Dark matter searches with Baikal

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on behalf of Baikal Collaboration

Institute for Nuclear Research of Russian Academy of Sciences

Baikal collaboration:

1. Institute for Nuclear Research, Moscow, Russia.
2. Joint Institute for Nuclear Research, Dubna, Russia.
3. Irkutsk State University, Russia.
4. Skobeltsyn Institute of Nuclear Physics MSU, Moscow, Russia.
5. Nizhny Novgorod State Technical University, Russia.
6. St.Petersburg State Marine University, Russia.
7. EvoLogics Gmb. Germany.
8. Kurchatov Institute, Moscow, Russia.
9. DESY-Zeuthen, Zeuthen, Germany


Lake Baikal in winter

Lake Baikal in other seasons

Winter expedition: 15 February - 15 April

Winter expedition: 15 February - 15 April

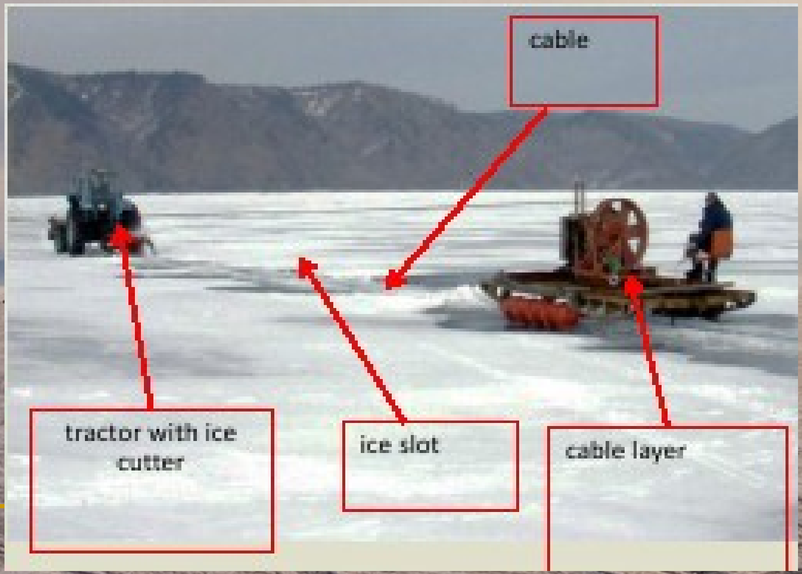
- Telescope installation, maintenance, upgrade and rearrangement
- Installation & test of a new equipment
- All connections are done on dry
- Fast shore cable installation (3-4 days)

Winter expedition: 15 February - 15 April

- **Telescope installation, maintenance, upgrade and rearrangement**
- **Installation & test of a new equipment**
- **All connections are done on dry**
- **Fast shore cable installation (3-4 days)**

Strong ice cover

Shore cable deployment



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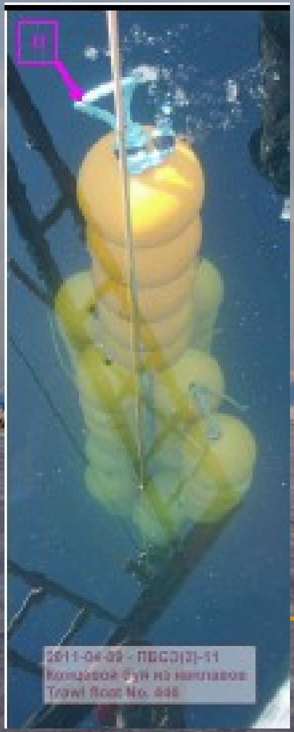
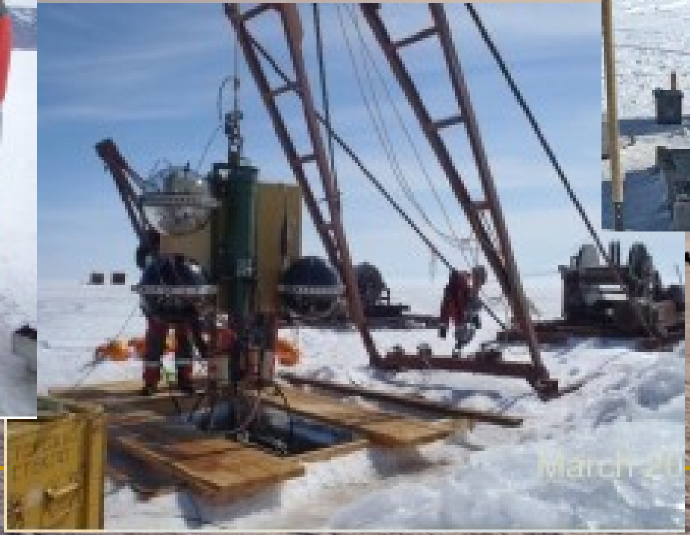
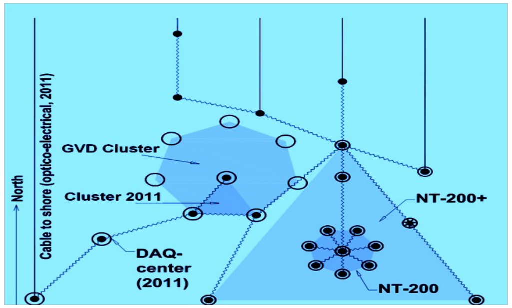


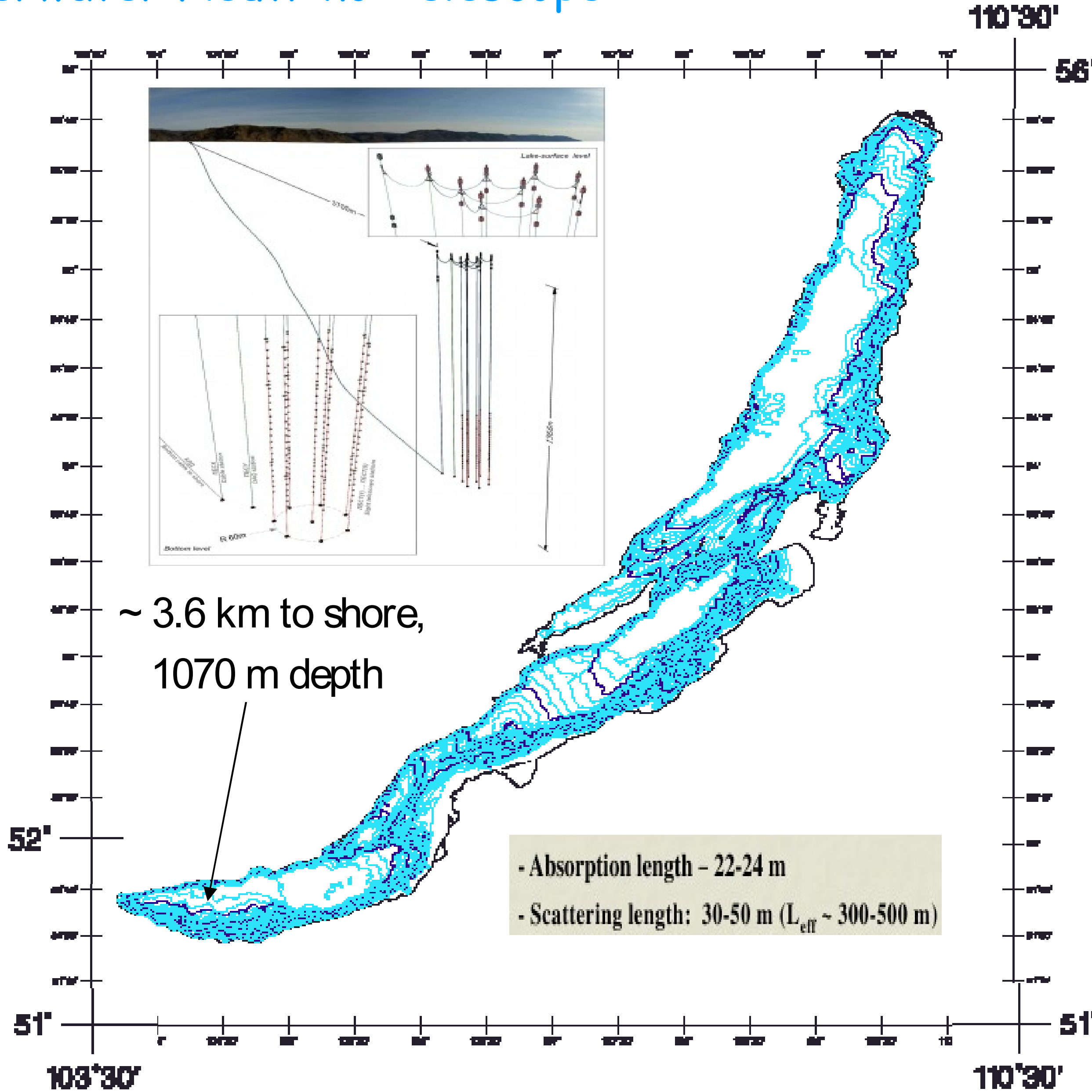
Maintenance



Site of Baikal Underwater Neutrino Telescope

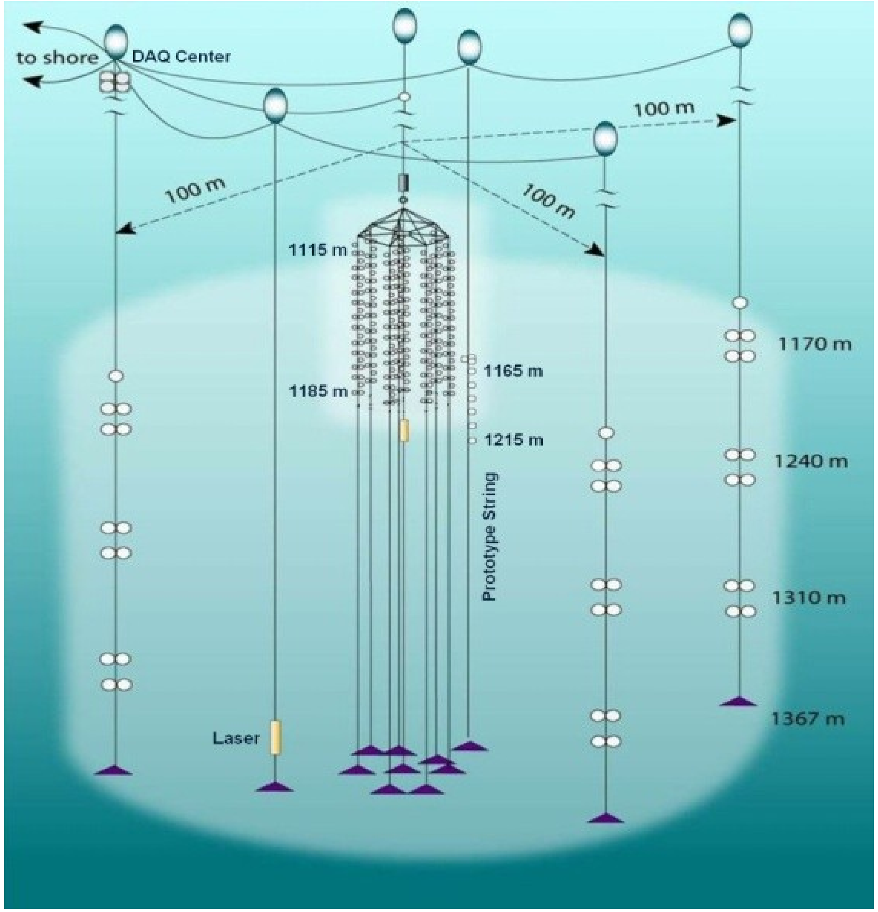


Sketch of prototype cluster, neutrino telescope NT200+, and communication lines locations.



Baikal Underwater Neutrino Telescope: 10 MT

Quasar photodetector
(∅=37cm)



1998 - NT200

NT200: 8 strings (192 OMs)
Height x ∅ = 70m x 40m,
$V_{inst}=10^5 m^3$
Effective area: 1 TeV ~2000m²
Eff. shower volume: 10 TeV ~ 0.2 M ton

2005 - NT200+

NT200+ = NT200 + 3 outer strings
(192+36 OMs)
Height x ∅ = 210m x 200m,
$V_{inst} = 5\times10^6 m^3$
Eff. shower volume: 10^4 TeV ~ 10 M ton

~ 3.6 km to shore, 1070 m depth

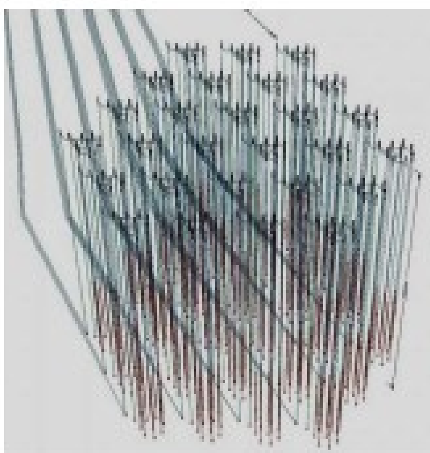
Gton Volume Detector in the Lake Baikal: TDR 2011

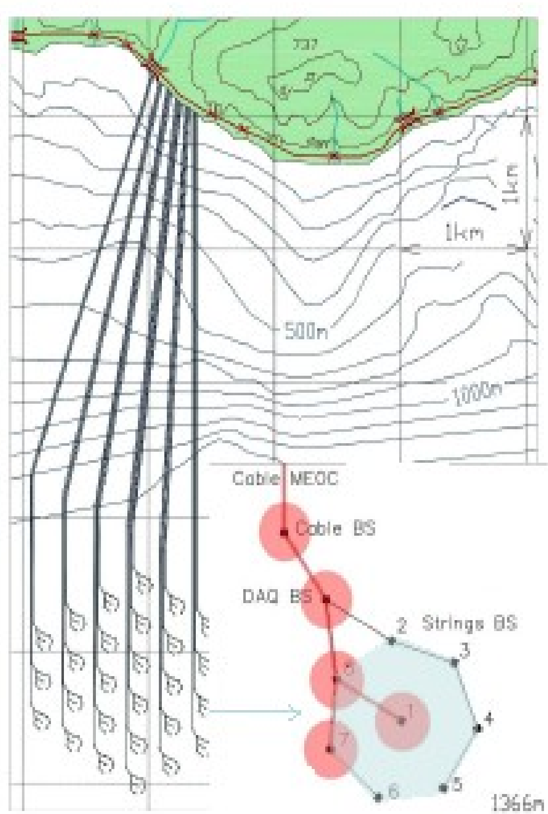
http://baikalweb.jinr.ru/GVD/

10368 optical sensors
27 subarrays (clusters with 8 strings)
String: 4 sections, 48 optical sensors
Depths: 600 – 1300 m
To Shore: 4 – 6 km

Instrumented water volume
V= 1.5 km^3 S = 2 km^2

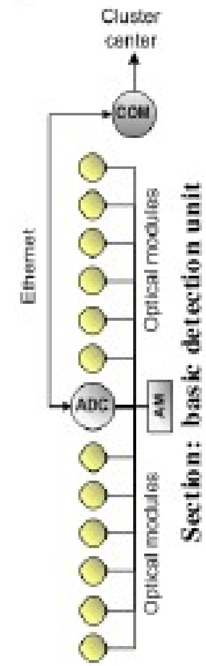
Angular resolution
Muons: 0.25 degree
Showers: 5-7 degree





GVD array

1st GVD cluster: 8 strings
- Installed strings and cable stations



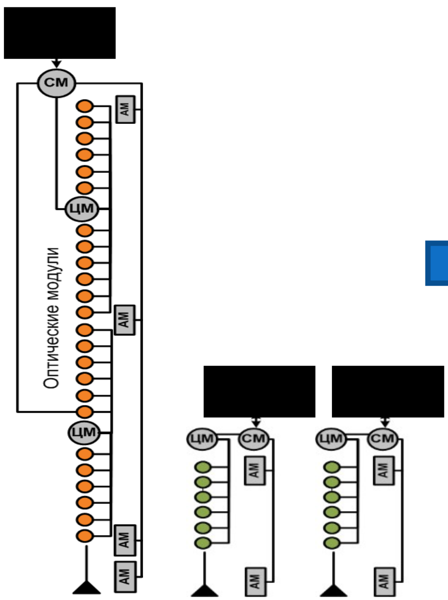
Optical module

Present and nearest future

2012

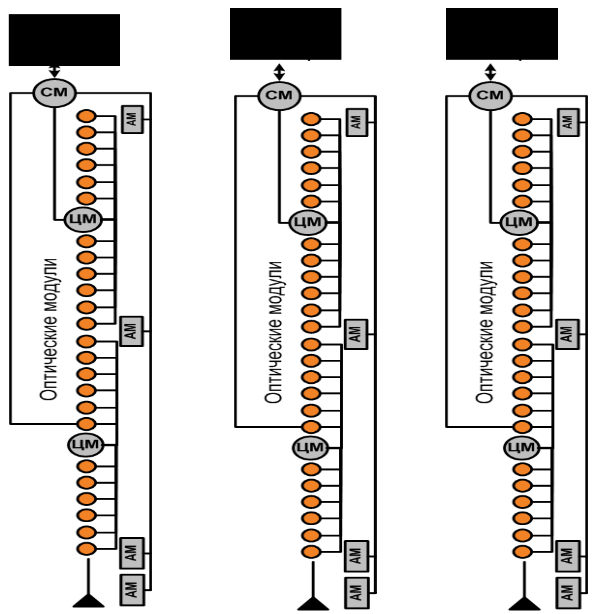
3-strings, first full scale GVD string (24 OM)

Data taking since April 2012



2013

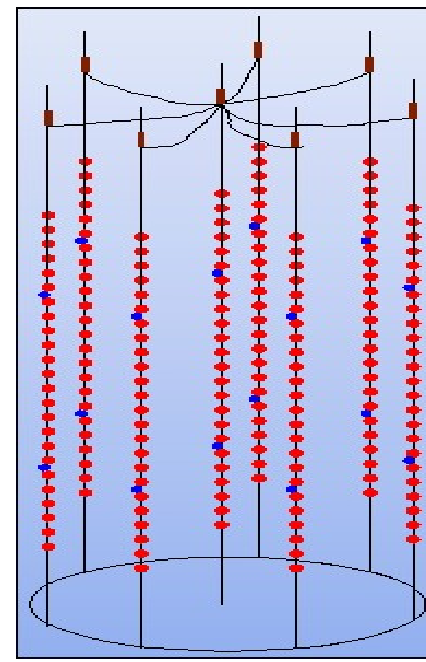
Detector with 3 full scale GVD strings



~10^6 м^3

2014-2015

Cluster (8 strings)



~4×10^6 м^3

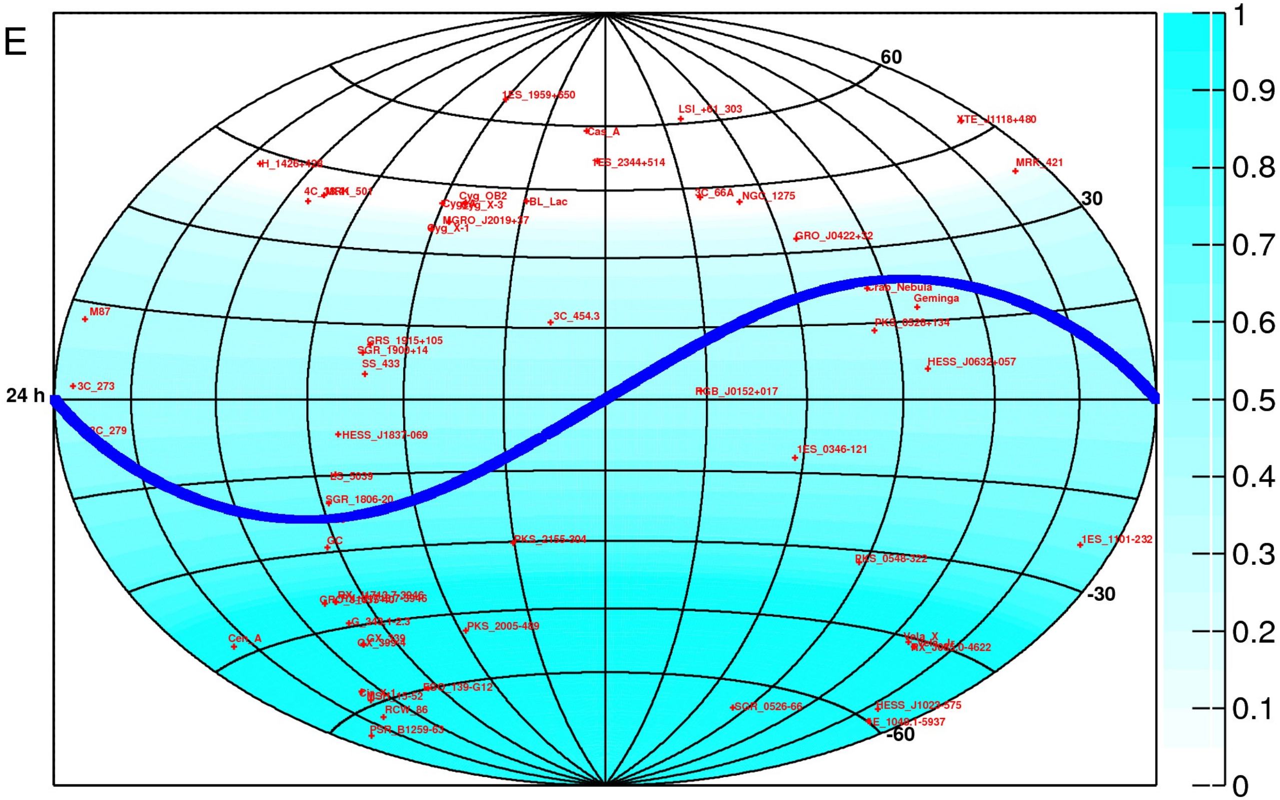
Skymap of visibility for Baikal Underwater Neutrino Telescopes

Baikal NT200,+,GVD

Latitude: 51.83 N

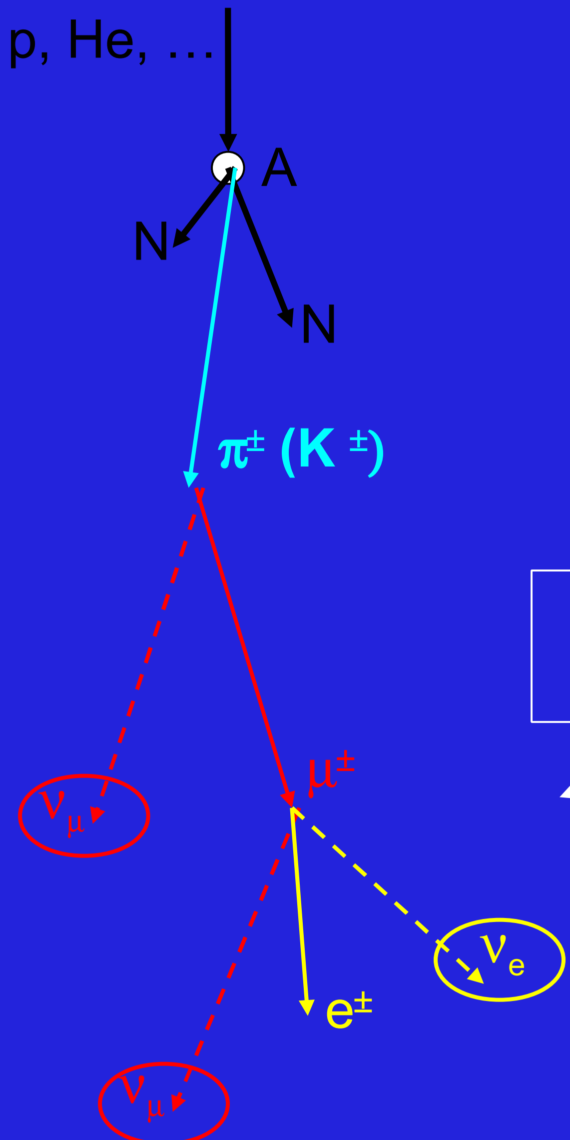
Longitude: 104.33 E

Site: Lake Baikal

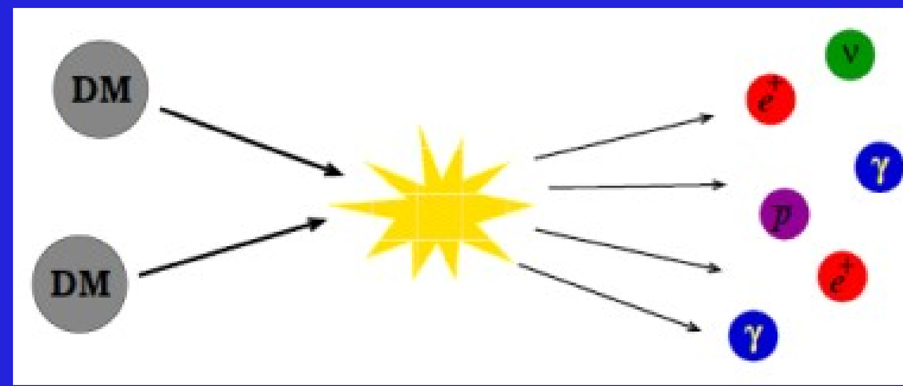


Neutrino fluxes from p-A and χ-χ

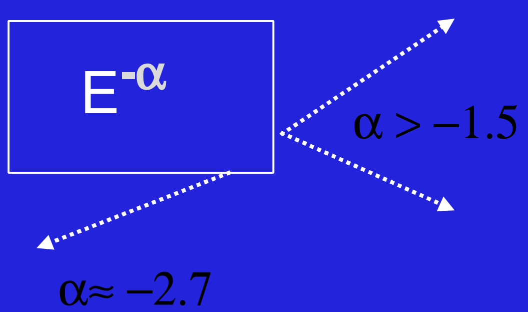
* In atmosphere of the Earth:



** Non-atm: DM annihilations in the Sun



hadronization, fragmentation, decays



Possible channels of “prompt” neutrinos:

$$\chi\chi \longrightarrow \tau^+\tau^- \longrightarrow \mu\nu_\mu\nu_\tau$$

$$\chi\chi \longrightarrow W^\pm H^\pm$$

$$\longrightarrow \tau^\pm\nu_\tau$$

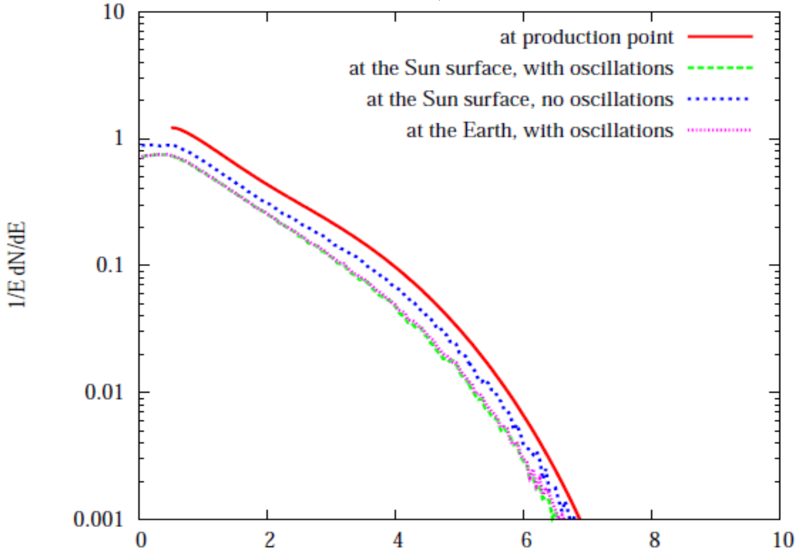
$$\longrightarrow l^\pm\nu_l$$

Branching of *i*-channel

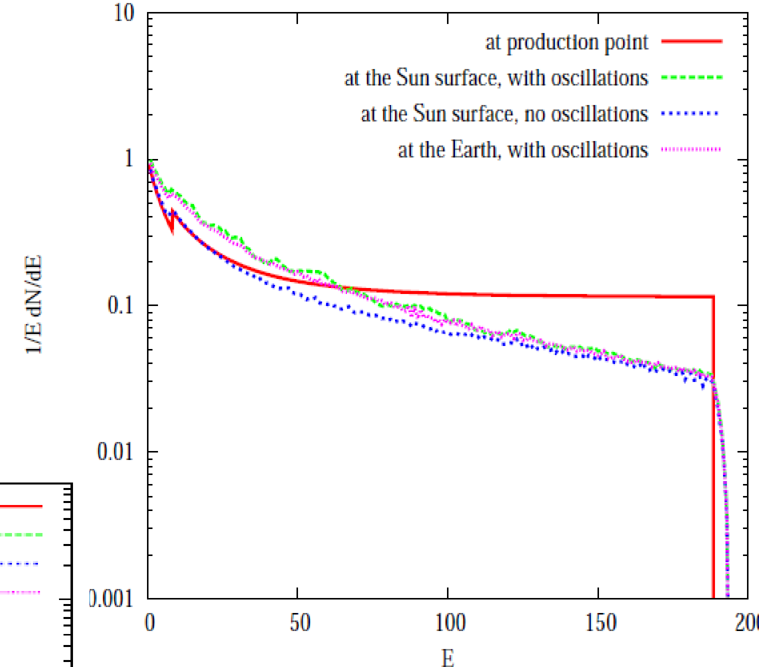
$$B_i = \frac{\langle\sigma_A \upsilon\rangle_i}{\Sigma\langle\sigma_A \upsilon\rangle_i}$$

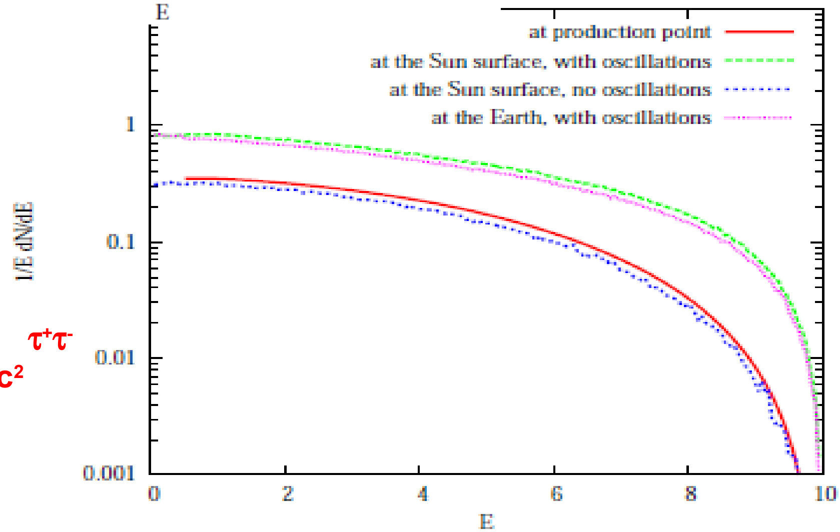
Transport of oscillating DM ν_μ and anti-ν_μ from the Sun to observer

Annihilation channel - bb, DM mass - 10 GeV/c²



Annihilation channel - W^+W^-, DM mass - 200 GeV/c²





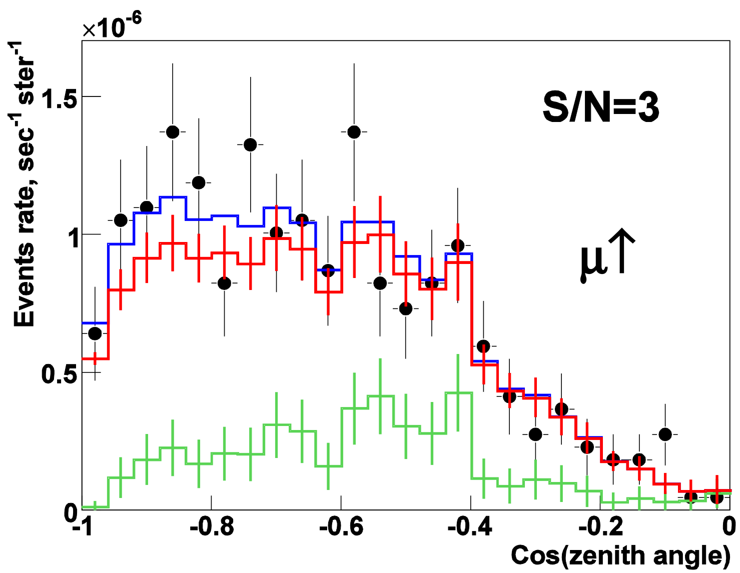
Annihilation channel $\tau^+\tau^-$
DM mass **- 10 GeV/c²**

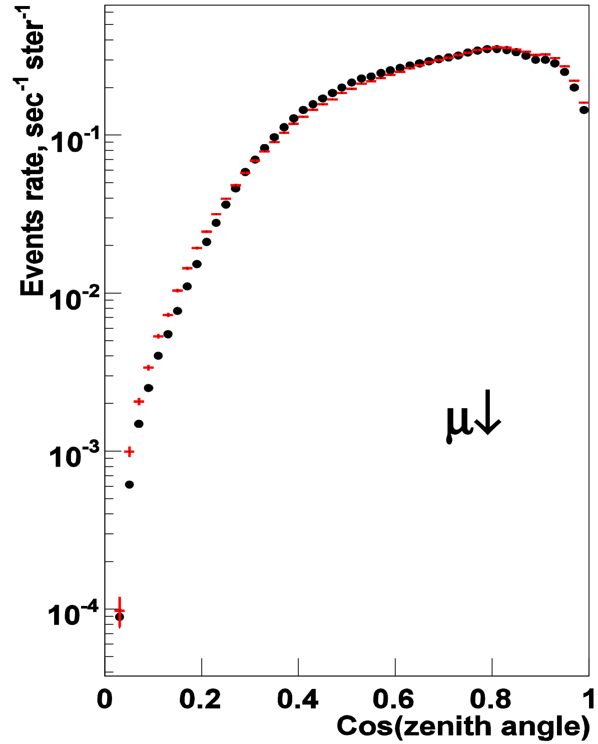
(see talk by S.Demidov)

Baikal NT200: MC and Reconstruction

NT200 soft: I.Belolaptikov et al., Astropart.Phys. 7, 1997

MUM code: I.Sokalski, E.Bugaev, S.Klimushin, Phys. Rev.D64, 2001



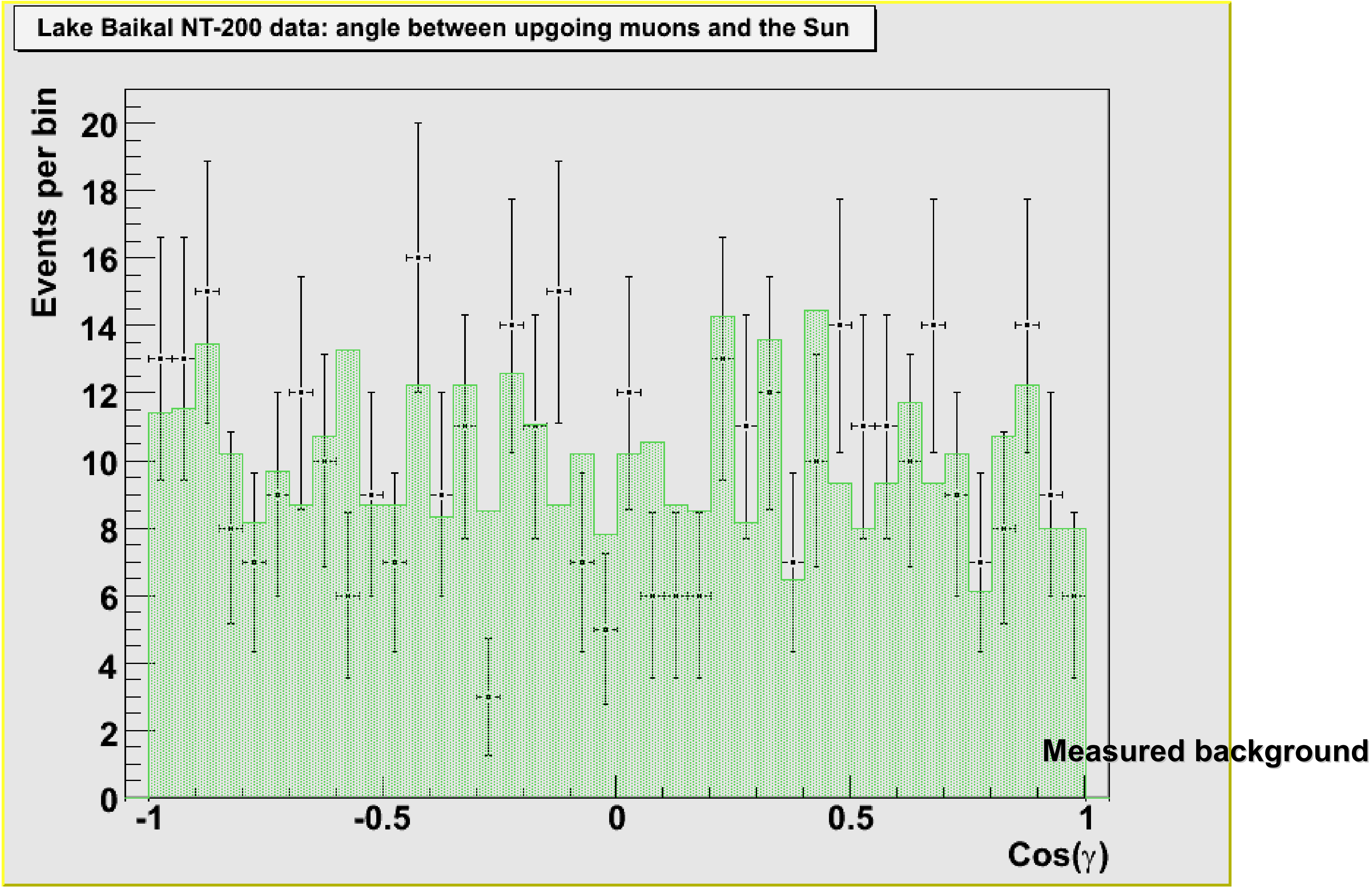


1998-2002yr: 1038 days l.t.

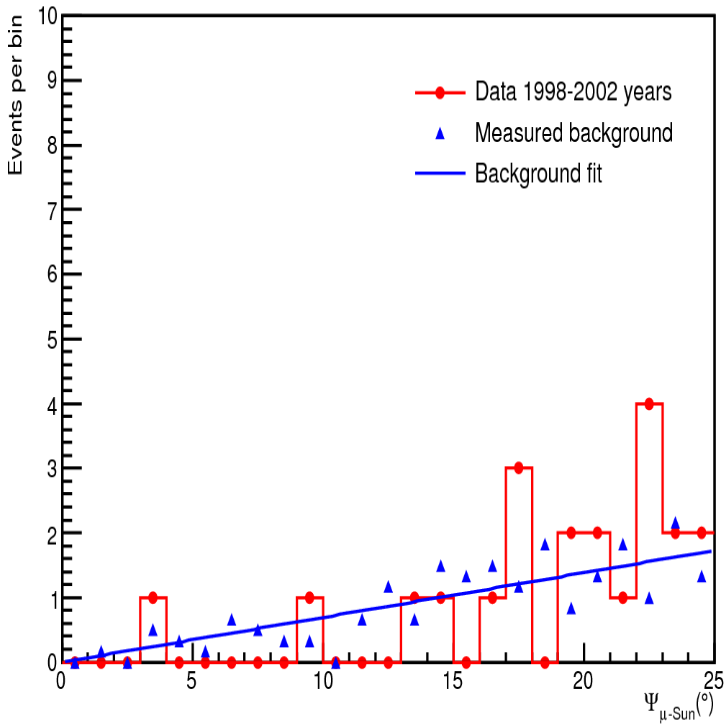
Eth   10GeV

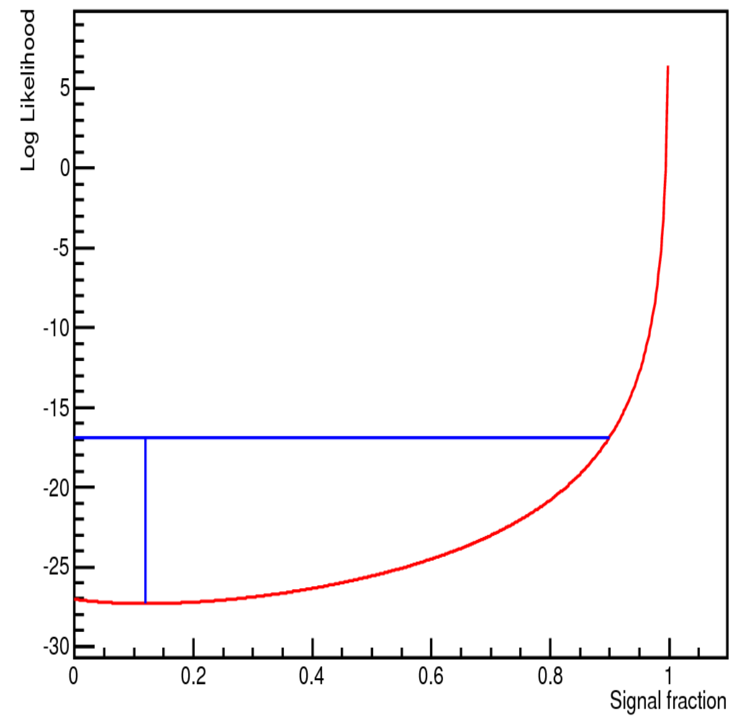
<Ψ> ~4 deg.

Baikal NT200: 1998 — 2002 years



Baikal NT200: 1998 — 2002 years





N^{UpL} - calcul follow to FC: G.Feldman & R.Cousins, Phys.Rev.D57:3873-3889, 1998

Muon flux detected by NT from neutrino scattering ν_μ-N

Flux:

$$I(\geq E_{th}, \cos\Theta_i) = \frac{N(E_{th}, \cos\Theta_i)}{T \times \int S'(E_{th}, \Omega_i) d\Omega_i}$$

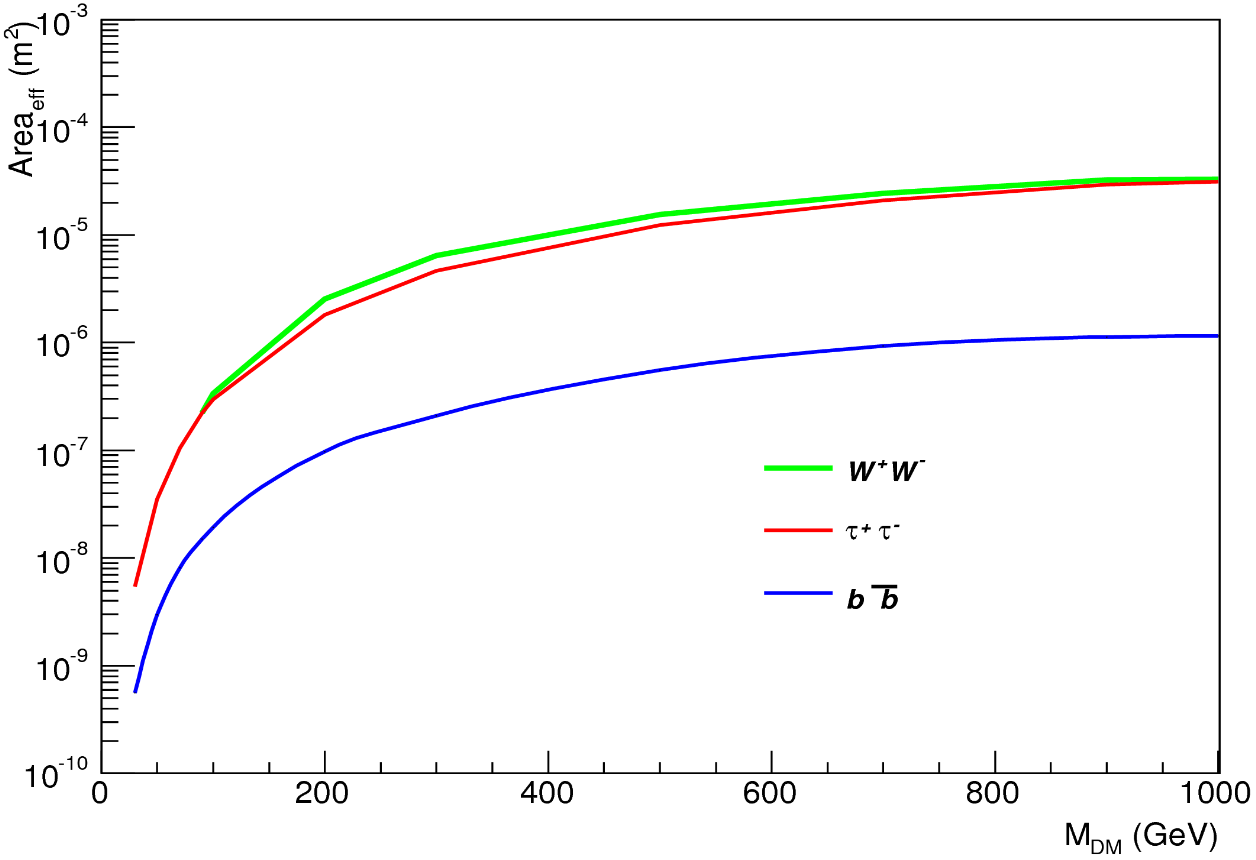
Eff.Area:

$$S'(E_{th}, \Omega_i) = \frac{\int S(E,\Omega) \times \varepsilon(E_{th}, E, \Omega) \times \Phi^{\nu}_{\mu}(E,\Omega) dE}{\int \Phi^{\nu}_{\mu}(E,\Omega) dE}$$

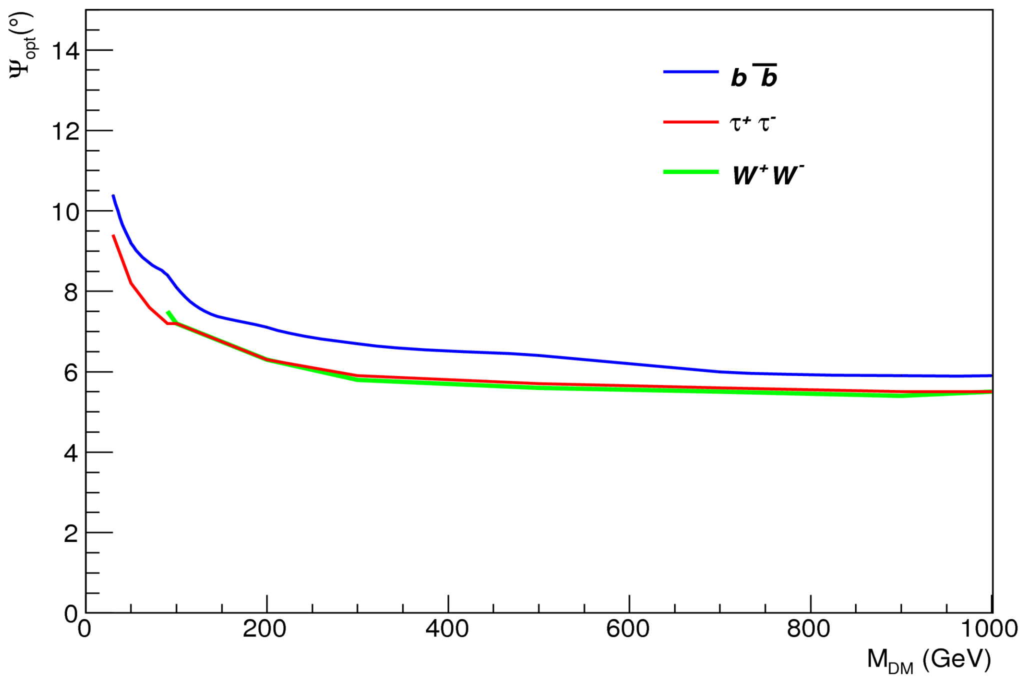
Probability:

$$P_j(E_\nu, E_{th}) = \int_{E_{th}}^{E_\nu} \frac{d\sigma^j(E_\nu, E'_\mu)}{dE'_\mu} \times \left[R(E'_\mu) - R(E_\mu)\right] dE'_\mu$$

Baikal NT200:
Effective areas for neutrinos expected from DM-DM in the Sun



Baikal NT200:
Optimal cone toward the Sun in search for muons from DM-DM



MRF
G.Hill & K.Rawlins
arXiv:astro-ph/0209350

$$\frac{\langle n\_Poisson \rangle}{n\_expected\_in\_cone}$$

In results, the expected signal parts within optimal cones are collected: in bb ~65%, tau-tau or WW ~ 70%

Upper limits on χ–χ annihilation Rate and on μ and ν Fluxes

μ-Flux:

$$\Phi_{\mu} = \Gamma_{A} \sum_{j=\nu,\tilde{\nu}} \int_{Eth}^{m_\chi} P_j(E_\nu, E_{th}) \times \frac{dF^j}{dE_\nu} dE_\nu$$

Annihilation rate

ν-Flux:

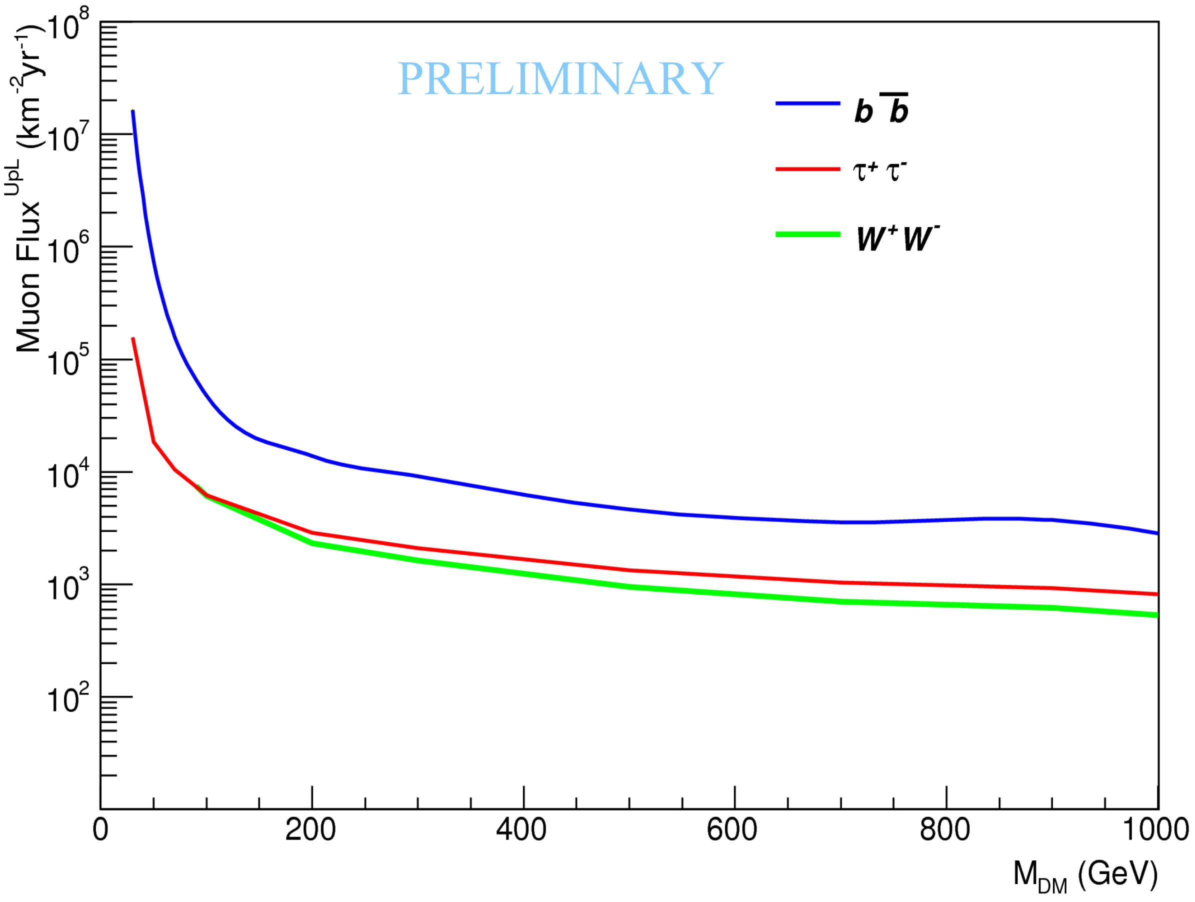
$$\frac{dF^j}{dE_\nu} = \frac{1}{4\pi R^2} \sum_i B_i \frac{d\Phi_i^j}{dE_\nu}$$

Annihilation branching ratio

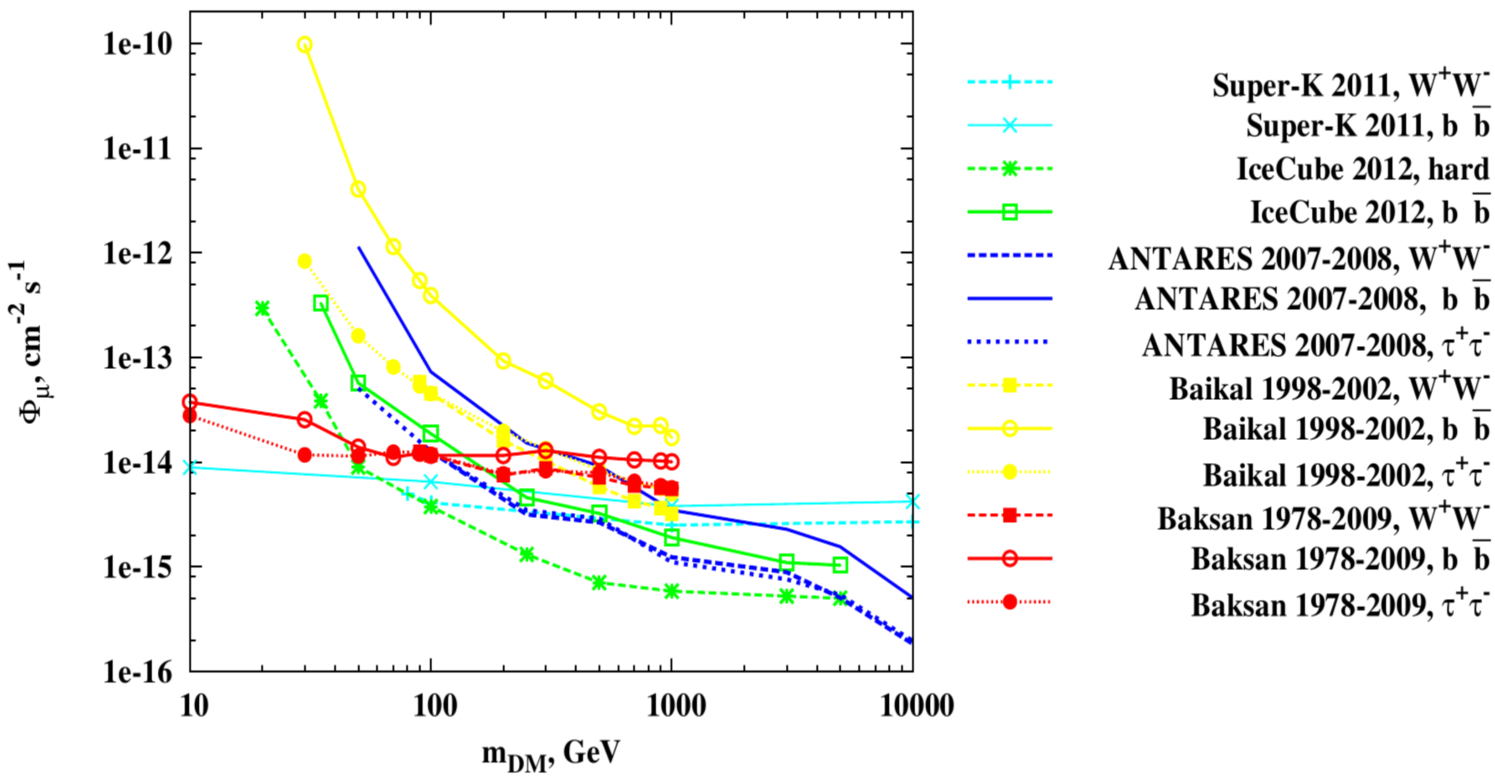
$$\Gamma_A^{UpL} = \frac{N^{UpL}}{T\varepsilon} \times \frac{1}{W}$$

Probability to detect muon from one χ–χ annihilation

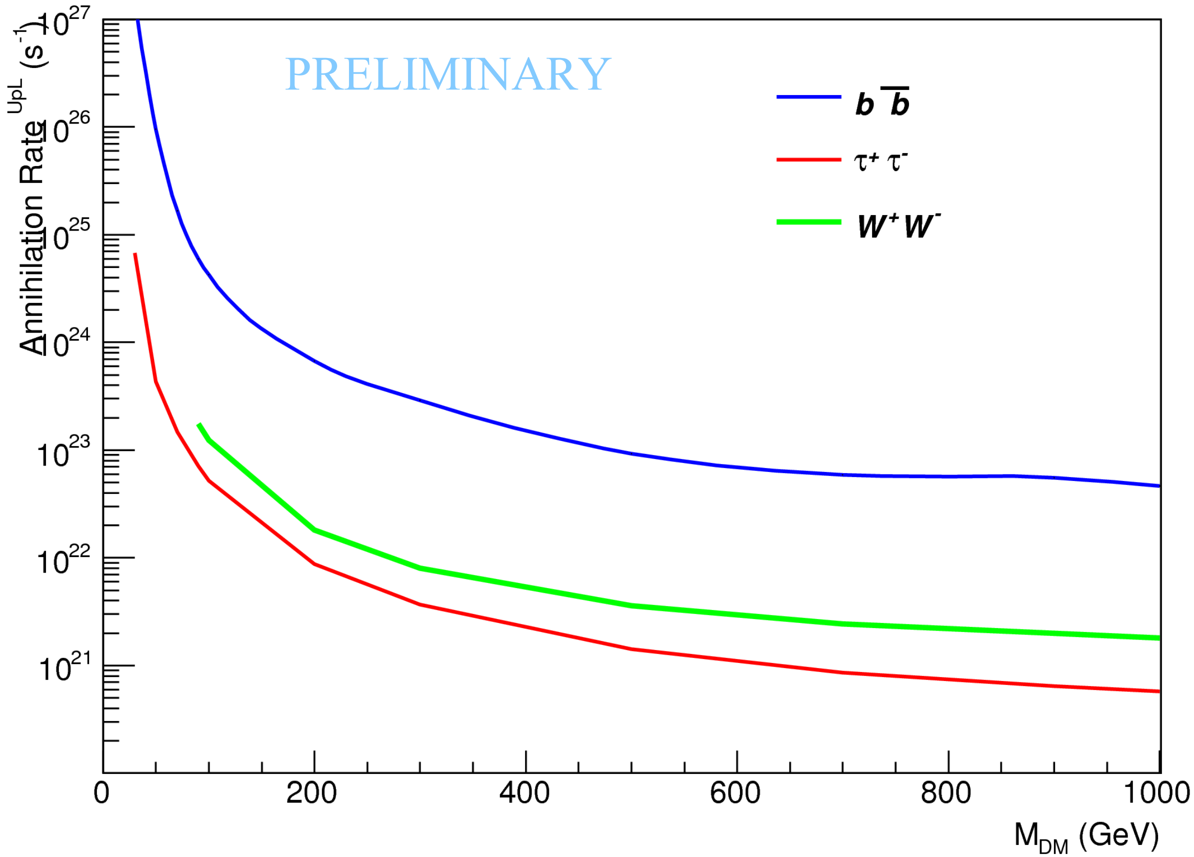
Baikal NT200:
90% C.L. Upper limits on muon fluxes from DM-DM in the Sun



Baikal NT200: preliminary
90% C.L. Upper limits on muon fluxes from DM-DM in the Sun



Baikal NT200:
90% C.L. Upper limits on $\chi\chi$ annihilation rate in the Sun



How to calculate Upper Limits on χ-N cross section

$$\frac{\sigma}{\Gamma_A} \cdot \Gamma_A^{\text{Upp.Lim.}} = \sigma^{\text{Upp.Lim.}}(m_\chi)$$

$\equiv \lambda$

Universal for any NT and model independent, although includes astro- and nuclear physical uncertainties

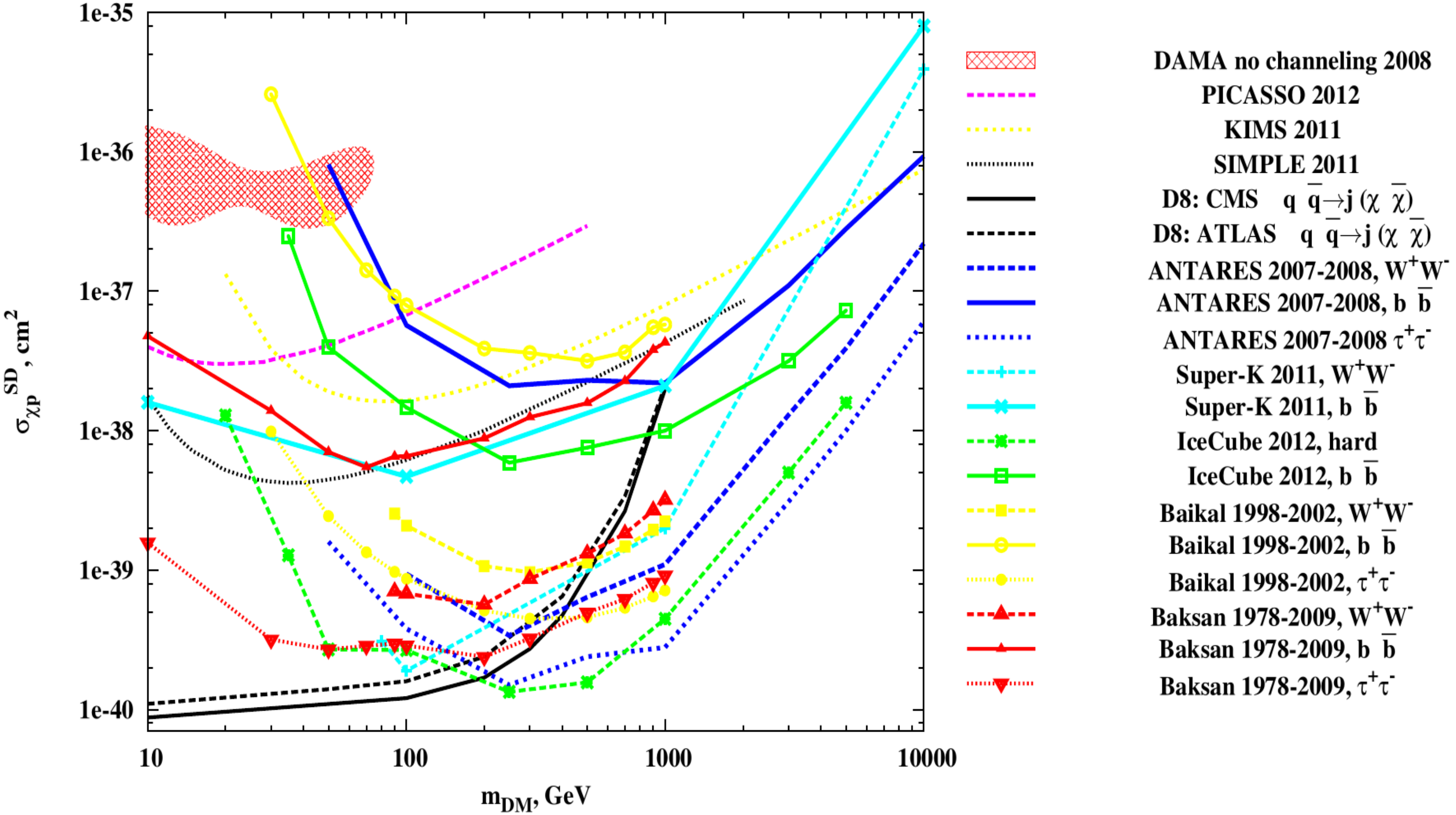
S.Demidov and O.Suvorova, arXiv:1006.0872, JCAP

$$\frac{\sigma}{F_\mu} \cdot F_\mu^{\text{Upp.Lim.}} = \sigma^{\text{Upp.Lim.}}(m_\chi)$$

G.Wicstrom and J.Edsjo, arXiv:0903.2986, JCAP

Baikal NT200: Preliminary

90% Upper limits on spin-dependent DM-proton cross section $\sigma_{\chi-p}$



SUMMARY

·A new DM analysis is presented with Baikal NT200 dataset of 1998-2002 years.

·No excess is observed toward the Sun for 1038 days of L.T.

·Are shown the preliminary results of 90% Upper limits on muon flux, DM self-annihhilation rate and DM cross sections of elastic scattering off proton .

Baikal Cold Matter:

Thank you !

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