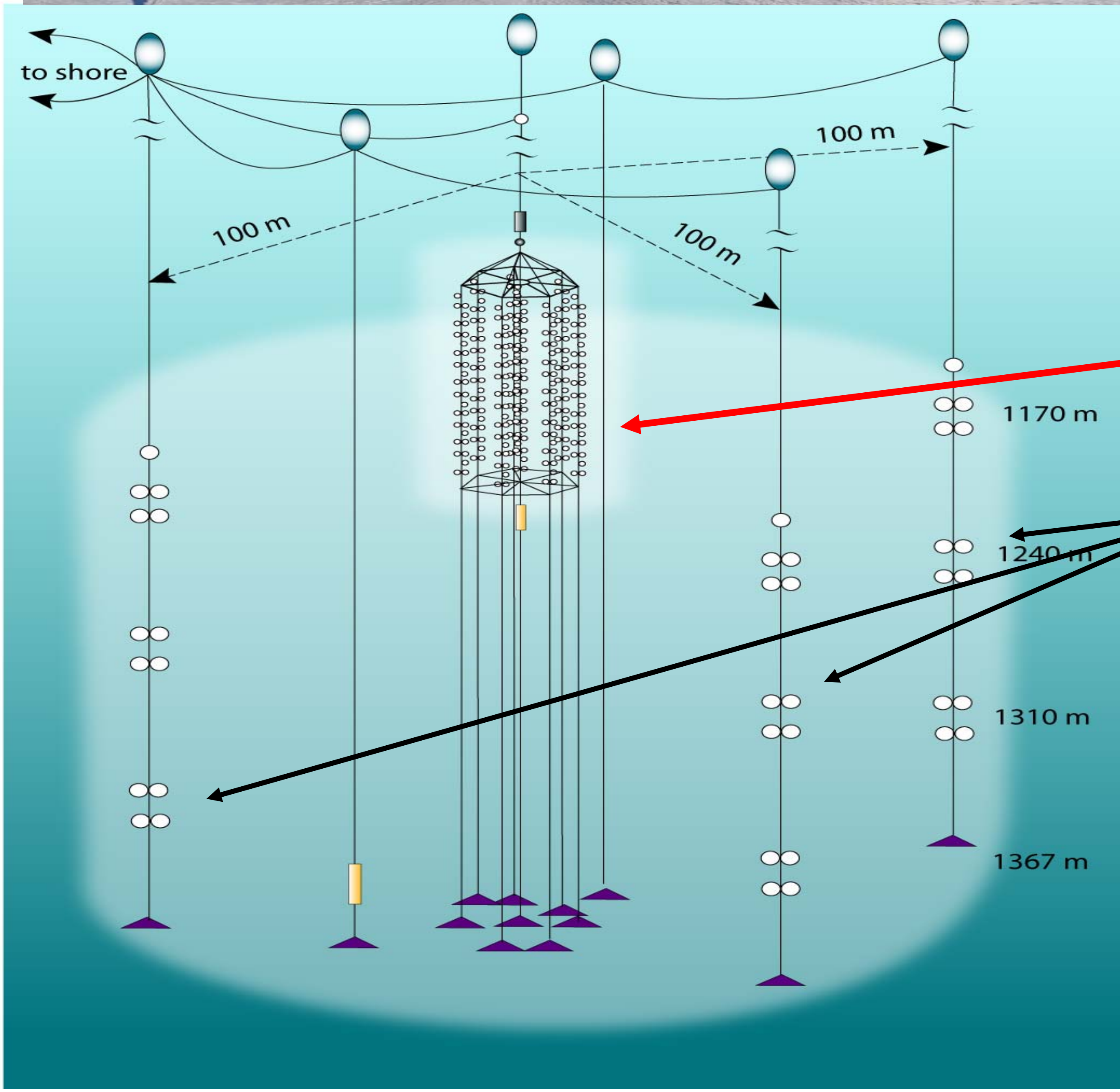
2005 - 2006:
Upgrade to NT200+ completed; operating

>2006: R&D activity for a Km3 detector in Lake Baikal
(„Gigaton Volume Detector“)

~2010: expected start of Km3 deployment


Baikal


Shore Station
4km OffShore
Depth: 1366m
51 d 45' 59" N, 104 d 25' 09" E
Lake Baikal



NT200+

=

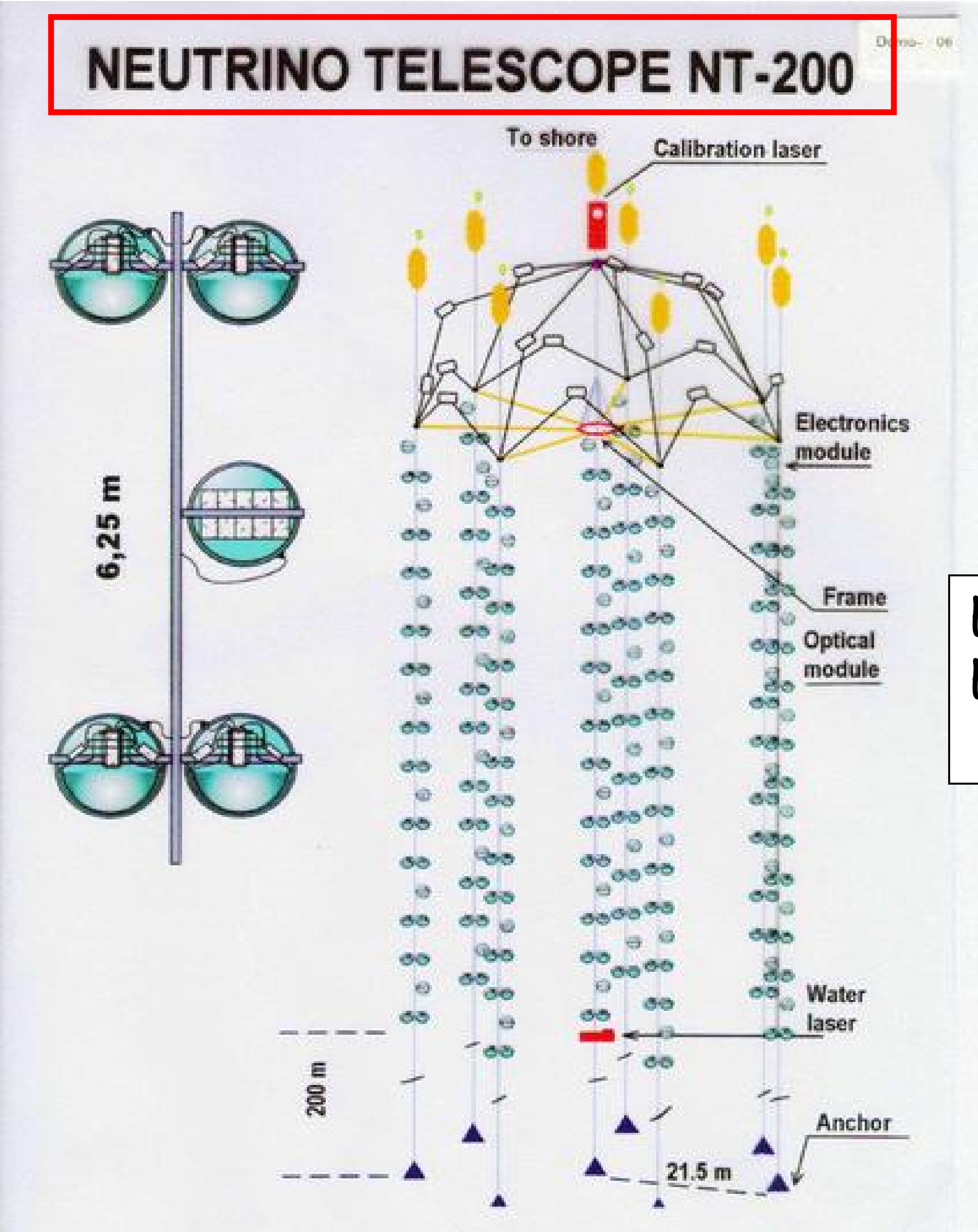
NT200

+

3 long outer strings

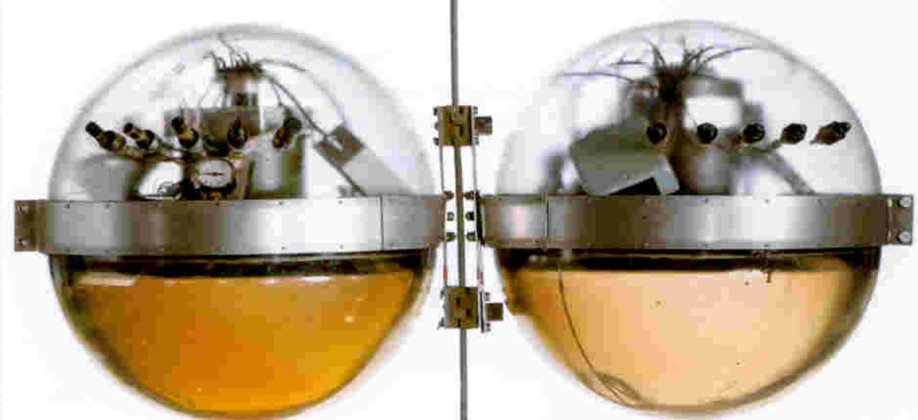
- **Height = 210m**
- **∅ = 200m**
- **Geom.Volume ~ 5 Mton**

R.Wischnewski ICRC, Merida, 2007



- 8 strings
- 192 optical modules
  = 96 pairs (coincidence)
- measure Time, Charge
  - $\sigma_T \sim 1$ ns
  - dyn. range ~ 1000 p.e.

Effective area: 1 TeV ~ 2000 m^2
Eff. Shower volume: 10 TeV ~ 0.2Mt
1 PeV ~ 1Mton !



Height = 70m, ∅ = 42m → $V_{inst} = 10^5\ m^3$

Quasar PMT: d=37cm (14.6")

Advantages (1): Ice – Perfect Deployment Platform

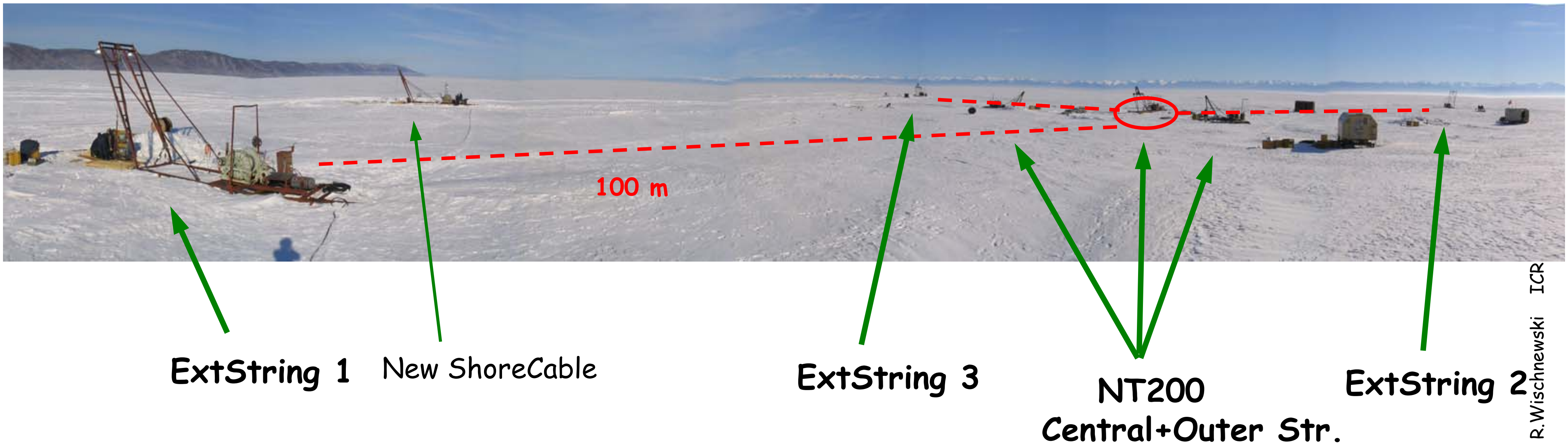
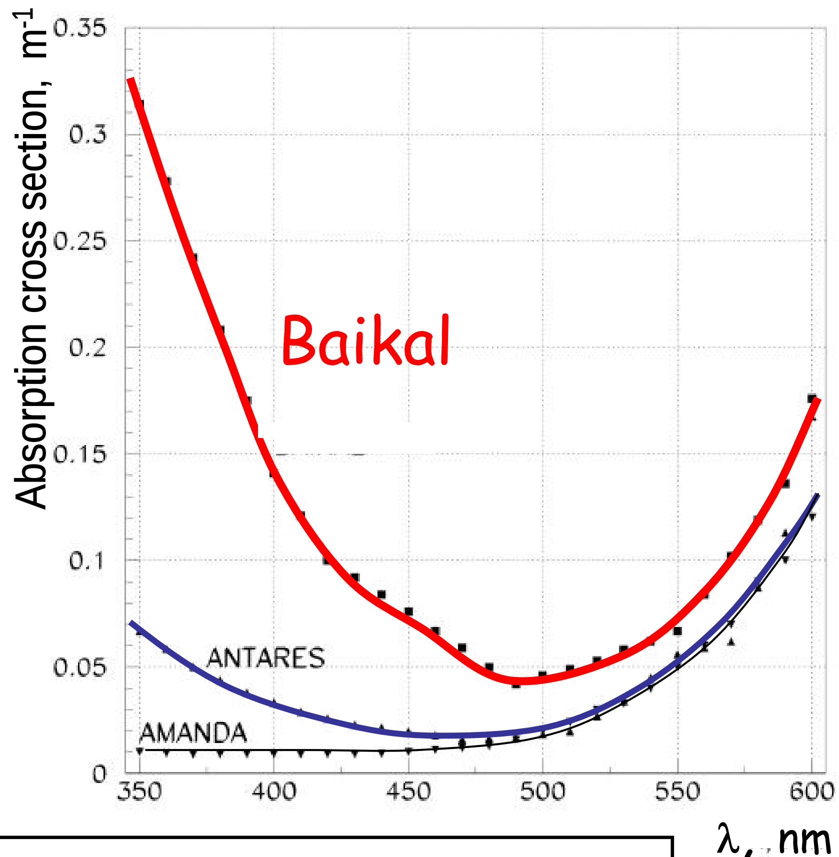


Foto from March, 2005, 4km off-s
NT200+ deployment from 1m thick

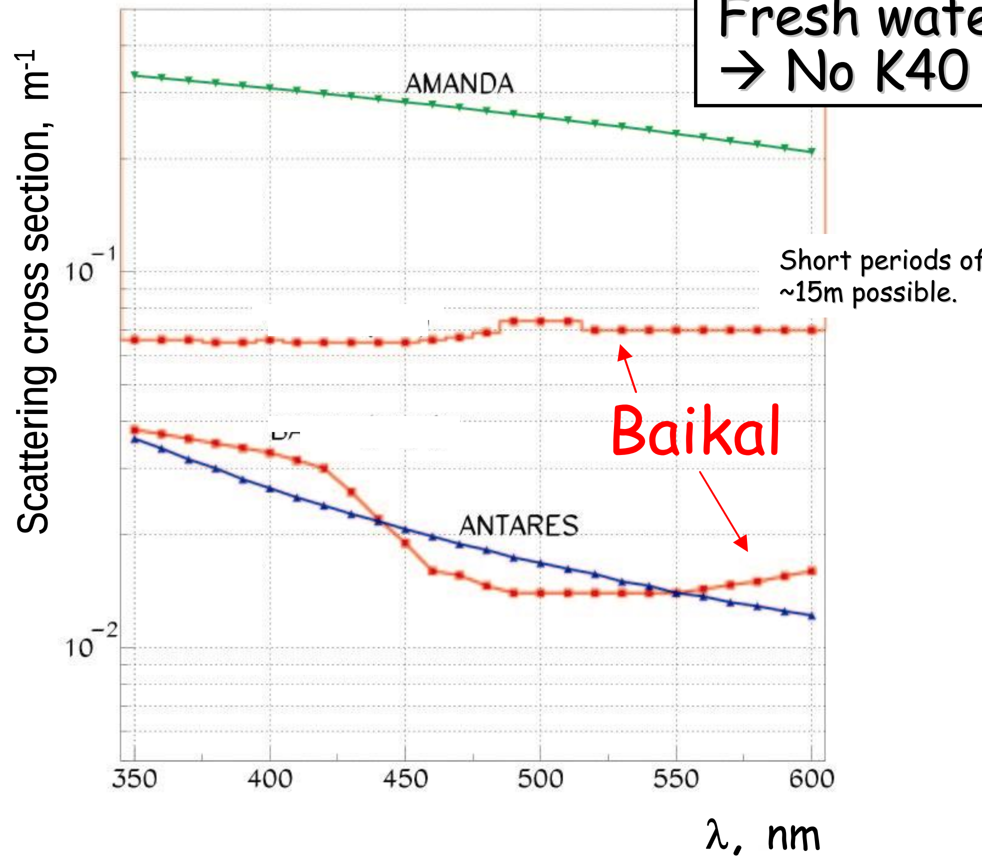
- Ice is available for 6-8 winter-weeks/year :
  - Upgrades & maintenance
  - Test & installation of new equipment
  - Operation of surface detectors (EAS, acoustics,…)
  - Electrical winches used for deployment operations (all connections done dry)

Advantages (2): Water – Good Optical Properties



Abs. Length: 22 ± 2 m

Baikal:
Fresh water
→ No K40 BG



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Scatt. Length ~ 30-50 m
⟨cos Θ⟩ ~ 0.85-0.9

(geom.scat.L.)

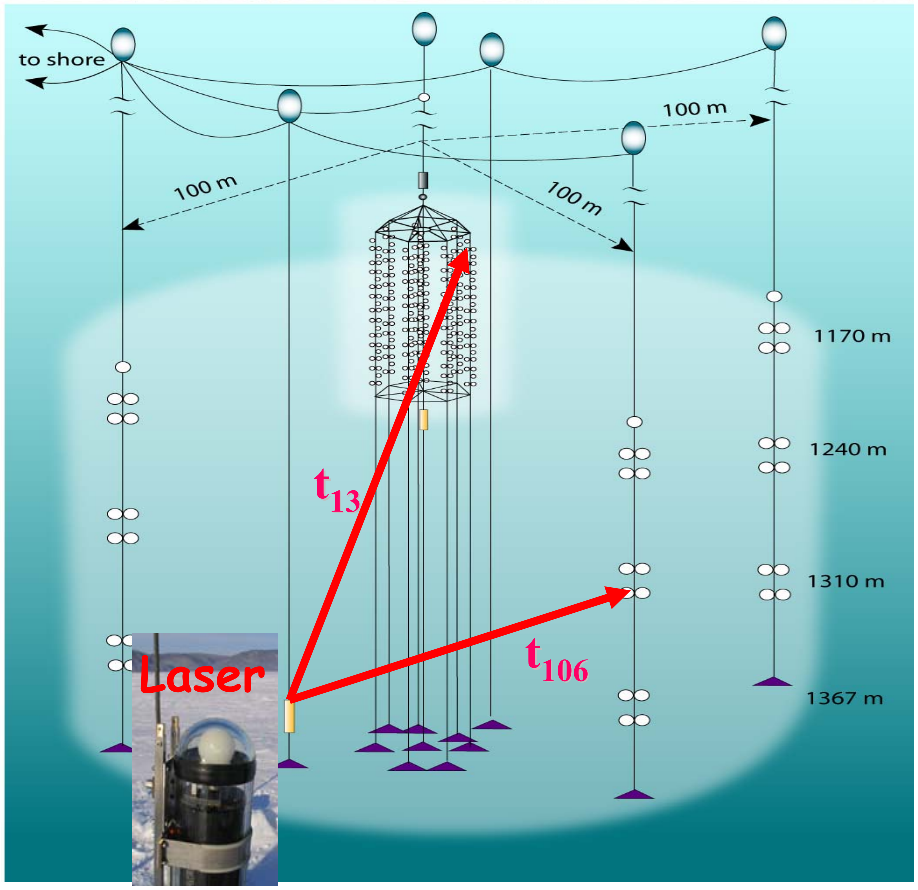
In-situ measurements
over many years

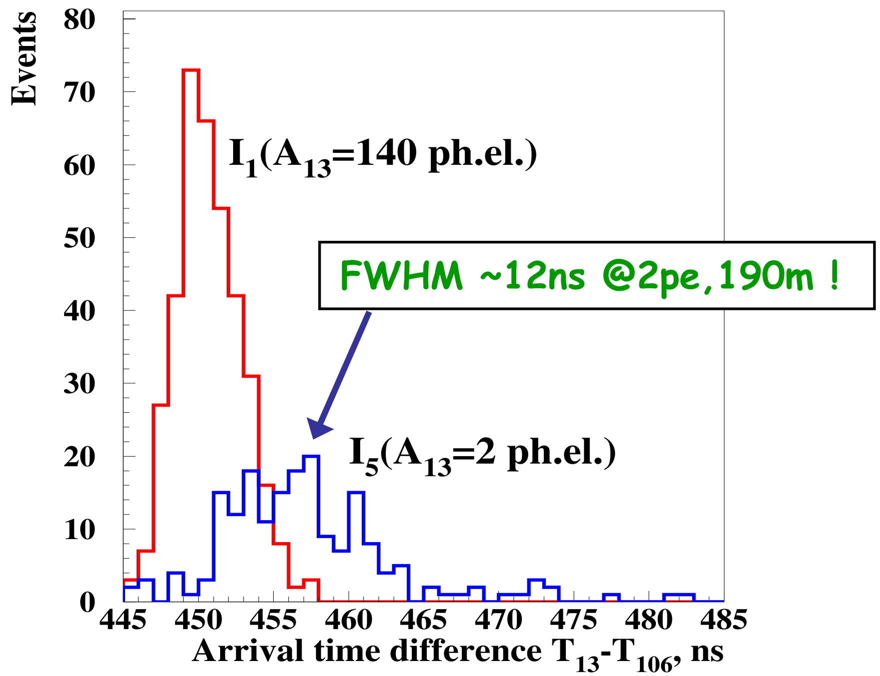
Note: IceCube's „effective" (diffusion) scattering is ~30m
→ for Baikal: ~300 - 500m !

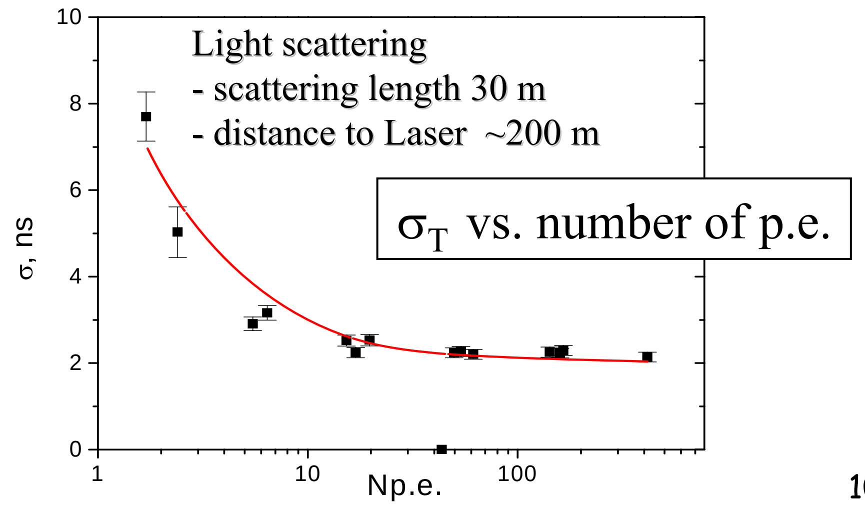
In-situ: Verification of Scattering @ large distances

Calibration Laser ~ 10^{12} – 5 10^{13} γ/pulse (1 ns)
→ E_Shower ~ 10 – 500 PeV

- Measure:
  Photon arrival times on Chan13 @187m distance
- Time Jitter = Scattering + Electronics





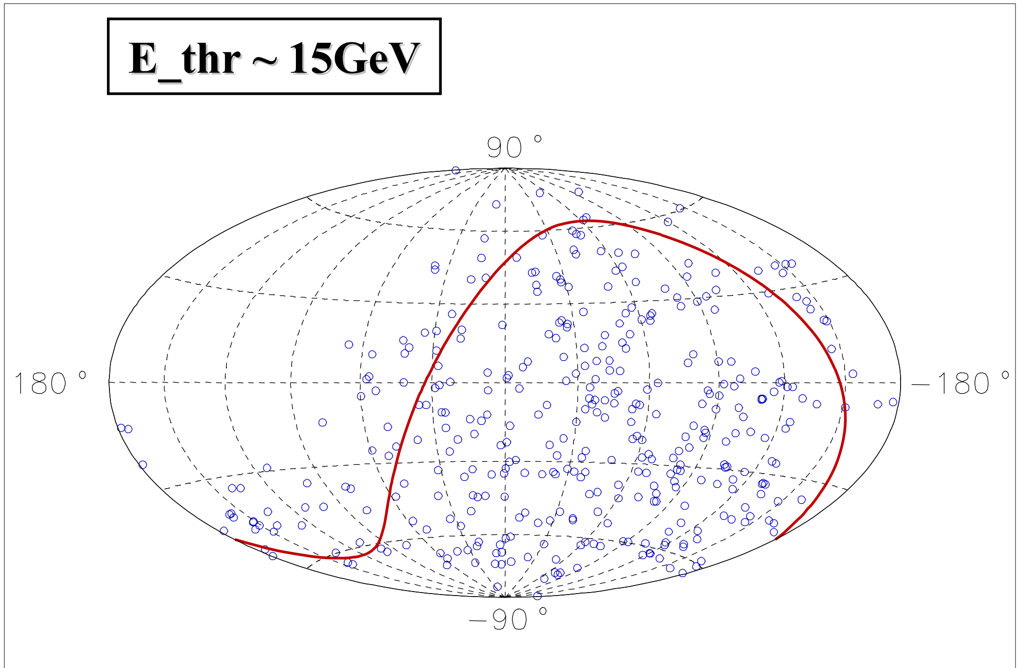


NT200 - Selected Results

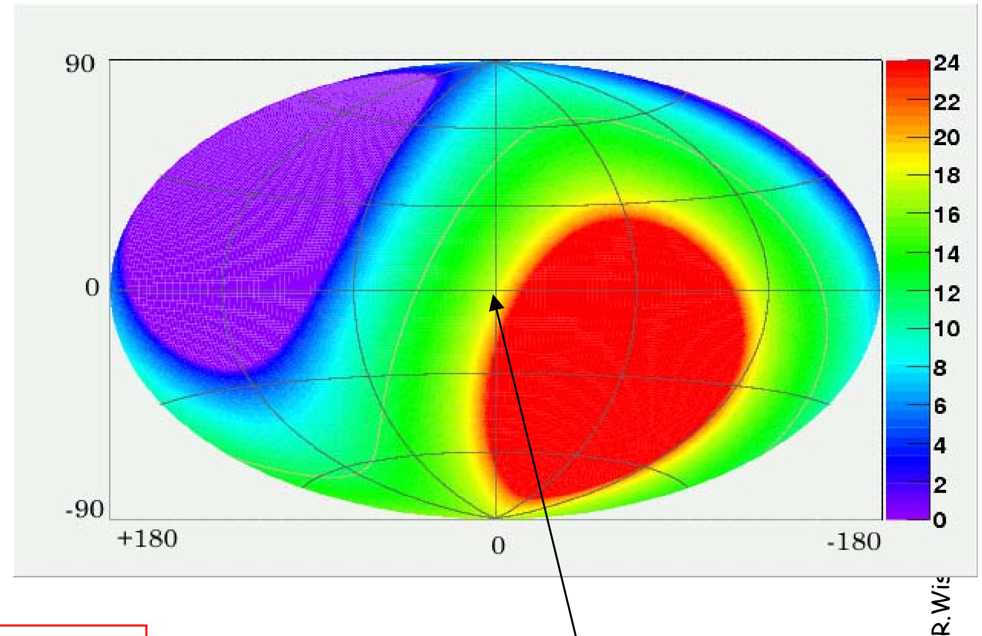
Data sample:
1998-2002 (Apr/98-Feb/03)
1038 days

- Low energy phenomena
  - Atmospheric neutrinos
  - WIMP Neutrinos
- Search for exotic particles
  - Relativistic Magnetic monopoles
- High energy phenomena
  - Diffuse neutrino flux
  - Neutrinos from GRB
  - Prompt muons and neutrinos
  - Exotic HE muons

Atmospheric Muon-Neutrinos



Skyplot of NT200 neutrino events / 5 years
(galactic coordinates)

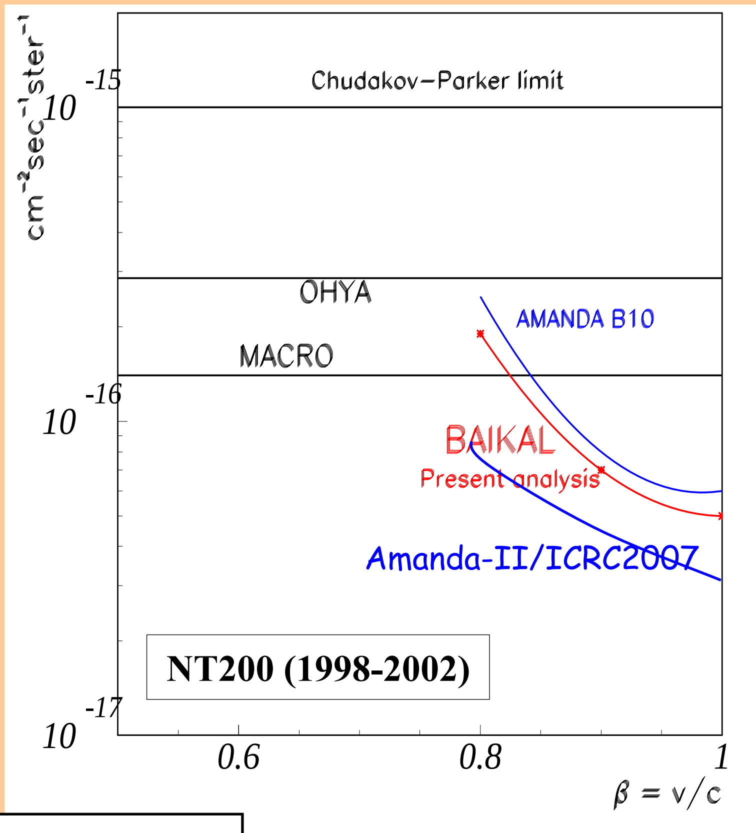


Galactic center
visible 18 hours per day

- Data: 372 upward ν events (1998-2002). (N_μ(>15GeV)/N_μ(>1GeV)~1/7)
- MC: 385 ev. expected (15%BG).

→ A high statistics neutrino sample for Point-Source Search, incl. GalCenter. **No evidence for non-atmosph. ν's.**

Search for Fast Monopoles ($\beta > 0.8$)



Baikal, 2006

90% C.L. upper limit on the flux of fast monopoles (1003 livedays).

$$N_\gamma(\lambda) = n^2 (g/e)^2 N_{\gamma\mu}(\lambda) = 8300\, N_{\gamma\mu}(\lambda) \quad (!!)$$

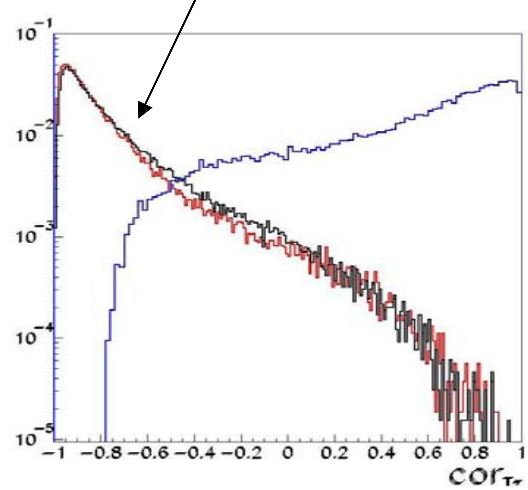
$$g = 137/2, \quad n = 1.33$$

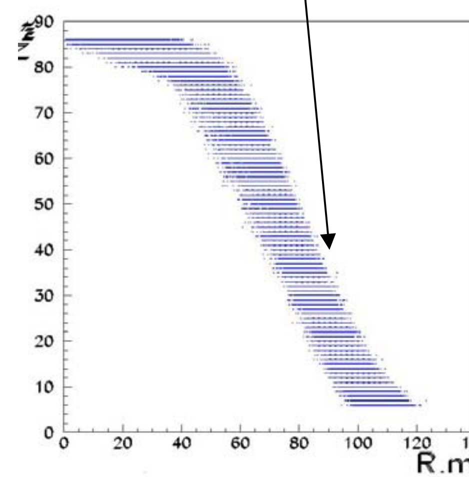
→ Bright light source, like muons $\sim E_\mu = 10^7$ GeV

Monopole selection criteria:

- **large hit channel multiplicity: $N_{hit} > 35$ ch**
- **clearly upward going track**

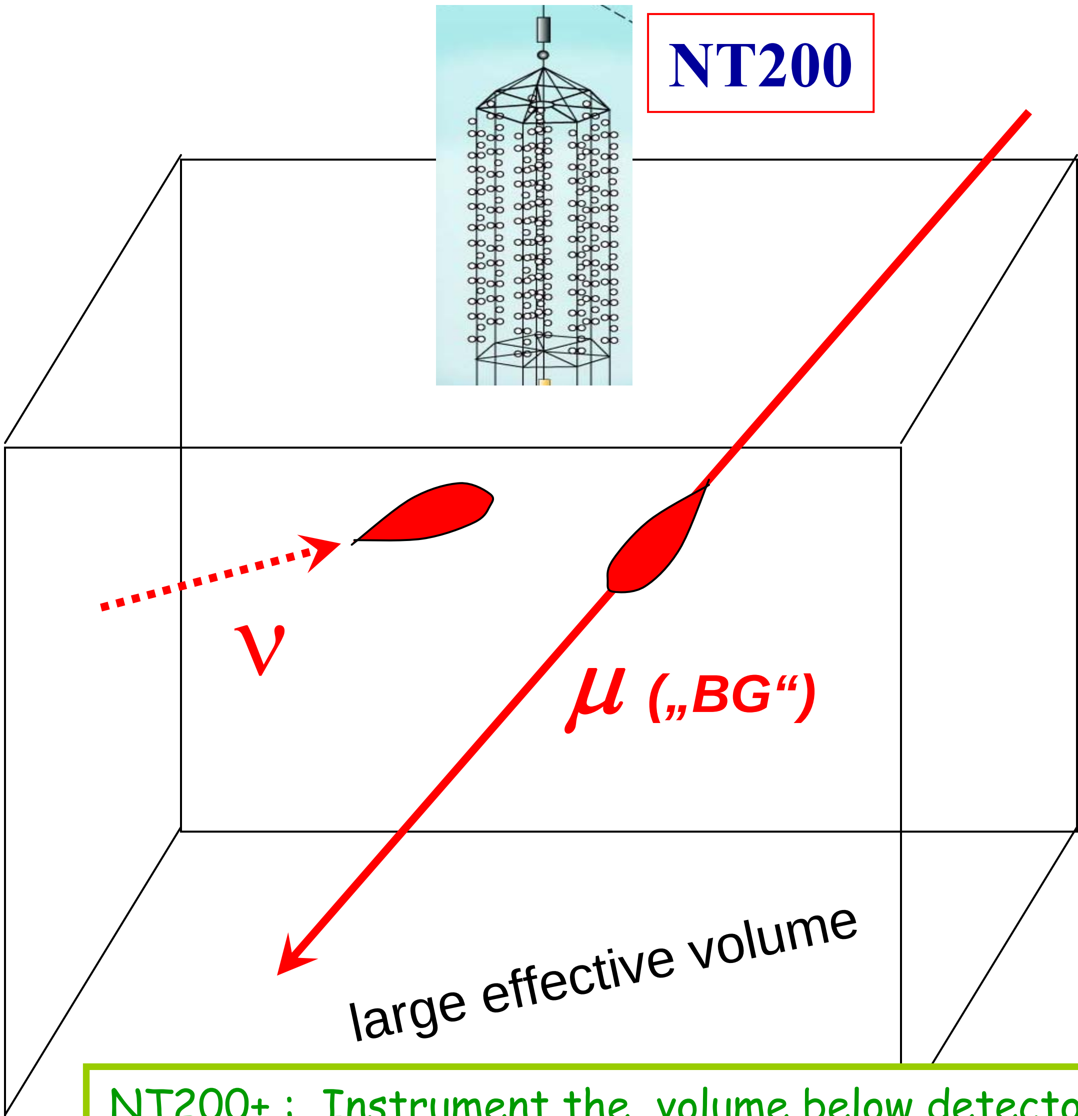
Background : atmospheric muons (downward)





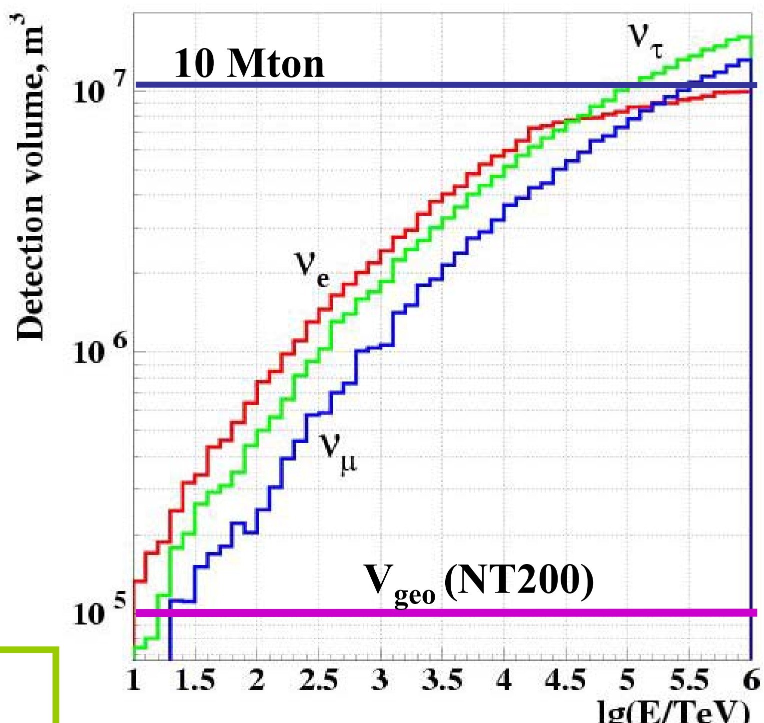
N_{hit} vs distance

Search for High Energy Diffuse Cascades



Search within non-instrumented volume below NT200 detector for cascades = Upward moving light fronts.

Effective Volume vs. Energy



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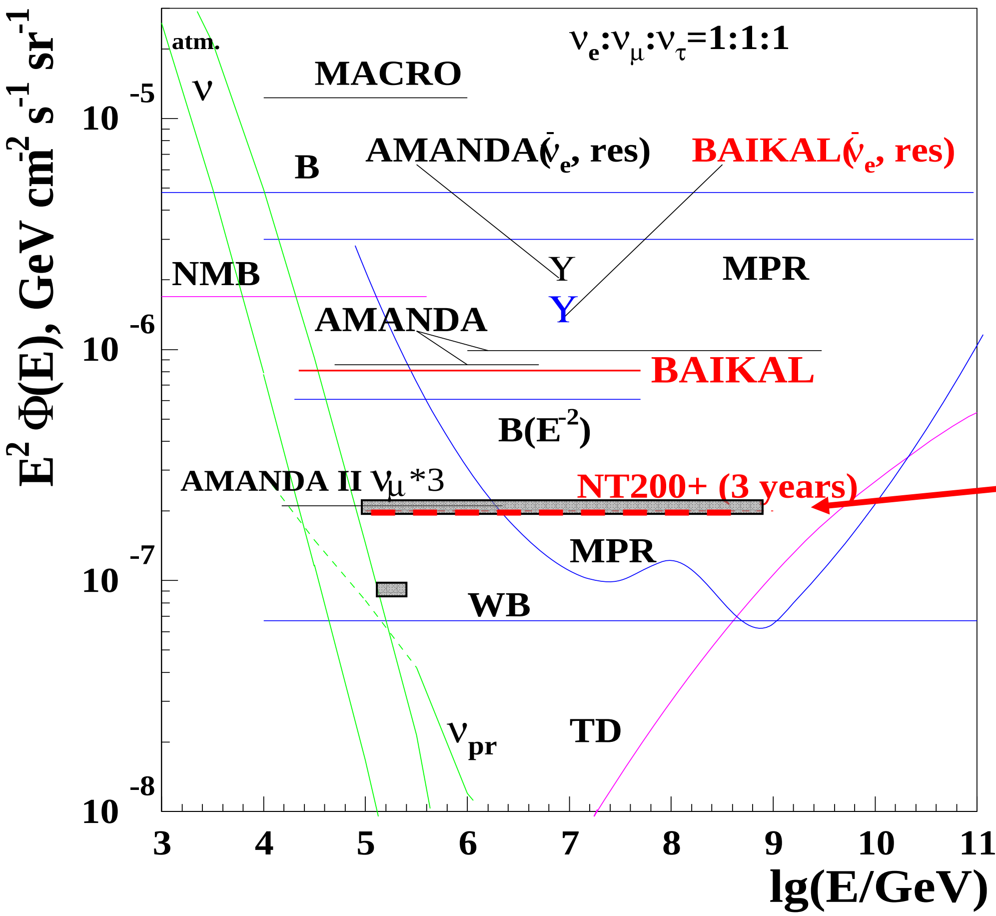
NT200+ : Instrument the volume below detector
→ better BG suppression and improved physics.

V_{det} > 1 Mton at 1 PeV

Diffuse Flux Limits

Exp. Limits, model predictions, and atmospheric ν-BG.



For a γ=2 spectrum $\Phi_\nu \sim E^{-2}$ the Baikal NT200 limit is (20 TeV < E < 50 PeV):
$E^2\,\Phi_\nu < 8.1 \cdot 10^{-7}$ GeV cm^{-2} s^{-1} sr^{-1}

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NT200+ sensitivity (~ Amanda-II)

Amanda-II, this conf.

limits given for all-flavors

1:1:1 flavor flux ratio @earth assumed (source1:2:0)

Exp. ν_μ limits are multiplied ×3

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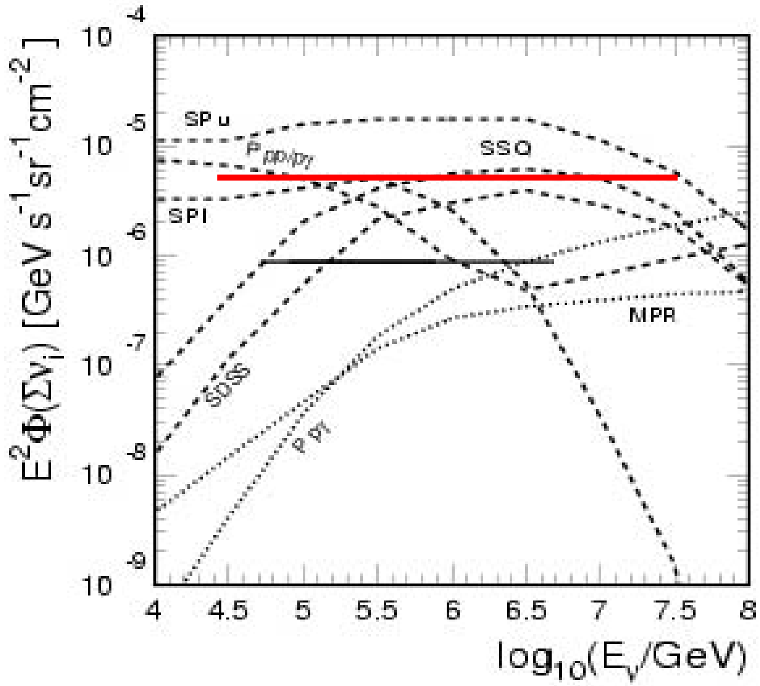
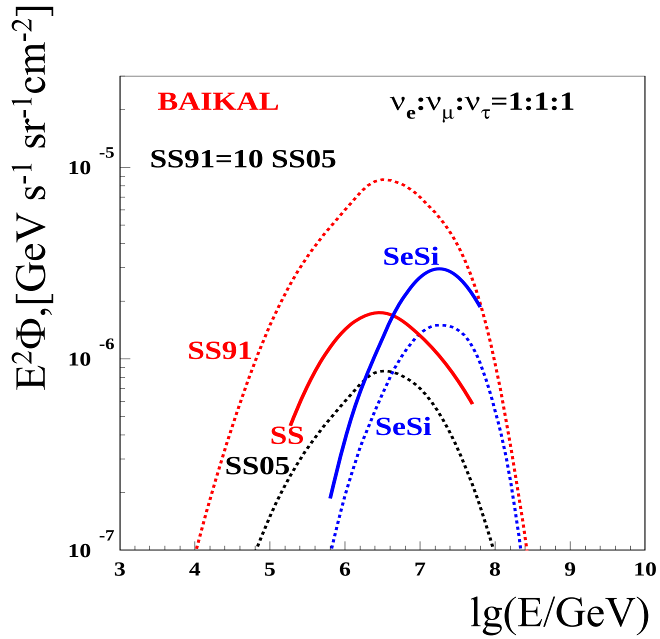




Neutrinos from Quasar Cores

SS – Stecker, Salamon (91,05)
SP – Szabo, Protheroe (92)

Neutrinos from Blazars

M pp+pγ - Mannheim (95)
P pγ - Protheroe (96)
MPR - Mannheim, Protheroe, Rachen (01)
SeSi - Semikoz, Sigl, (03)

Model survival factor $n_{90\%}/N_{model}$

The New Project:

A Km3 – size Detector in Lake Baikal

("Gigaton Volume Detector")

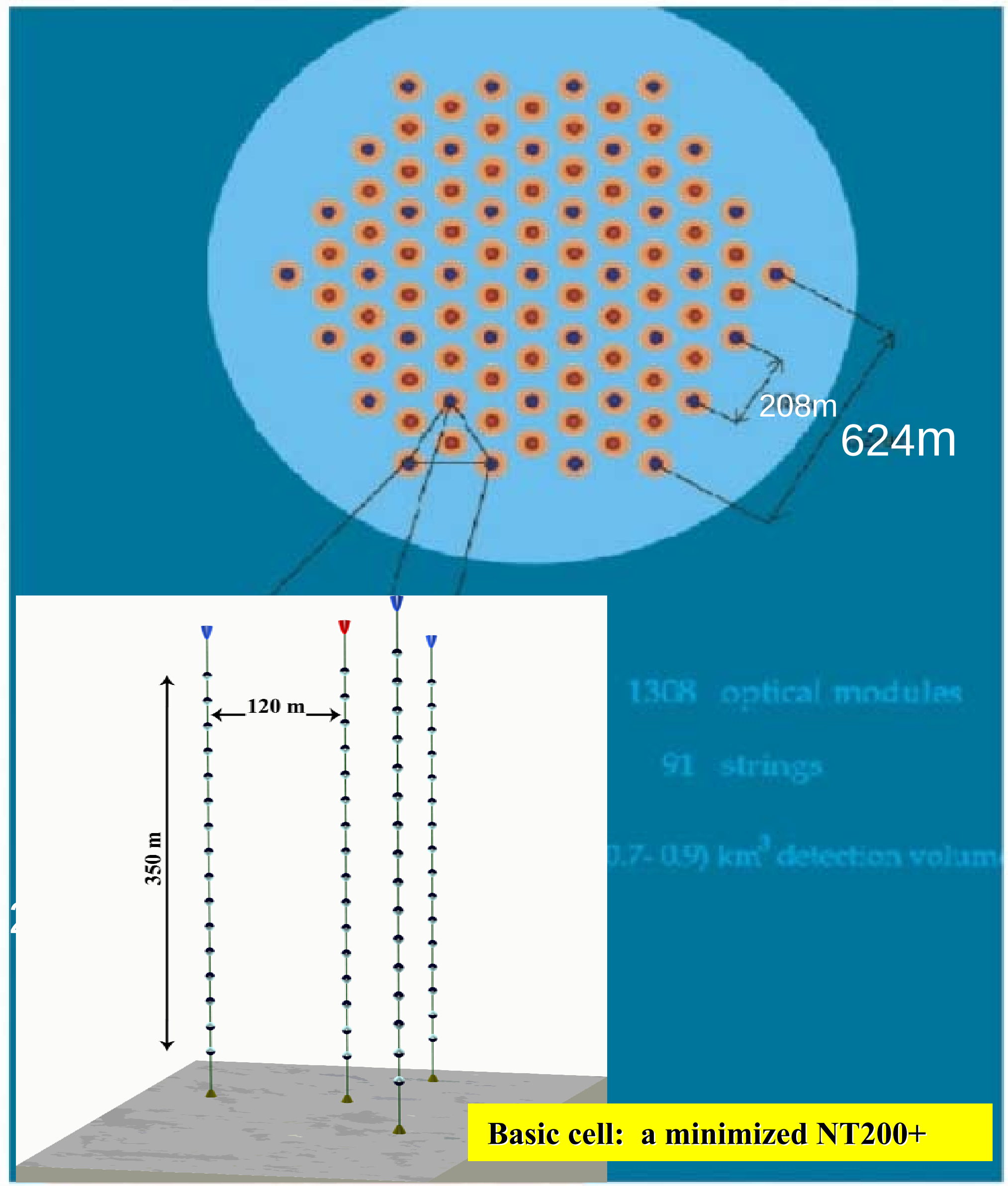
A Km3 - Scale Baikal Neutrino Detector

A sparsely instrumented array:

- 1300-1700 OMs
- 90-100 strings, 350m length
- 12-16 OM/string
- string radial distance ~120m *

→ Casacde effective volume for
$\geq$ 100 TeV: ~ 0.5-1. km³
$\delta \lg(E) \sim 0.1,\ \delta\theta_{med} < 4^{o}$

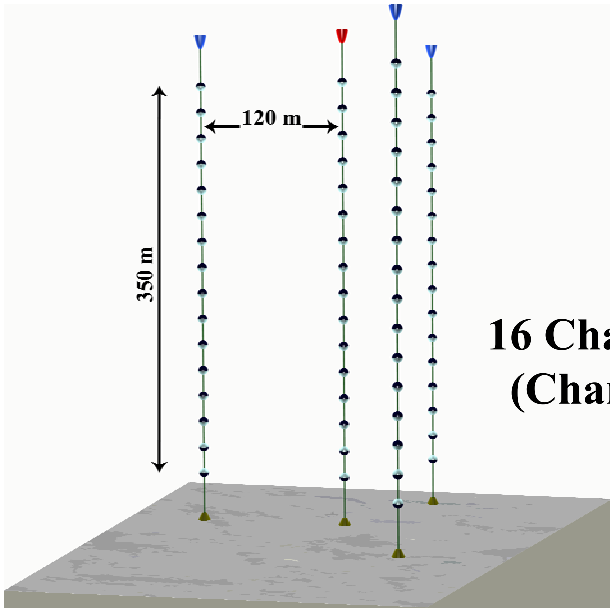
→ Muon detection from 10-30TeV



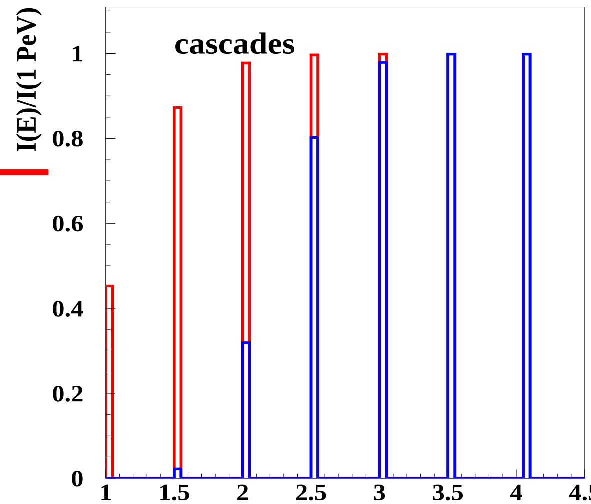
*Toy model (MC optimization in progress)

Km3 Design Studies (in progress)

contained events



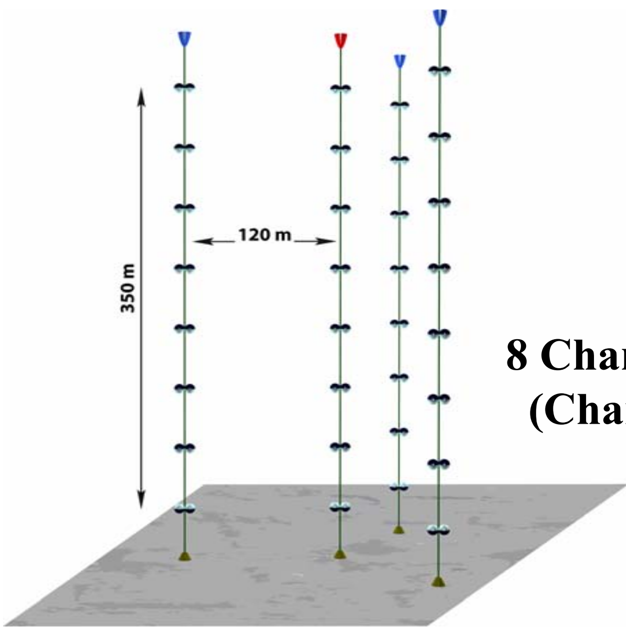
16 Channel / String
(Channel = 1 OM)



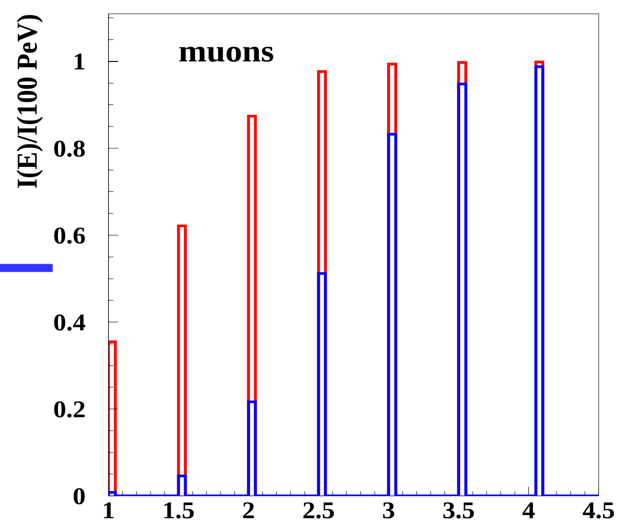
lg(E_sh/TeV)

Cascades

instrumented volume
V=3.5 10^8 m^3



8 Channel / String
(Channel = 2 OM)



lg(E_mu/TeV)

Muons

<S>= 0.8 10^6 m^2

R.Wischnewski ICRC, Merida

PMT Selection for Km3

Basic criteria of PM selection is effective sensitivity to Cherenkov light
which depends on
Photocathode area × Quantum efficiency × Collection efficiency
and Optical Module design (FOV).

Baikal
NT200+

IceCube
Antares
NEMO?

Quasar-370
D ≈ 14.6″
Quantum efficiency ≈ 0.15

$\overset{?}{\approx}$

Hamamatsu R8055
D ≈ 13″
Quantum efficiency ≈ 0.20

$\overset{?}{\approx}$

Photonis XP1807
D ≈ 12″
Quantum efficiency ≈ 0.24

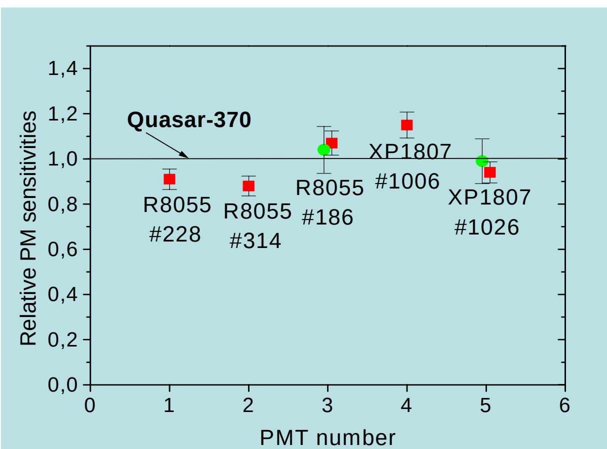
PMT development now is an active field with KM3NET/ BAIKAL-km3/… :
QE >30% , new Smart-PMT designs (QUASAR-like by Photonis/…?), …

PMT Selection: Underwater Tests (2007)

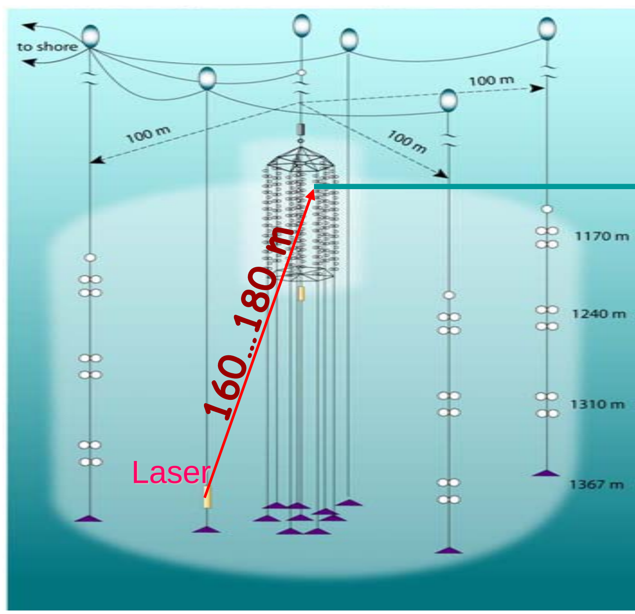
6 new PMTs installed in April 2007 inside NT200+:

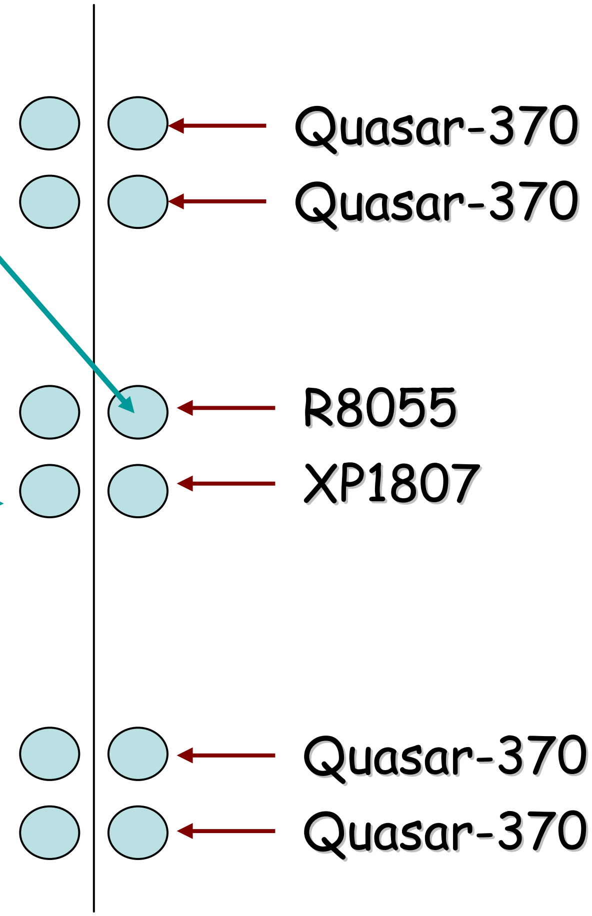
- 4 PM R8055 (Hamamatsu)
- 2 XP1807 (Photonis)

FADC readout for 2xR8055.



Relative effective sensitivities of large area PMs R8055/13" , XP1807/12" and Quasar-370/14.6". Laboratory (squares) and in-situ tests (dots).





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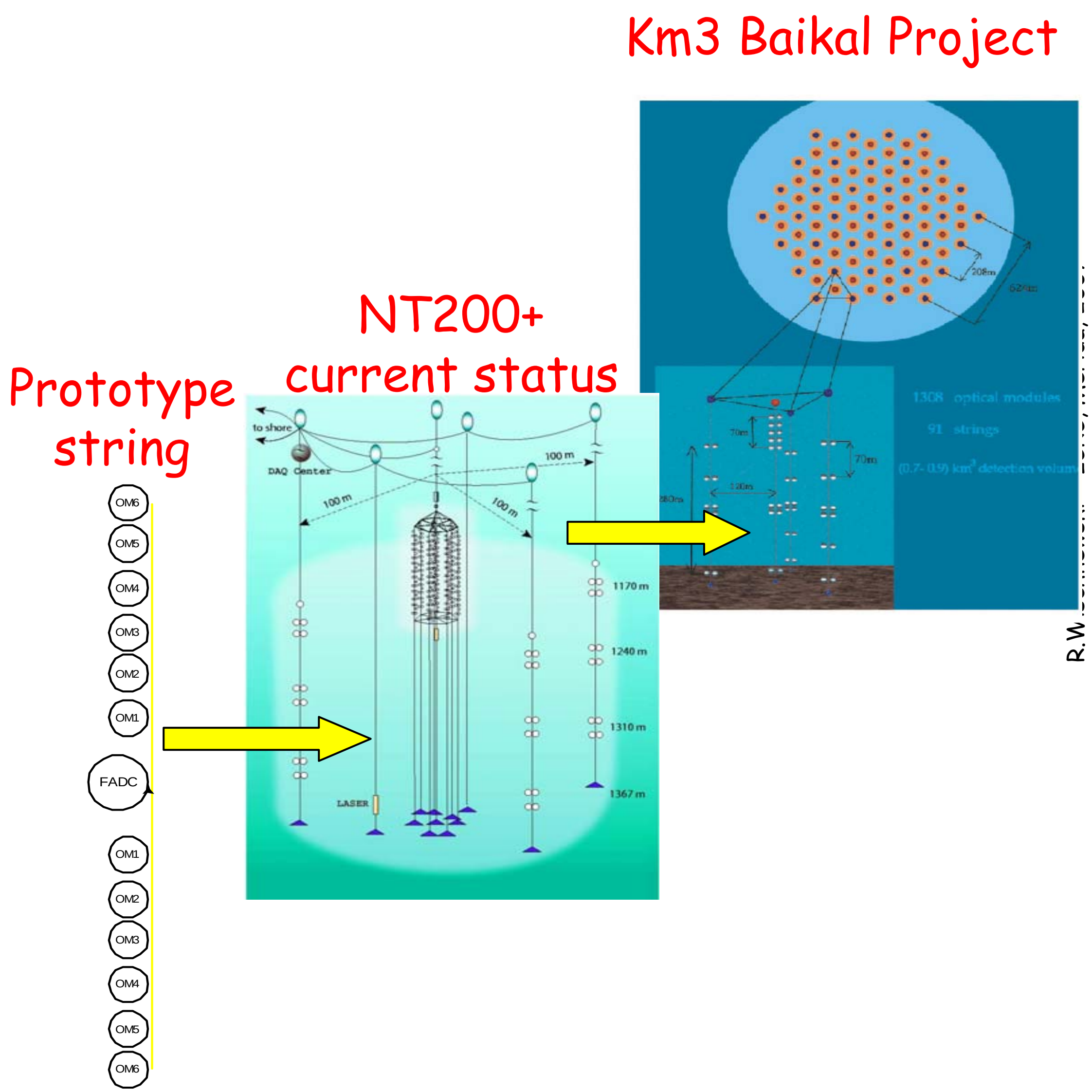
Prototype String for Km3 Baikal Neutrino Telescope

April 2008:
<u>Installation of a "new technology" prototype string as part of NT200+</u>

- Investigation and in-situ tests of all basic elements of the future detector:
  - Optical modules
  - DAQ system
  - new cable communications.

- Study of DAQ/Triggering concept for the km3-detector;
  e.g. "quasi-local coincidences"

- Comparison of new FADC readout with classical TDC/ADC approach (200MHz).



Baikal – Km3: Schedule

06-07	R&D, Testing NT200+
08	Technical Design
08-14	Fabrication (OMs, cables, connectors, electronics)
10-12	Deployment (0.1 – 0.3) km3
13-14	Deployment (0.3 – 0.6) km3
15-16	Deployment (0.6 – 0.9) km3

Summary

- The Baikal Neutrino Telescope operates successfully since 1998.

- NT200 : focusing on diffuse HE-neutrino search.
  - HE-diffuse search: A "Mton-detector" with only 100kton geometric volume.
  - Magnetic Monopoles, WIMPs, HE-atm.μ

- NT200+ : is designed for diffuse cosmic ν-search.
  - 4x sensitivity gain; improved vertex, energy + direction for shower.
  - 5 Mton instrumented volume, V_eff > 10 Mton at 10 PeV.

- Baikal-Km3 activities started in 2006.
  - Optimal PMT choice & redesign of F/E & trigger electronics.
  - 2008: Deploy prototype km3-string.
    Design based on NT200+ experience and in-situ tests.

Thank you.

Final deployment step for NT200+. April, 2005.