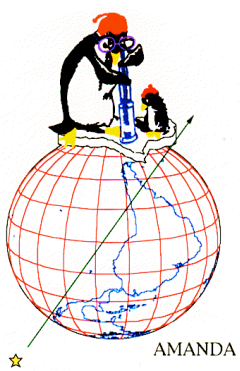
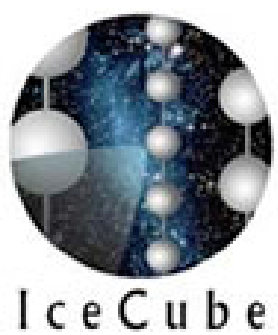
Status Report
Neutrino-Astrophysics at DESY
AMANDA, Baikal, IceCube

Stefan Schlenstedt, DESY



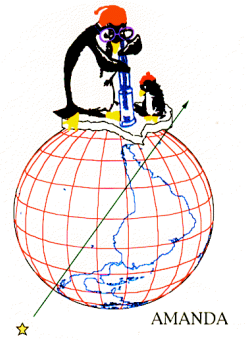
58th Meeting of the DESY PRC
October 28, 2004



Neutrino Astrophysics at DESY

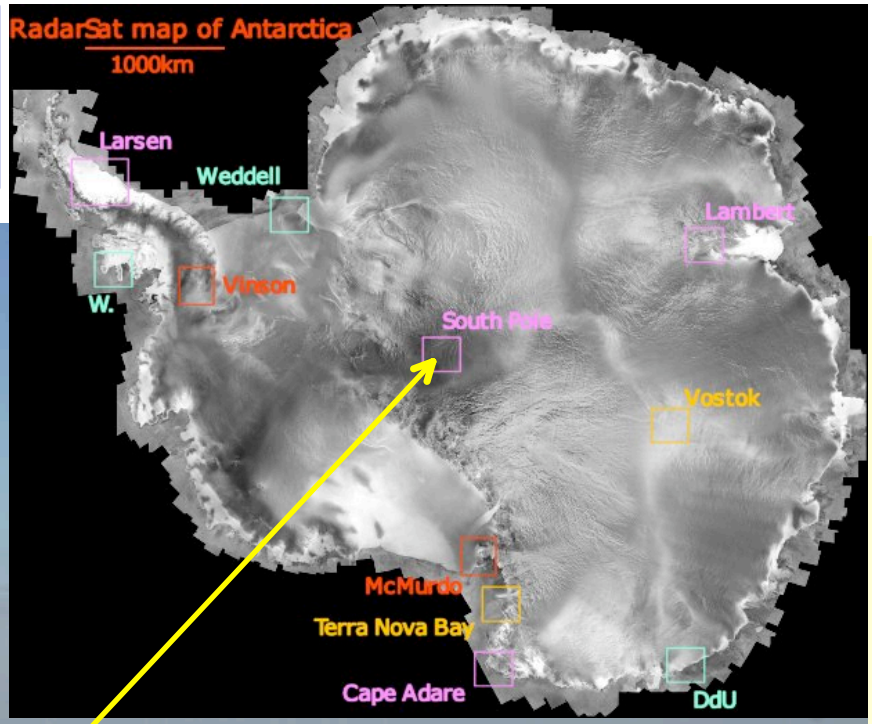
- Started working on the Baikal experiment in 1988
- Currently active in the upgrade

- Working in AMANDA since 1994
- One of the leading institutes doing analysis, data processing, responsible for reconstruction software and time calibration of the Optical Modules



- Since 2001 IceCube
- Responsibility for Optical Module production, surface electronics, reconstruction software and integration with AMANDA, and actively involved in “Future Group”

The Antarctic Site



IceCube

AMANDA

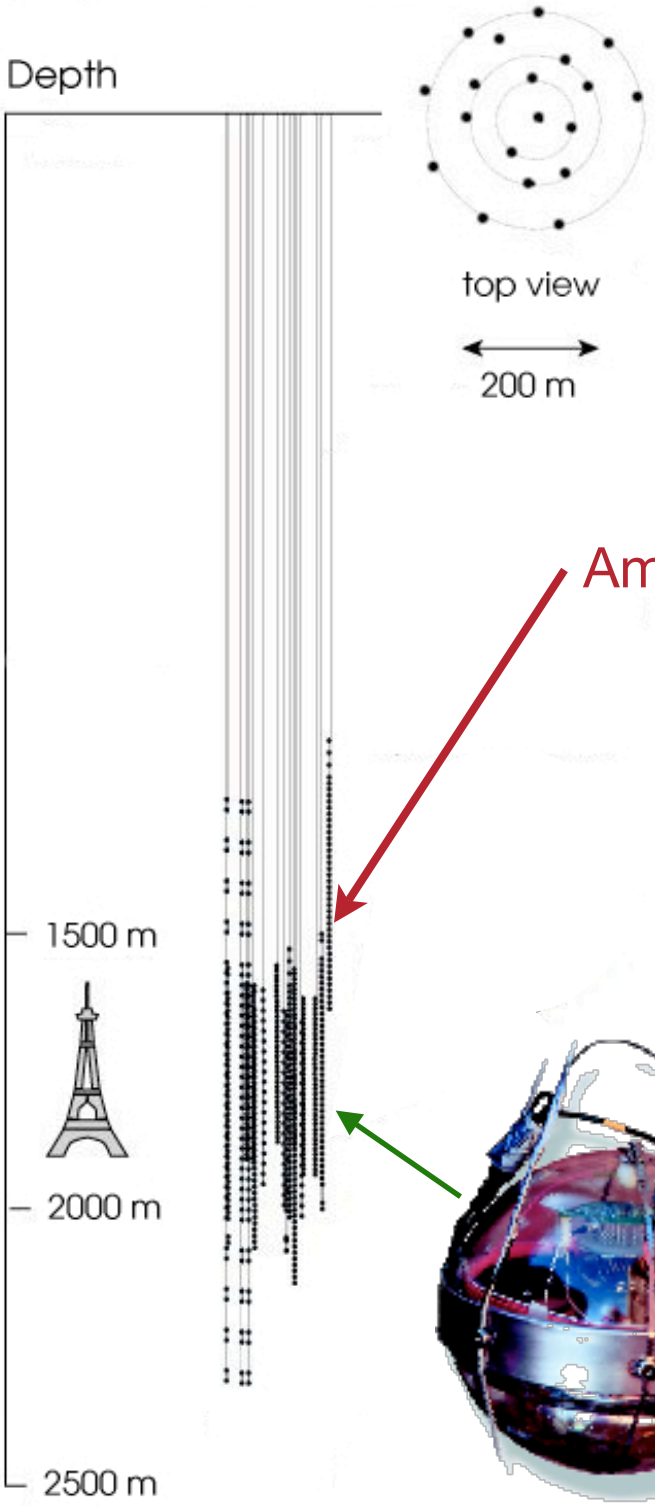
19 strings

70...80 strings

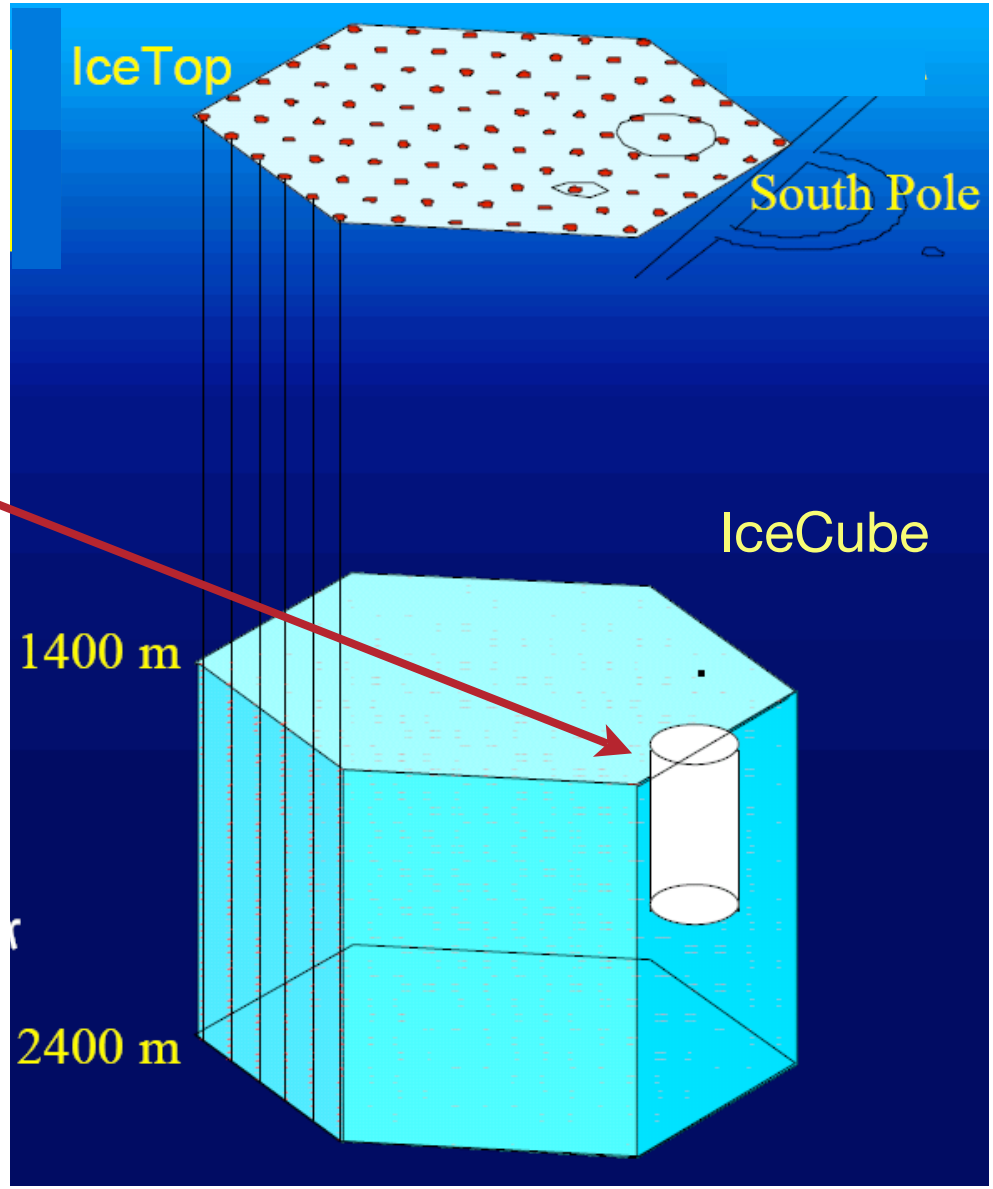
geographic Pole

Amundsen-Scott South Pole station

The Antarctic Telescopes

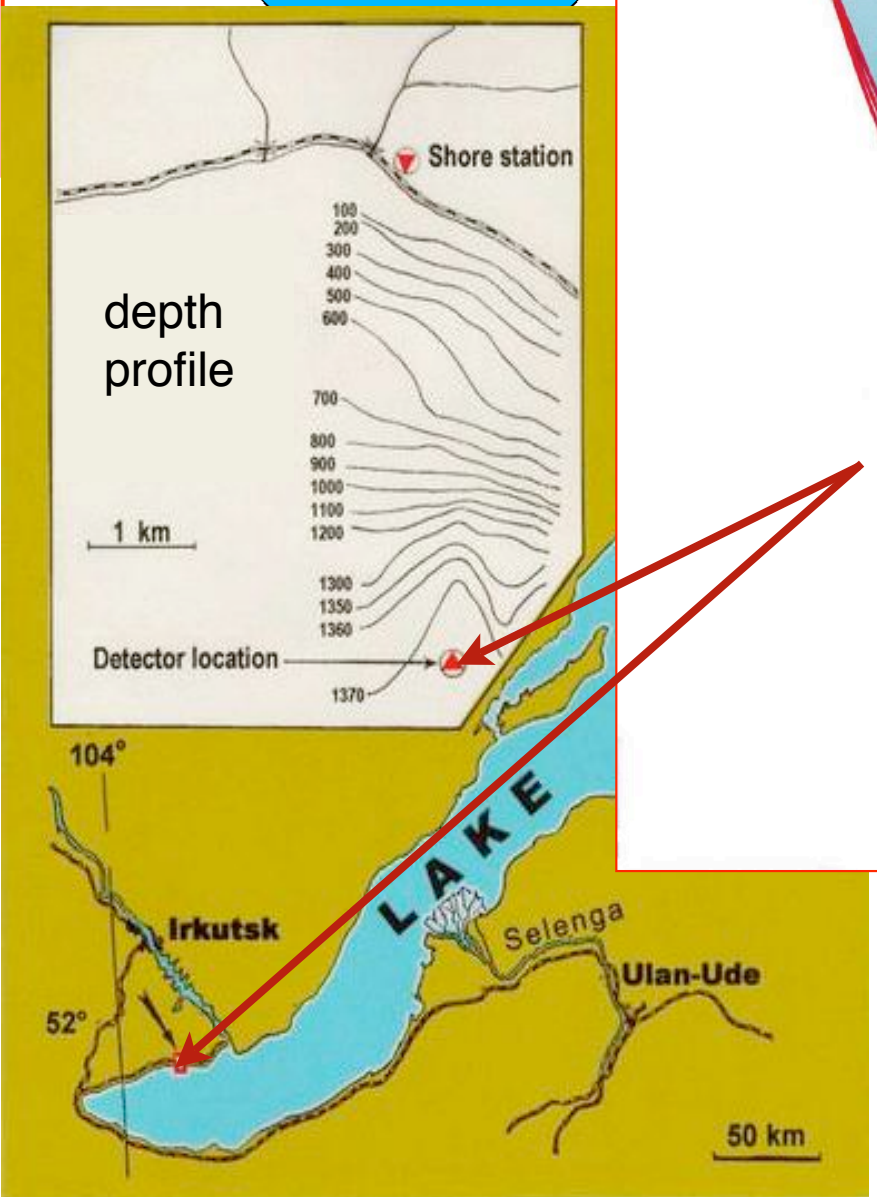


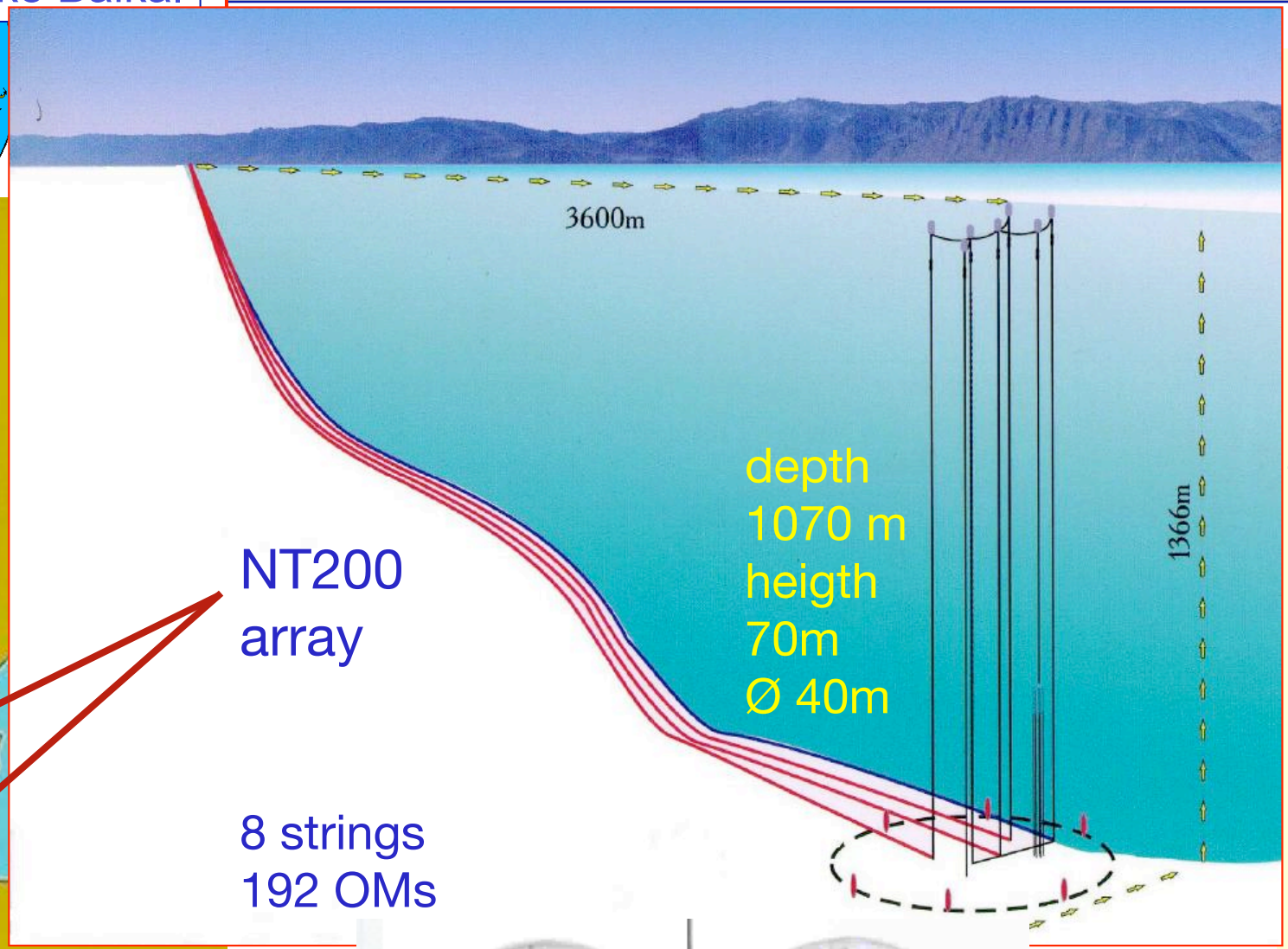
Amanda II



Optical Module 8”

The Baikal Site and Detector





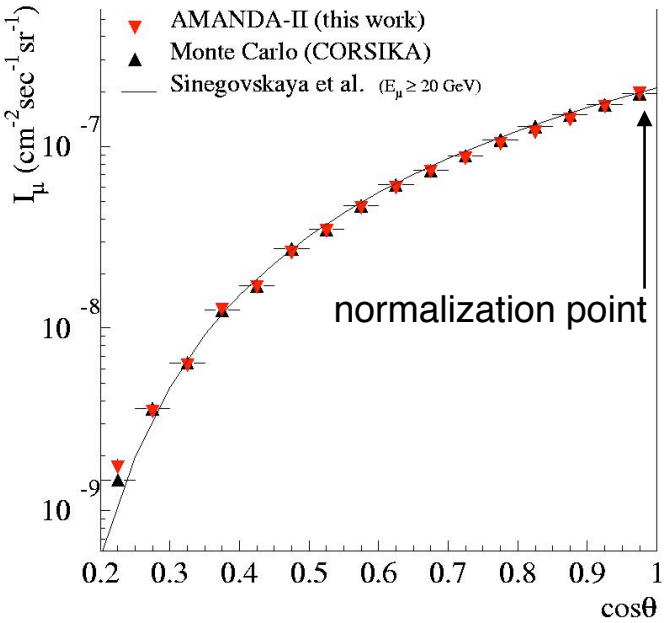
Quasar tubes
Ø 37 cm

Physics topics of AMANDA and Baikal

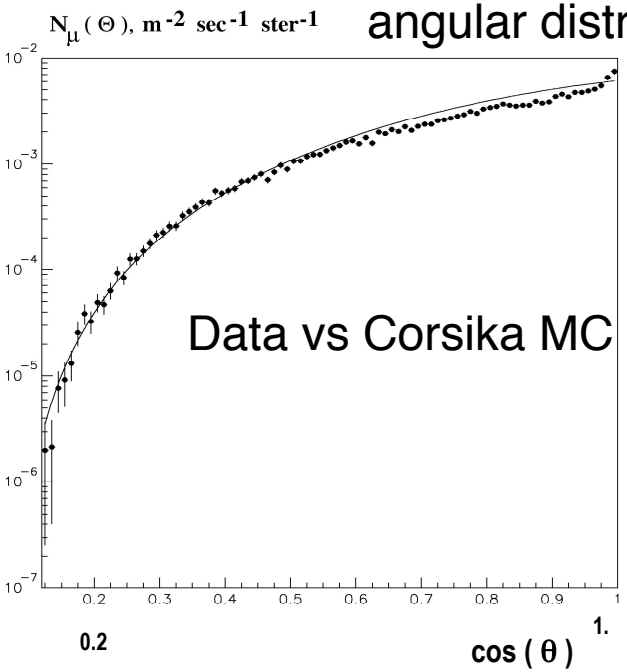
- Atmospheric muons
- Atmospheric muon neutrinos
- Search for extra-terrestrial muon neutrinos from point sources
- ν's from Gamma Ray Bursts
-
- Search for flux of diffuse extra-terrestrial neutrinos
  - muon neutrinos
  - electron or tau neutrinos
  - of ultra-high energies
  -
- High energy muons of prompt or exotic origin

- Search for WIMPs caught in Earth or Sun
- Magnetic monopole
- Neutrinos from Super Novae
- Chemical composition of Cosmic Rays

Measurement of Atmospheric Muons

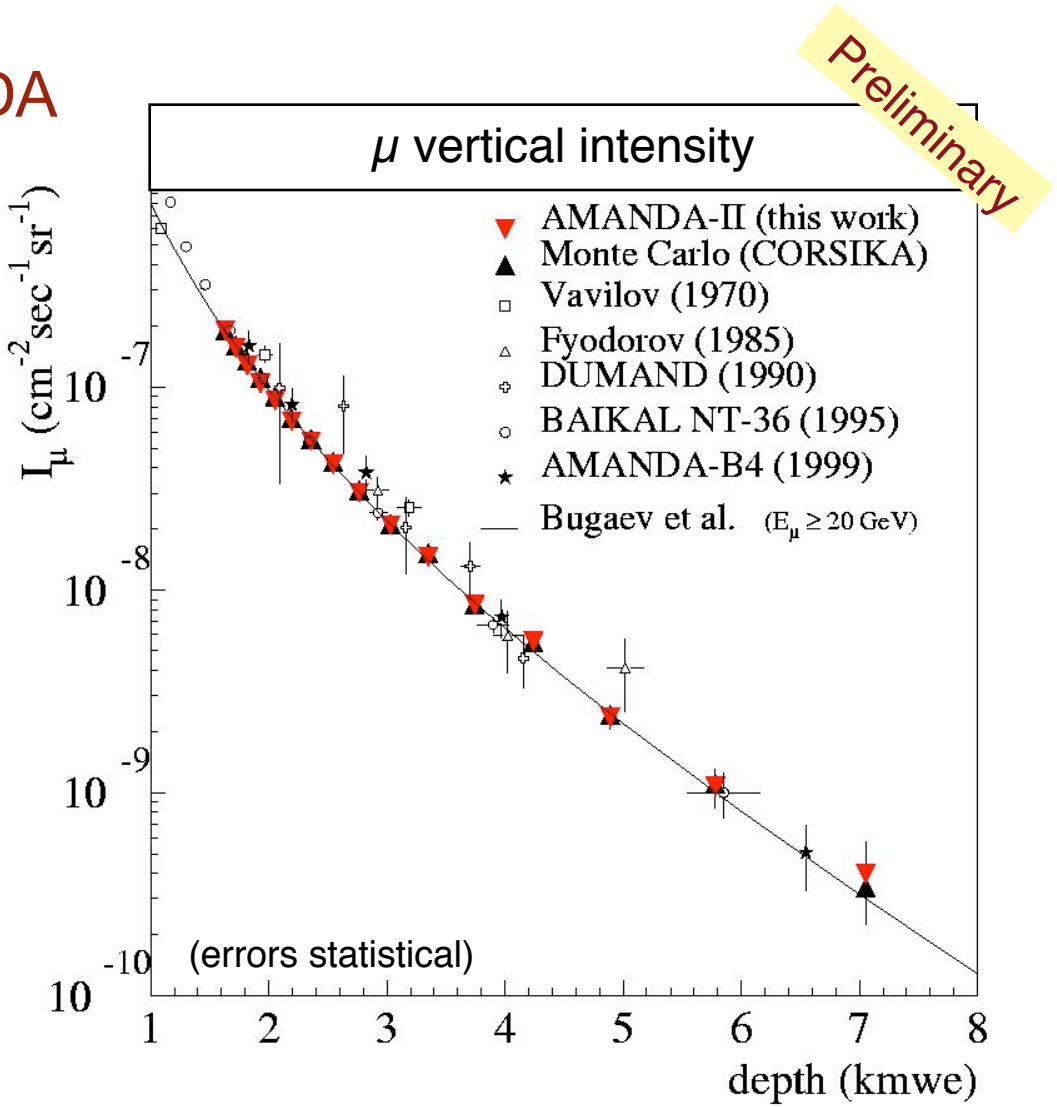


angular distribution



AMANDA

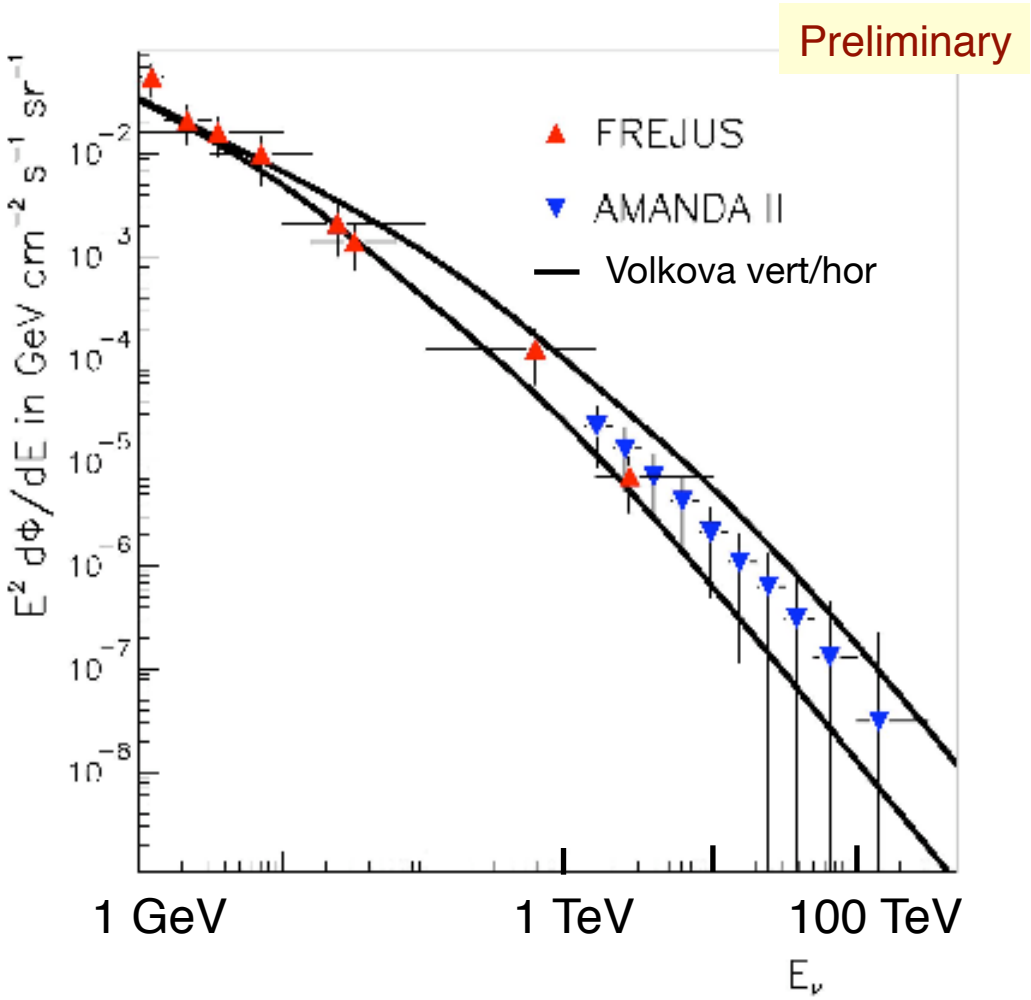
Baikal



Shape of the data well described
Normalization exceeds theoretical calculation by ~30%

Atmospheric μ–Neutrinos

Interaction of Cosmic Rays in the atmosphere
deliver the test beam (and background) of neutrinos



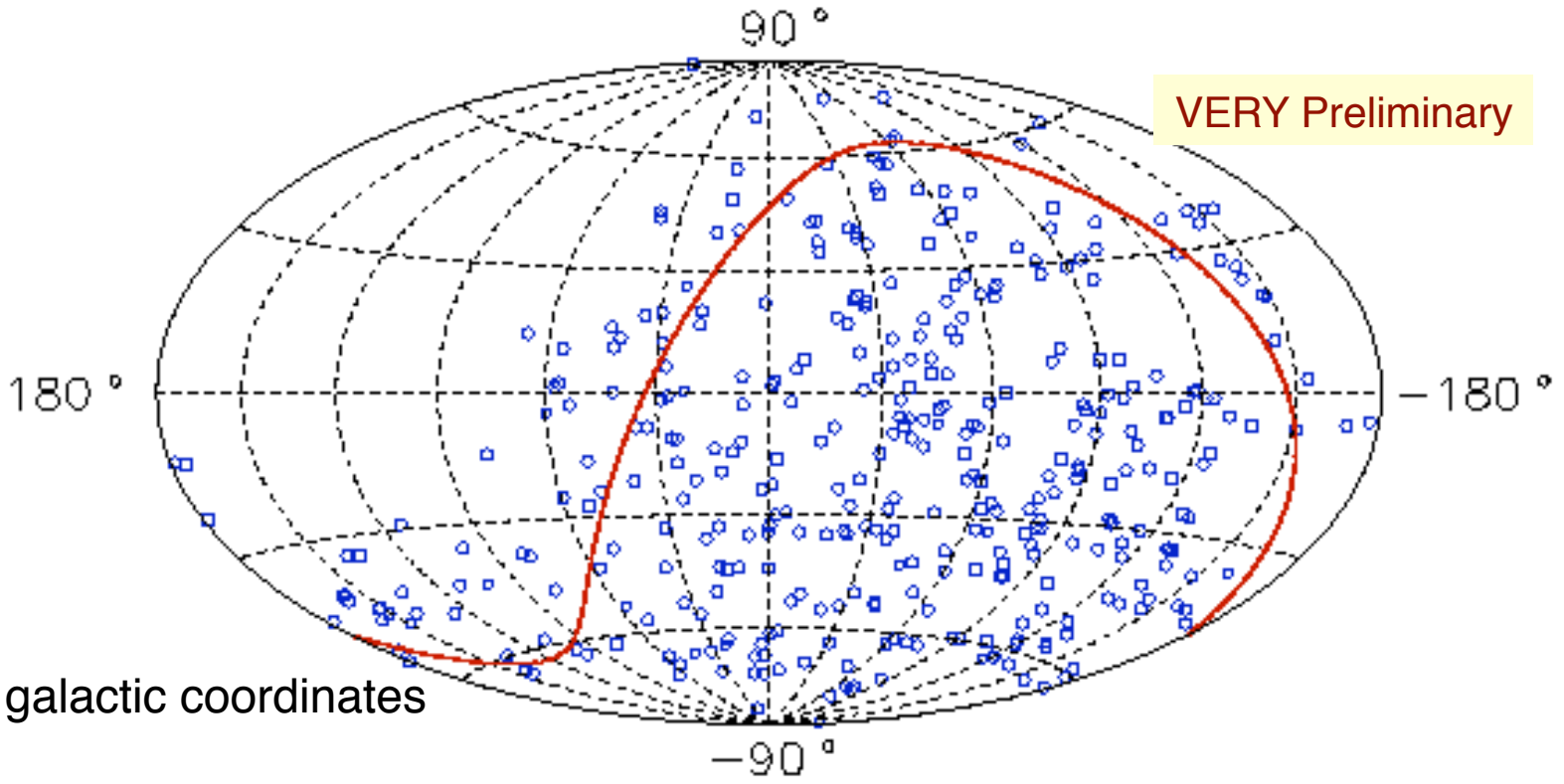
Unfolding of atmospheric muon-neutrino spectrum

AMANDA spectrum above 1 TeV matches lower-energy data

Compatible with expectation for atmospheric neutrino flux (see below)

Atmospheric μ–Neutrinos

- Published result 1998-99 (502 days) → 84 events
- New analysis with different search strategy 1998-2000 data (780 days) → 372 events



Complementarity to AMANDA
– different view: to the South
– independent analyses

Search for Neutrino Point Sources

Select upgoing events: maximize ↑ν and minimize ↓μ

Optimize cuts in each declination band optimizing for $E^{-2...-3}$ signal spectrum

Sensitivity ~independent of direction

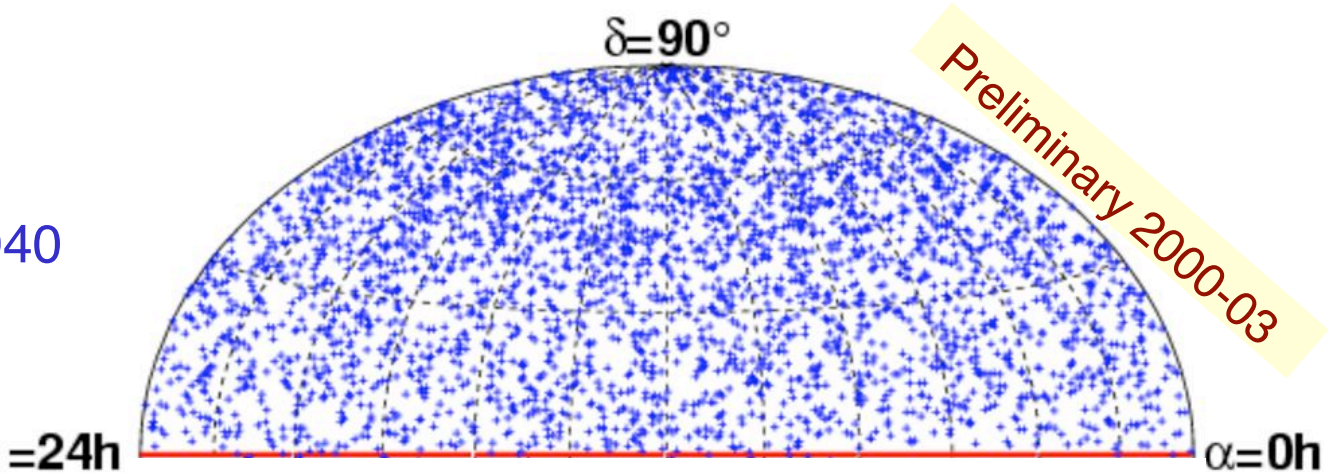
Published analyses:

– 1997 data

Astrophys.J. 583(2003)1040

– 2000 data

PRL 92(2004) 071102



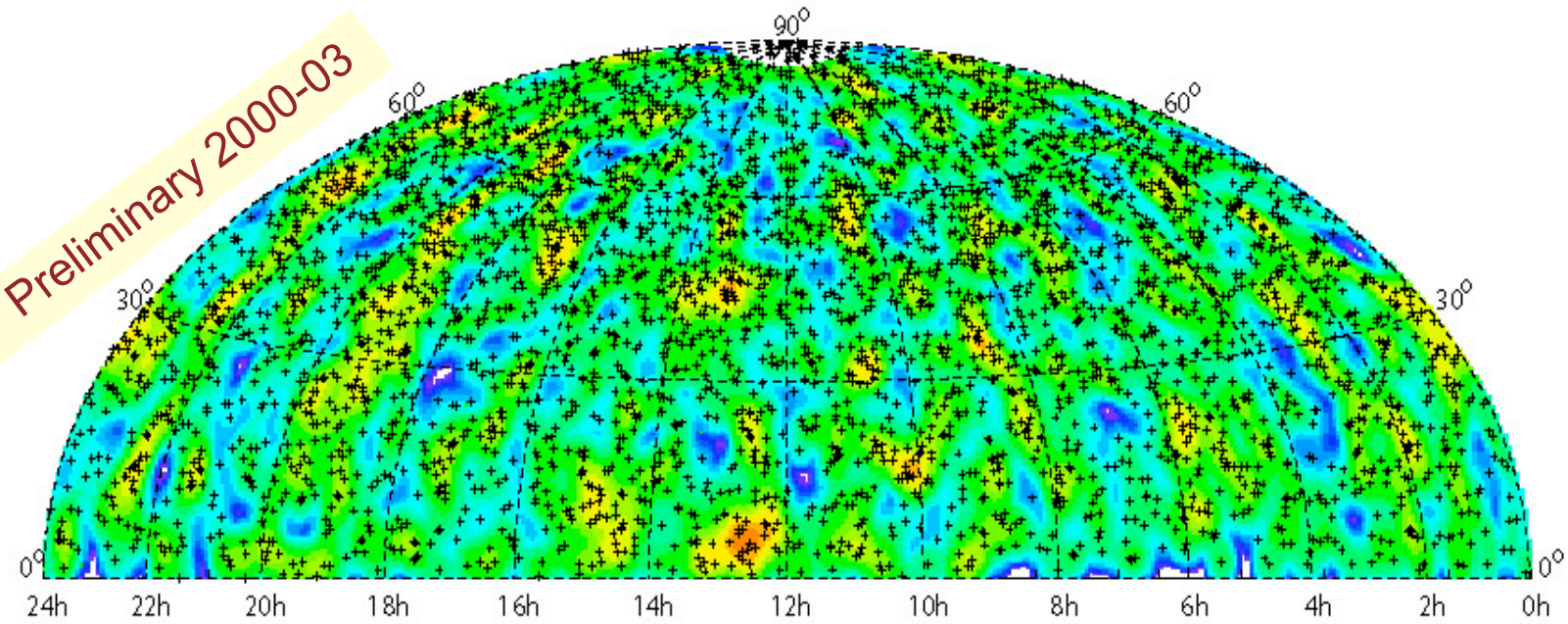
New preliminary results with different strategies:

• 2000-01 and 2002 data

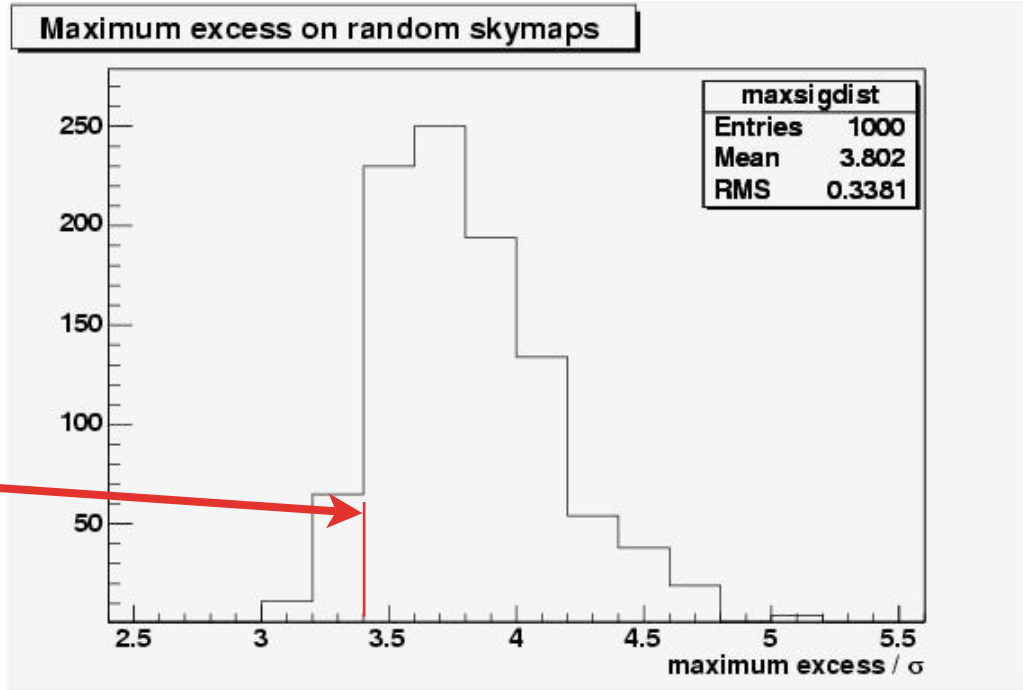
• 2000–03 data: 3370 evts in 807 days
(sensitivity ~3 higher as 2000)

No clustering in skyplot observed →
No evidence for steady point sources
(measurement compatible with atmospheric ν's)

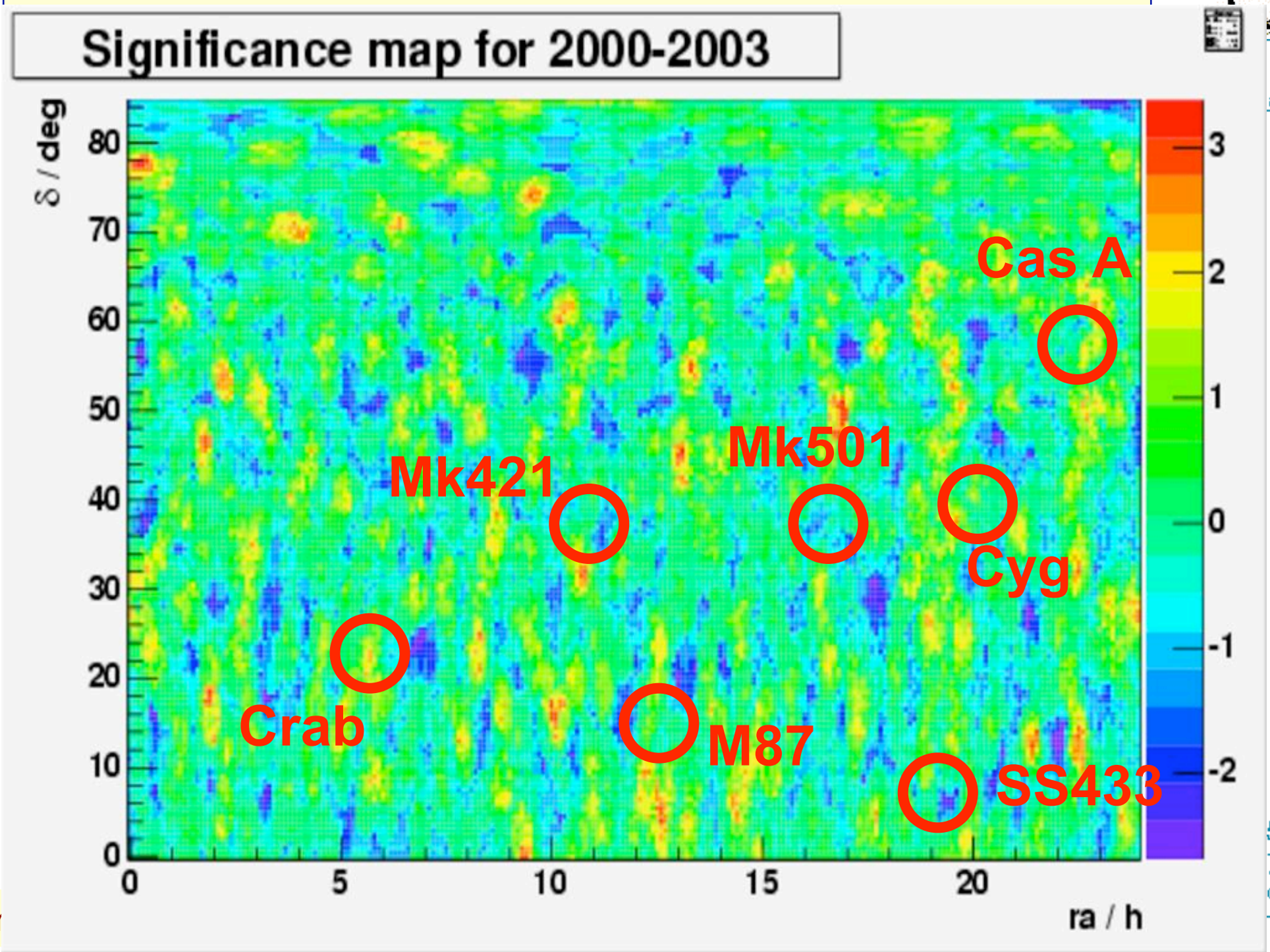
Search for Neutrino Point Sources



- calculate significance of local fluctuations from expectation of atmospheric ν_μ
- un-binned statistical analysis
- maximum of 3.4 σ - compatible with background fluctuation (many search points penalty)

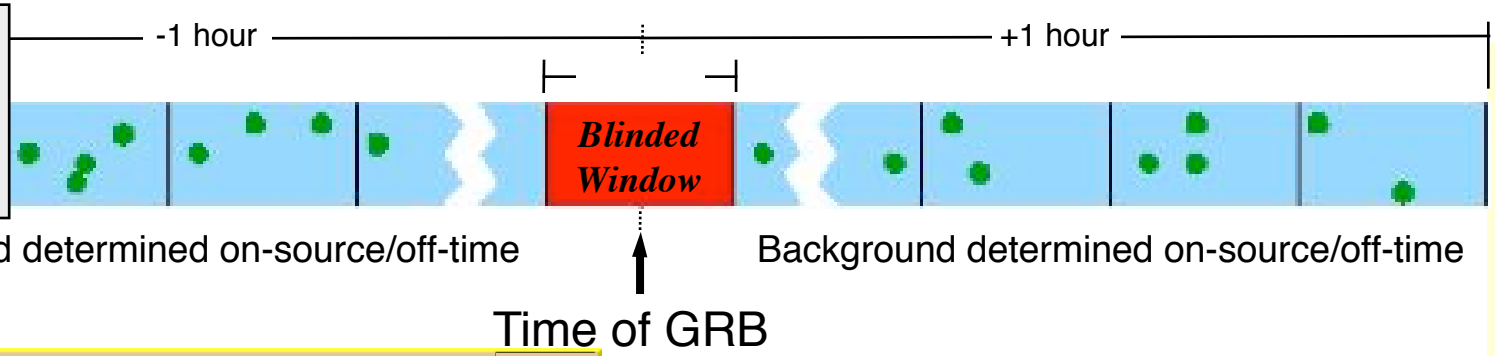


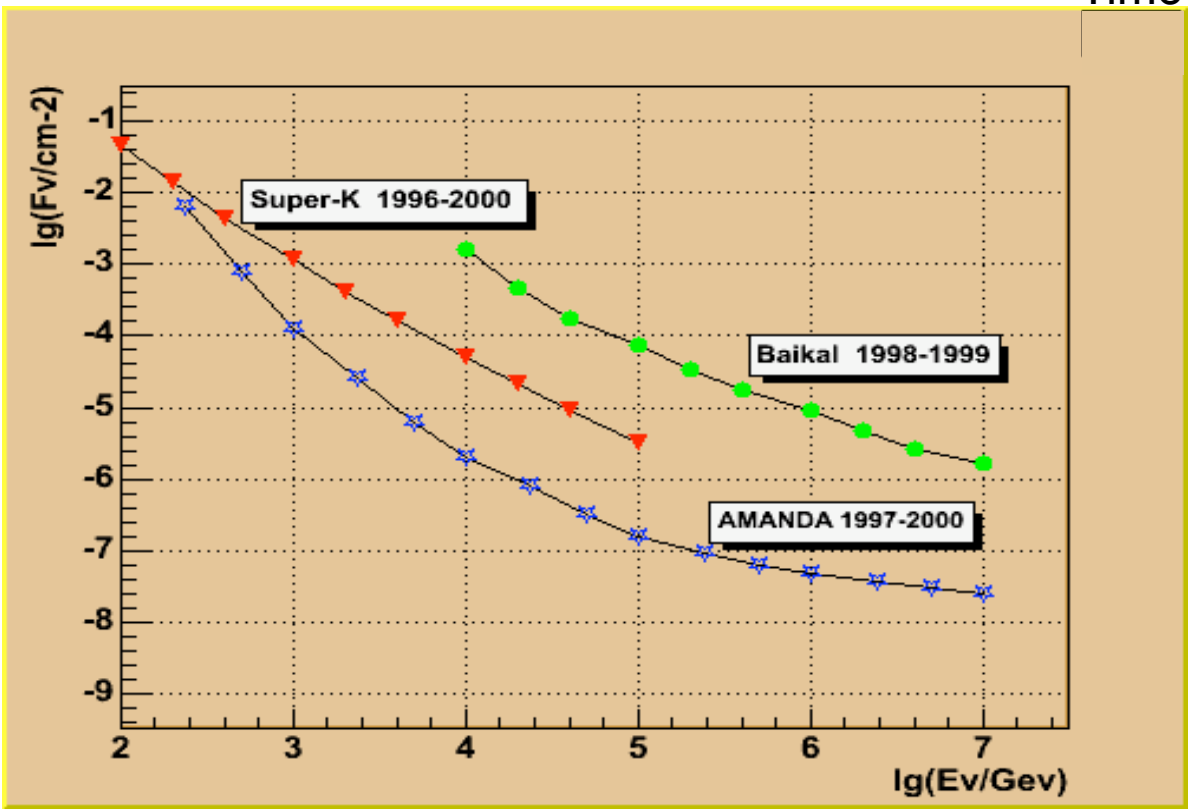
Neutrinos from known Sources?



Association of ν with Gamma Ray Bursts

Low background analysis due to space and time coincidence





Use sources from GRB catalogs: BATSE (triggered and non-triggered) and IPN3 & GUSBAD ("new")

AMANDA

	312 BATSE GRBs:	observe 0
	68 BATSE and 46 new:	observe 0
Baikal	722 BATSE evts:	observe 0

Data consistent with expected μ-bg

90% C.L. differential flux limits

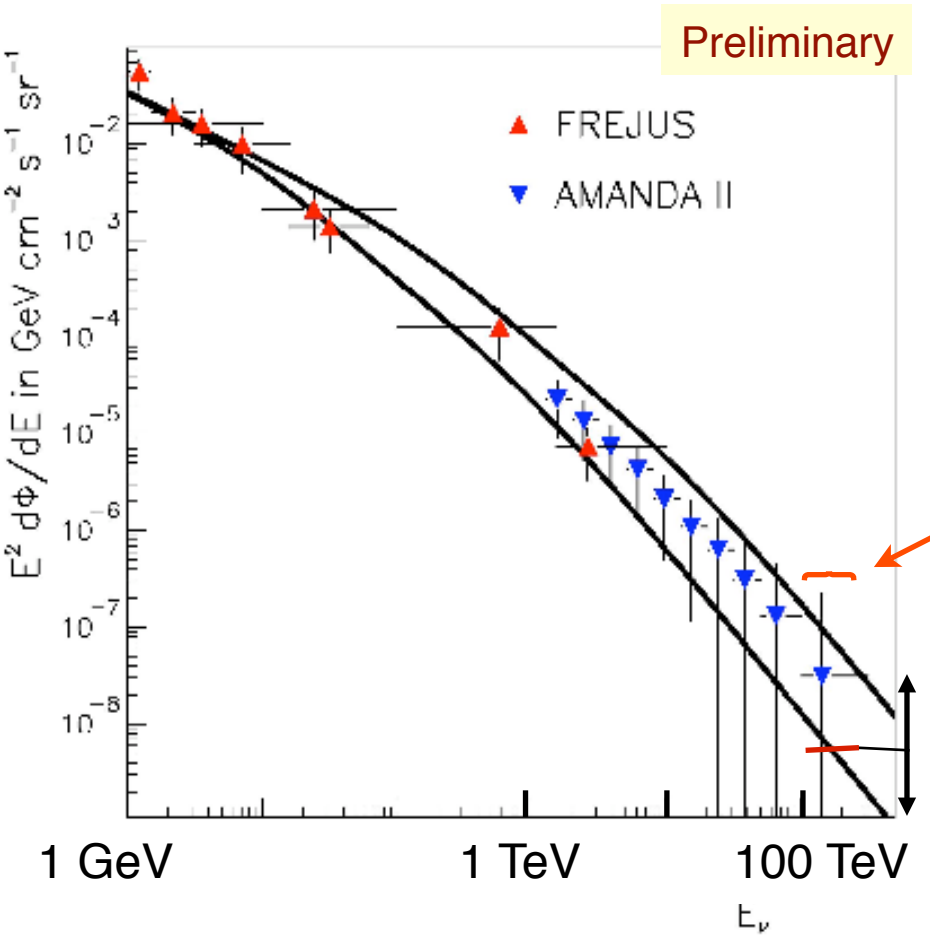
Baikal uses the cascade sample:

$E^2\Phi_\nu \leq 2\cdot10^{-6}$ GeV cm^{-2} s^{-1} sr^{-1}

AMANDA uses the muon neutrinos:

$E^2\Phi_\nu \leq 4\cdot10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}

Search for Diffuse μ–Neutrinos



Use the unfolded atmospheric muon-neutrino spectrum

How much E^{-2} extra-terrestrial ν-signal allowed within uncertainty?

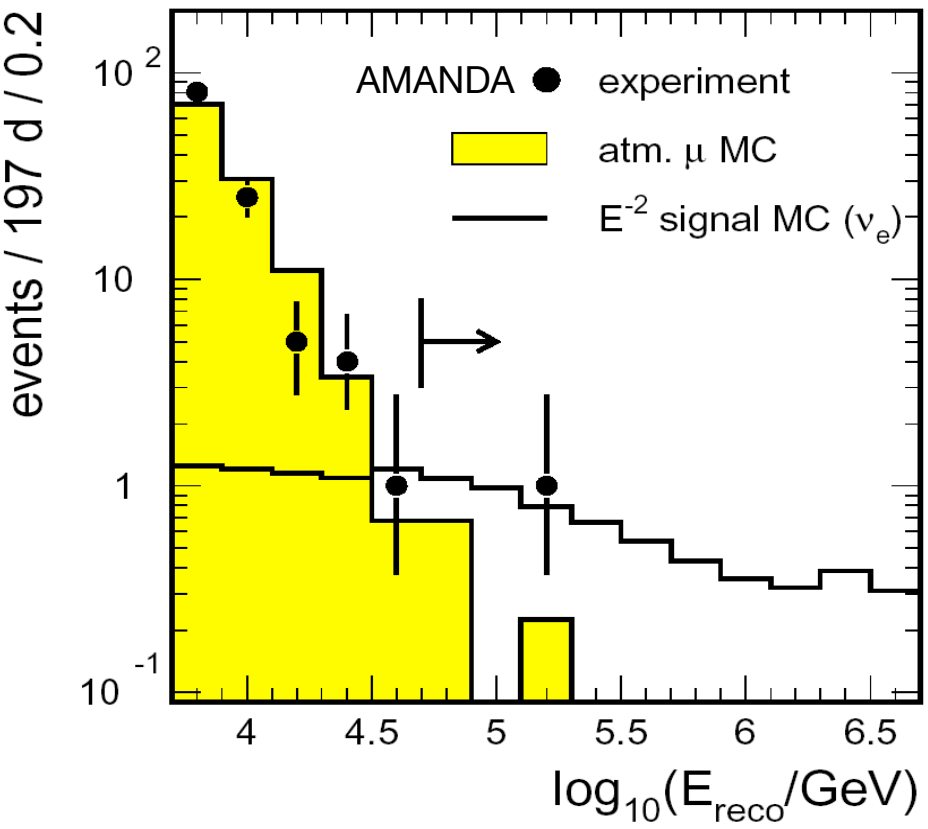
Set limit on diffuse E^{-2} ν_μ flux from the bin 100-300 TeV

$$E^2\Phi_{\nu\mu}(E) < 2.9\cdot10^{-7}\ \text{GeV cm}^{-2}\ \text{s}^{-1}\ \text{sr}^{-1}$$

1997 results
PRL 90, 251101 (2003)

Search for Diffuse Neutrinos

Electromagnetic and hadronic cascades ⇒ Sensitivity to all three flavours



N_{obs} = 1 evt

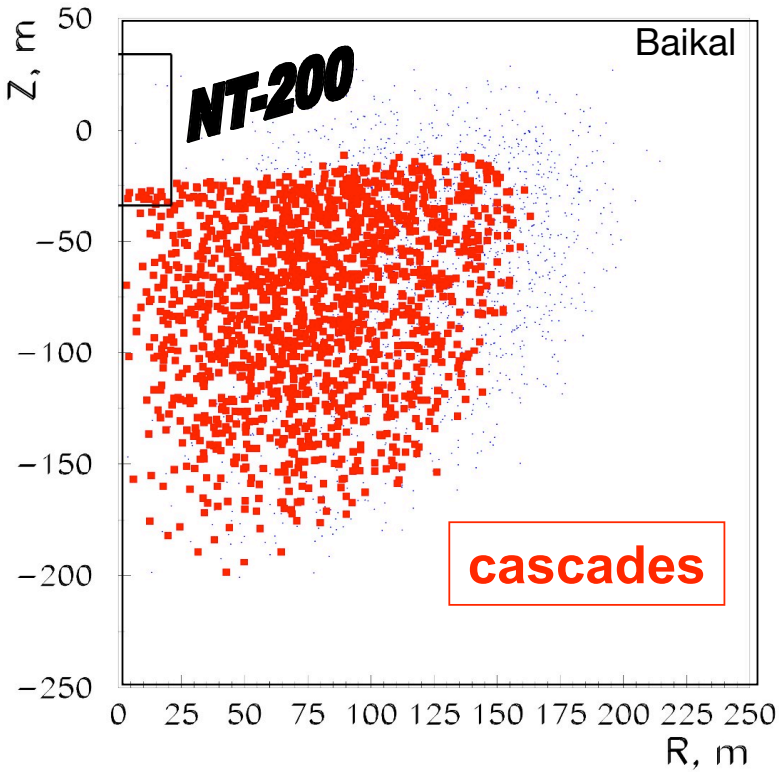
N_{bg} = 0.96 +0.7-0.3 evts

$E^2 \Phi_{all\ \nu}(E)$ [GeV cm^{-2} s^{-1} sr^{-1}]

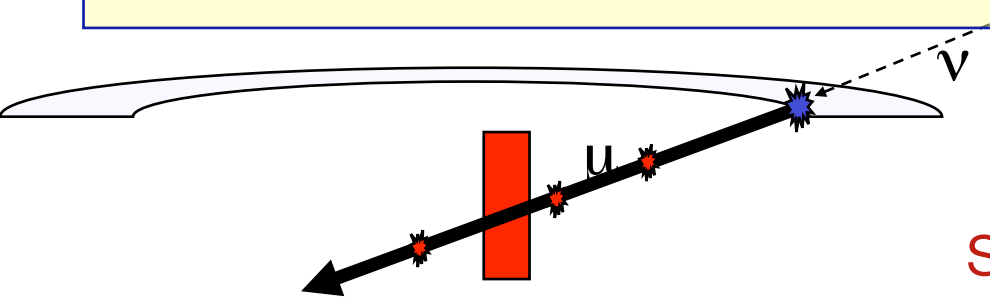
AMANDA: $< 0.87 \cdot 10^{-6}$

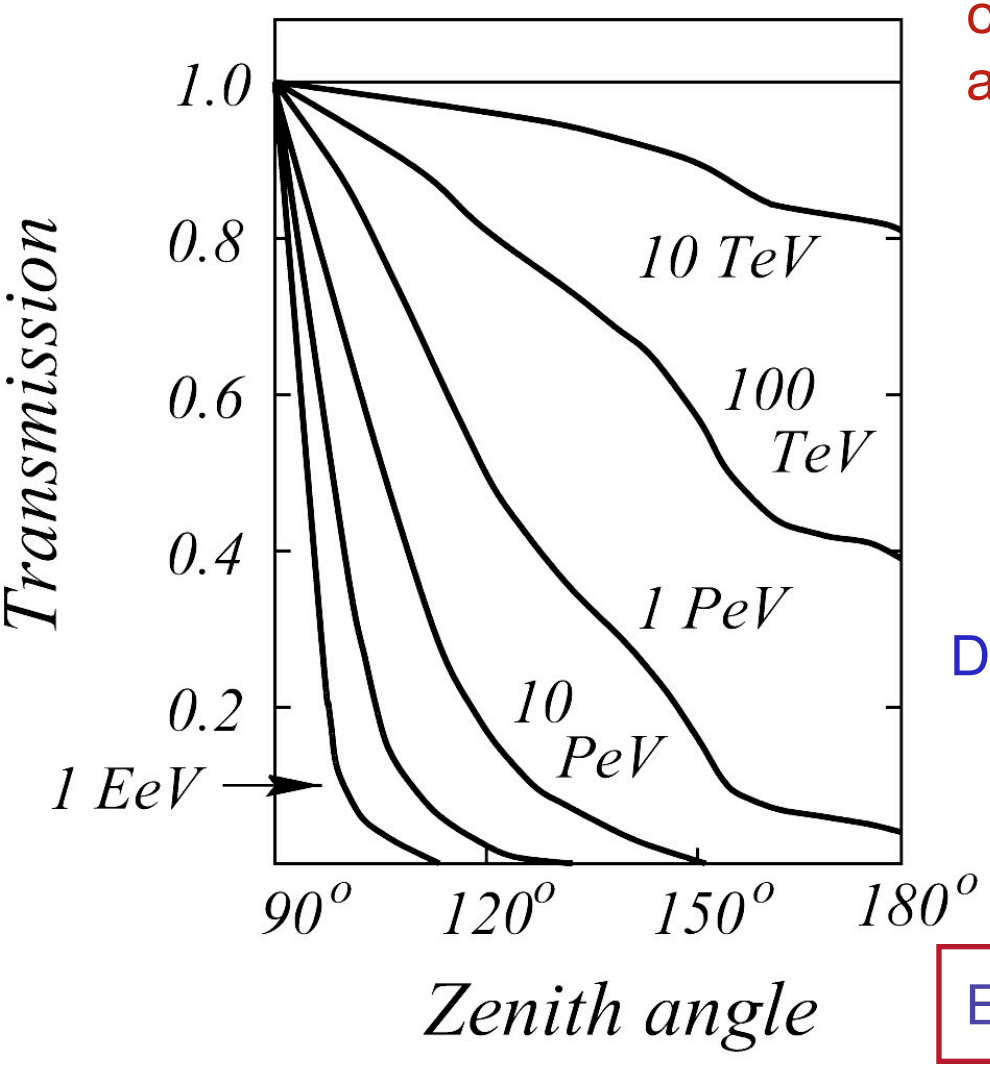
Baikal: $< 1.0 \cdot 10^{-6}$

(equal mix of all flavors)



Neutrinos with Ultra-High Energies





Search in upper (Southern) hemisphere and close to the horizon for very bright events and muon tracks of km lengths

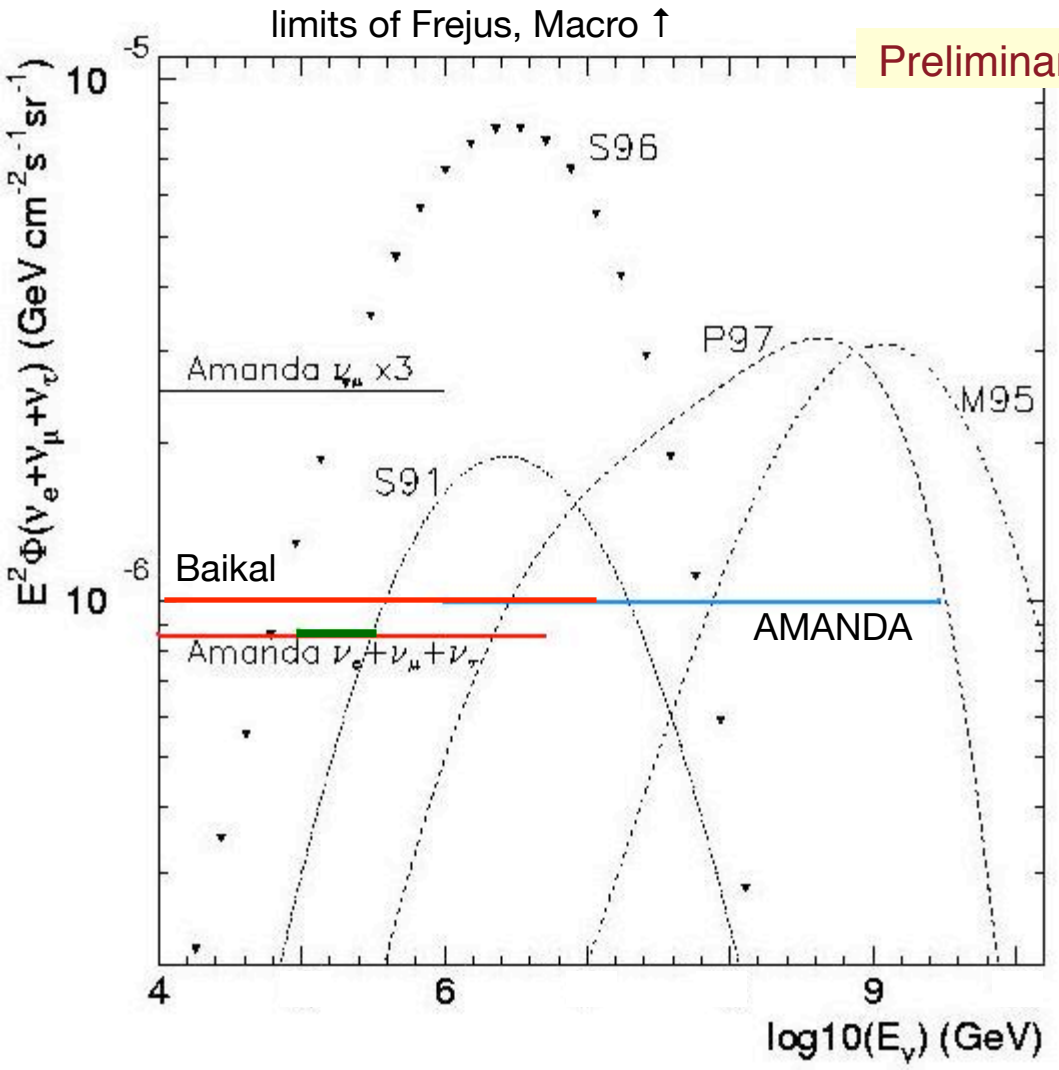
- N_{obs} = 5 events
- N_{bg} = 4.6 ± 1.2 ± 36% (syst) events

Derive upper limit in the 1 PeV–3 EeV region on a possible diffuse flux of neutrinos from an E^{-2} source (90% CL)

$$E^2 \Phi_{all\ \nu}(E) < 0.99 \cdot 10^{-6}\ \text{GeV cm}^{-2}\ \text{s}^{-1}\ \text{sr}^{-1}$$

(flavor mixing $\nu_\mu:\nu_e:\nu_\tau = 1:1:1$)

Summary Diffuse Fluxes



AMANDA and Baikal

90% CL upper limits to a diffuse E^{-2} all-ν flux determined from

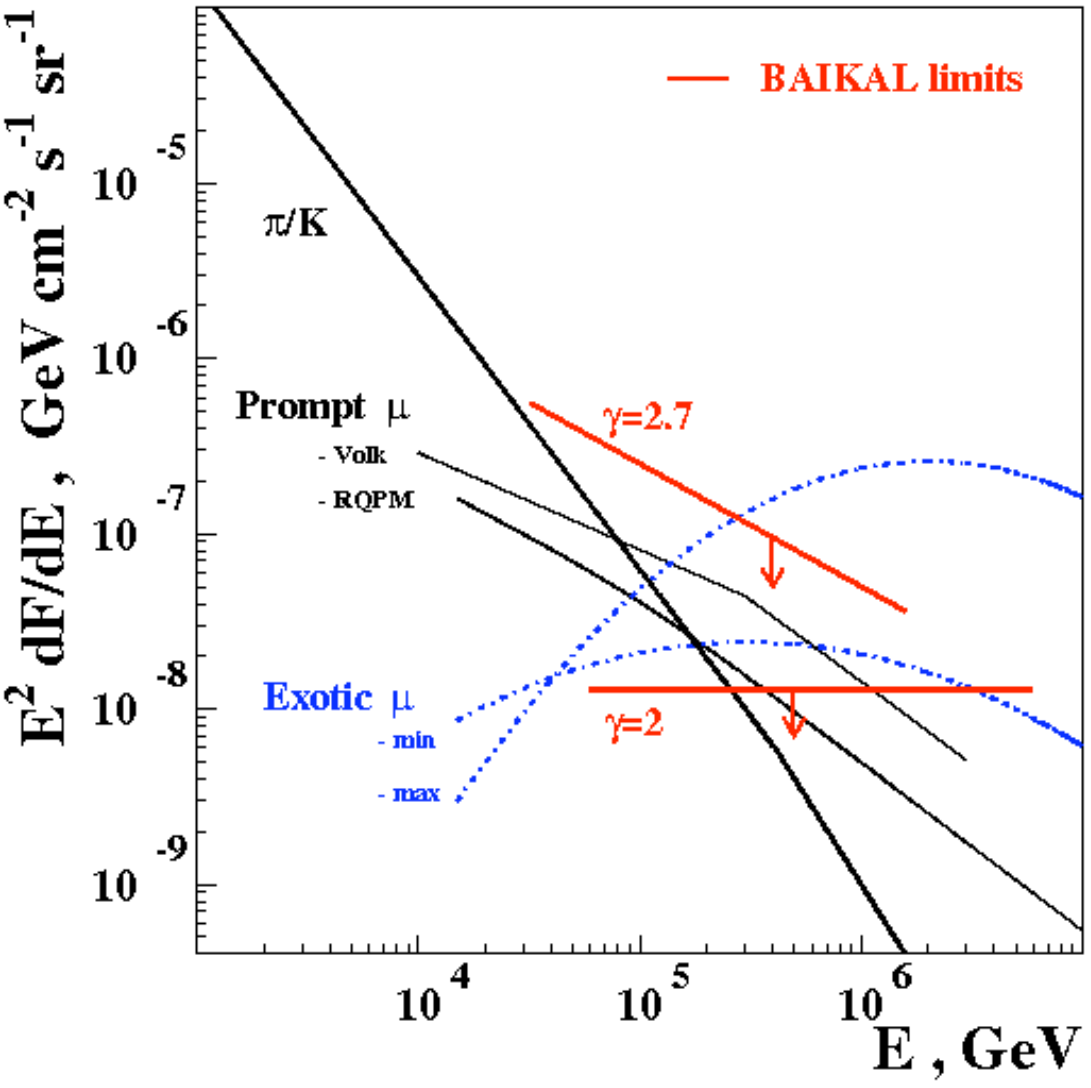
search for cascade events

high energy tail of the atmospheric ν_μ spectrum (x3)

search for UHEnergy events

Several models of AGN neutrino emission are ruled out by AMANDA measurements

Exotic Models for the Knee



Use high energy cascade sample to search for an

"Exotic Muon Component" – proposed (Petrukhin) to explain the CR-knee by onset of "new physics" at E_{thr}~1 PeV that pumps "Extended Air Shower" energy to exotic muons/ neutrinos

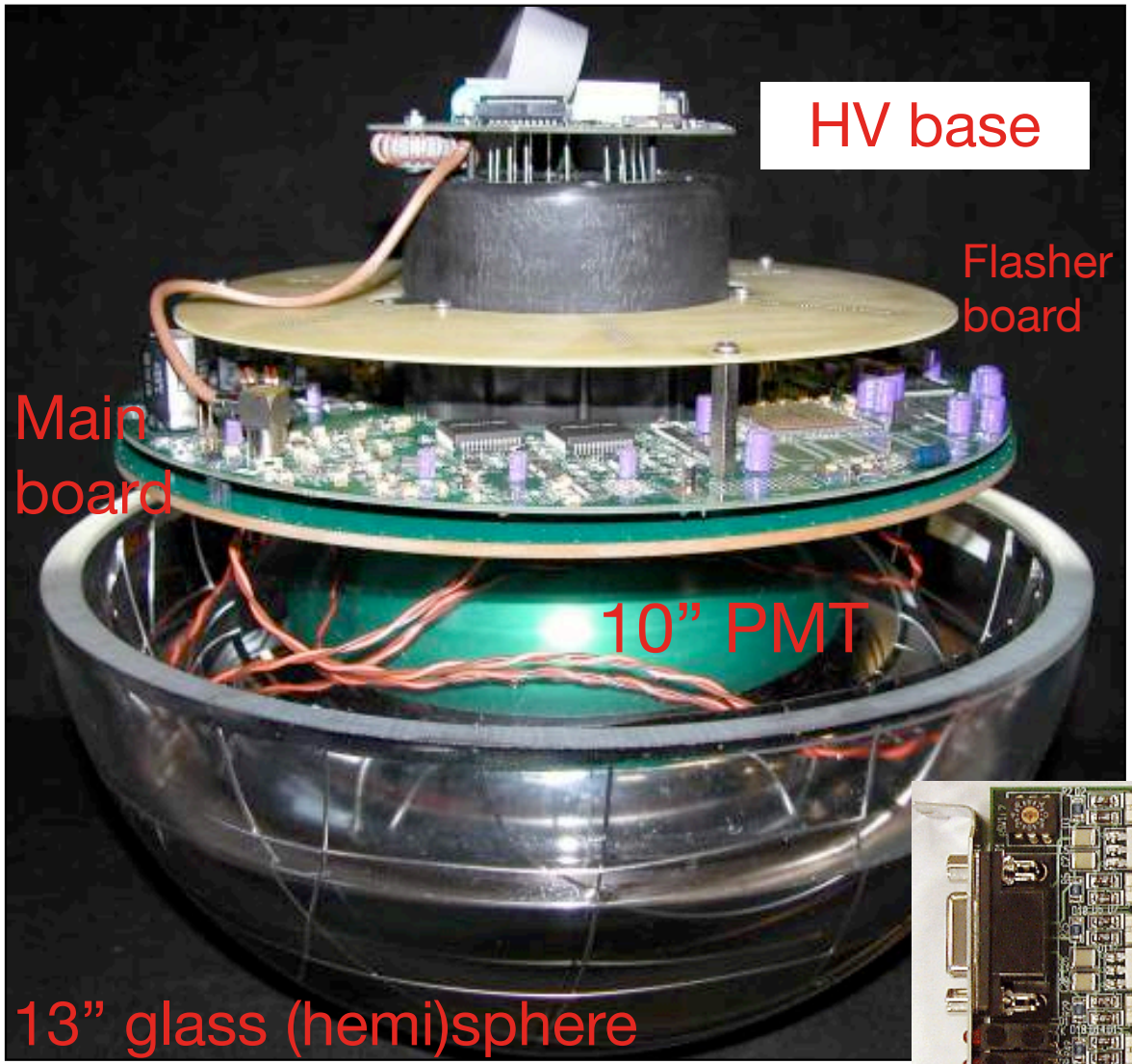
⇒ model excluded

IceCube under Construction

- Full NSF funding since February 2004
- Belgium, Sweden, DESY funded, German unversities in 2005
- Deployment of 4200+ Digital Optical Modules on 70+ strings and 140+ DOMs in 70+ IceTop stations between 2005–2010
- This season: install the full chain from DOM to surface electronics, event builder, trigger, data handling and reconstruction, simulation, data verification/ analysis
- and AMANDA integration

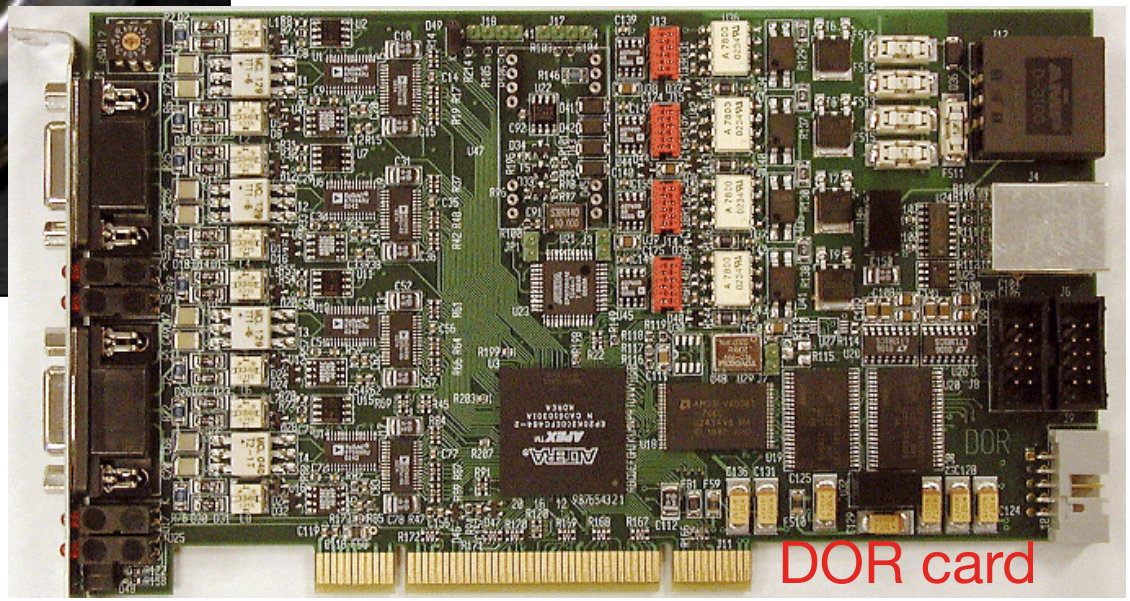
DESY responsibilities
(and contributions)

IceCube DOM and DOR production



– Electronics built at LBNL
– DOM production in Madison, Uppsala, Zeuthen

– two strings in transit to Pole
– DOMs for two strings and IceTop under test

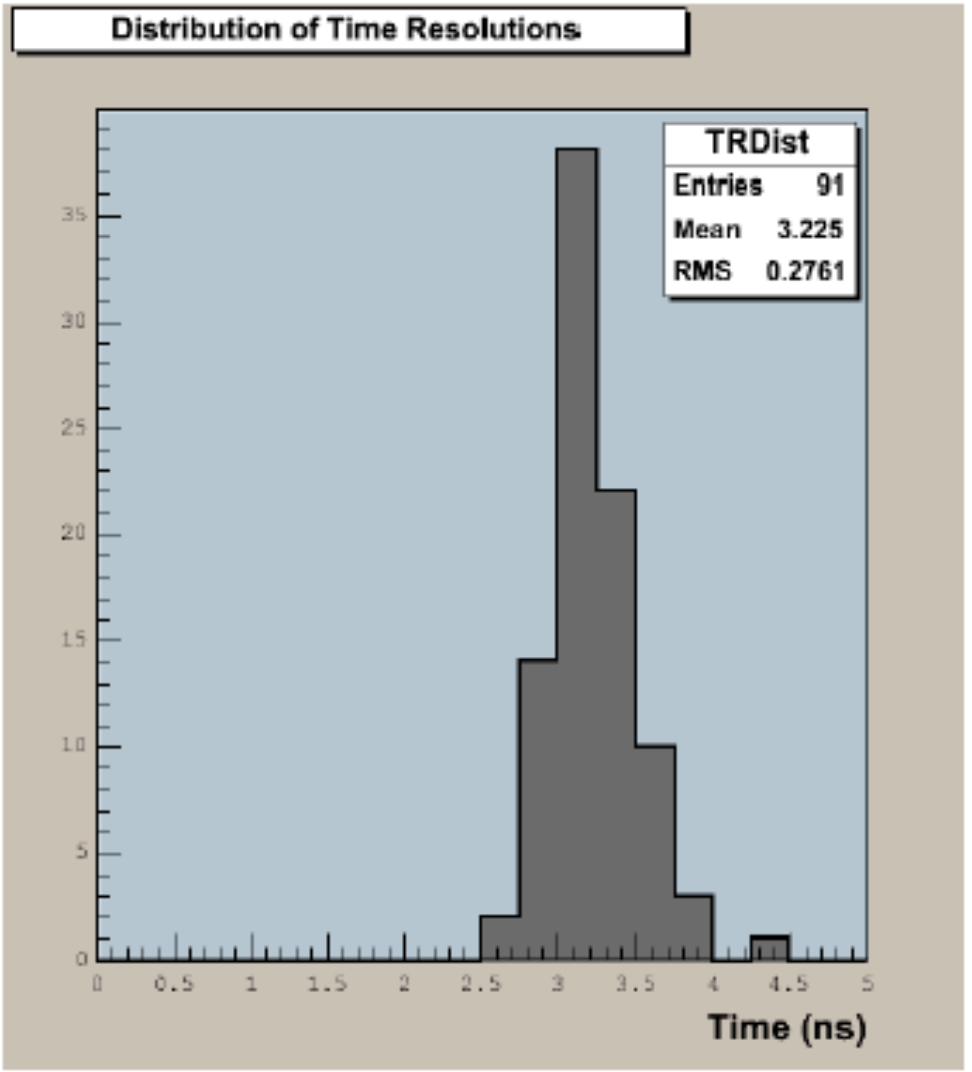


DESY contribution essential
- for DOM production
- Digital surface receiver

DOM production

Extensive tests of bare PMs and DOMs (temperature cycle from -45 to +25 °C) of

noise, linearity, sensitivity, pedestal, gain, time

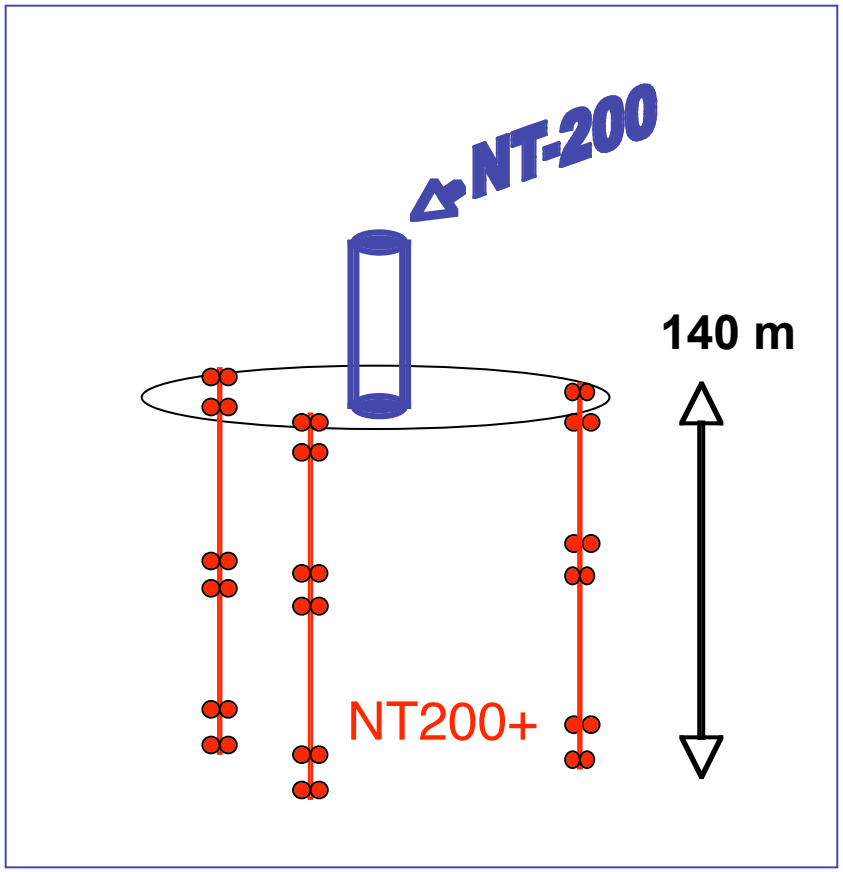


Analysis of data still going on:

A full report at the next PRC

Upgrades of the Baikal experiment

from NT200 to NT200+



36 additional PMTs on three far strings
⇒ four times larger effective volume

and improved cascade coordinates
and energy measurement

Status:

– virtual control room in Moscow
and Zeuthen
– DAQ upgrade
– new shore cable installed
– faster data transmission installed
– two strings installed

Completion in 2005

Summary

AMANDA and Baikal are unique and complementary

(Northern/ Southern sky, ice/ water, different analyses techniques)

Both experiments have a rich physics program

- Understanding of atmospheric μ's as calibration "beam"
- Measurement of the atmospheric neutrino spectrum
- Point source search in data between 1997 and 2003
- Search for neutrinos coincident with Gamma Ray Bursts
- Limits on diffuse extraterrestrial neutrino flux for TeV-EeV ν's
- Search for "exotic" muon component around the knee

No extraterrestrial ν signal observed…yet

Many other results not shown
See http://amanda.uci.edu
http://baikal1.jinr.ru

– SuperNova-DAQ → contribution to SNEWS
– Indirect search for WIMPs in Sun and Earth
– Search for fast and slow monopoles
– Prompt muons

Outlook I

AMANDA

– new FADC readout (TWR) will be used in trigger and analyses
– data taking and analyses continue

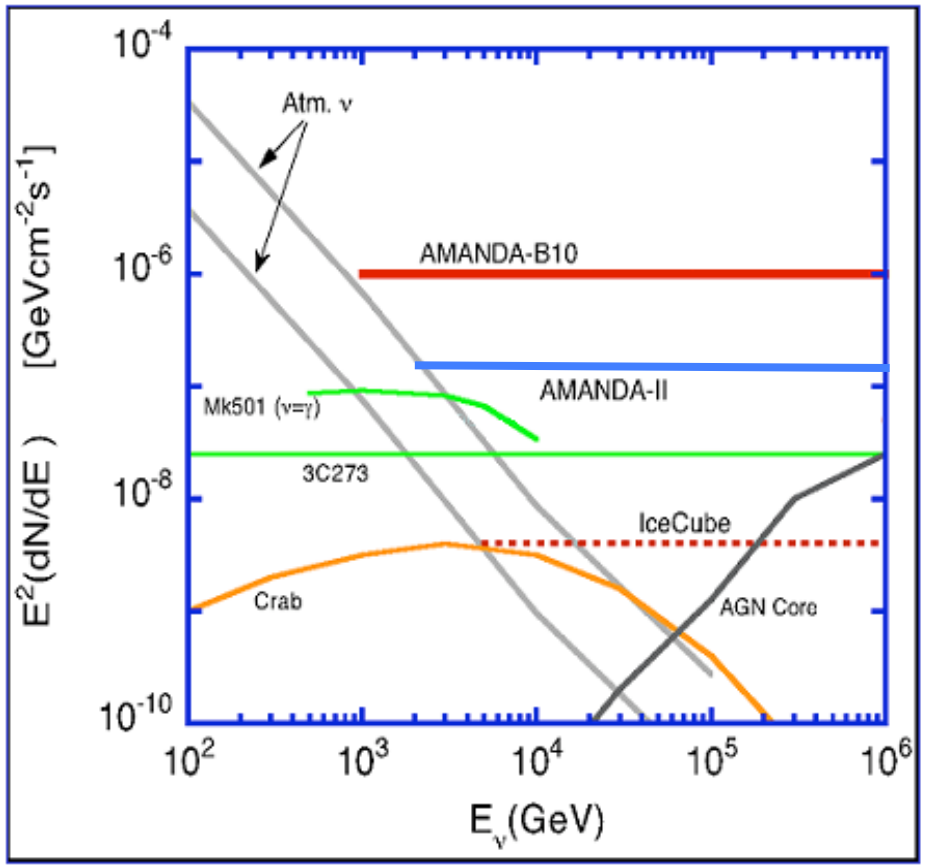
Baikal

– NT200+ upgrade with DESY support
– Ensure stable operation

IceCube

– Installation: four strings early 2005
... finally 70+ strings early 2010
and IceTop stations
– will do physics with the first strings
and include AMANDA

Sensitivity point sources (1 y)



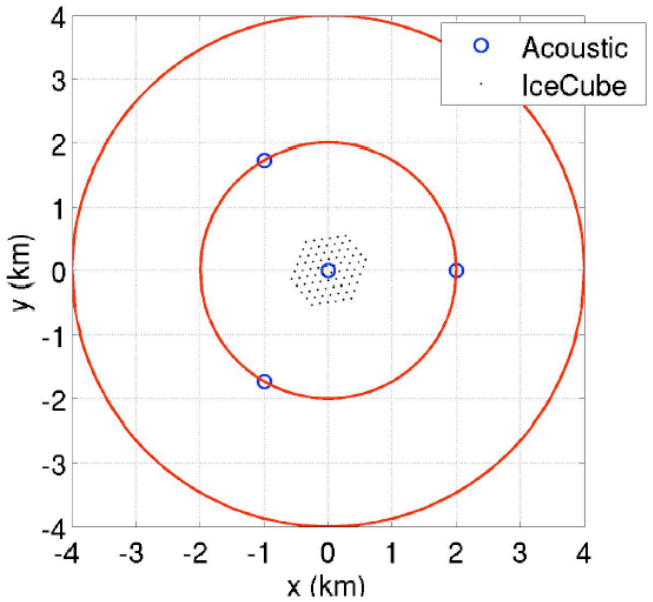
Outlook II: IceCube Future Group

- Discuss possibilities to increase physics potential of the experiment at highest energies > 10^8 GeV already during construction
- Measure GZK neutrinos as a standard candle with “reasonable” statistics
- Compare different technologies: optical (HyperCube), radio (SuperRICE) and acoustic (still R&D)
- Study issues like calibration, signal production and ice propagation, deployment, cost and advantages of corresponding combinations
- ARENA Detector – volume needed: O(50 km^3)

Studies at UCBerkeley and Wuppertal predict 20...80 GKZ neutrinos/ year

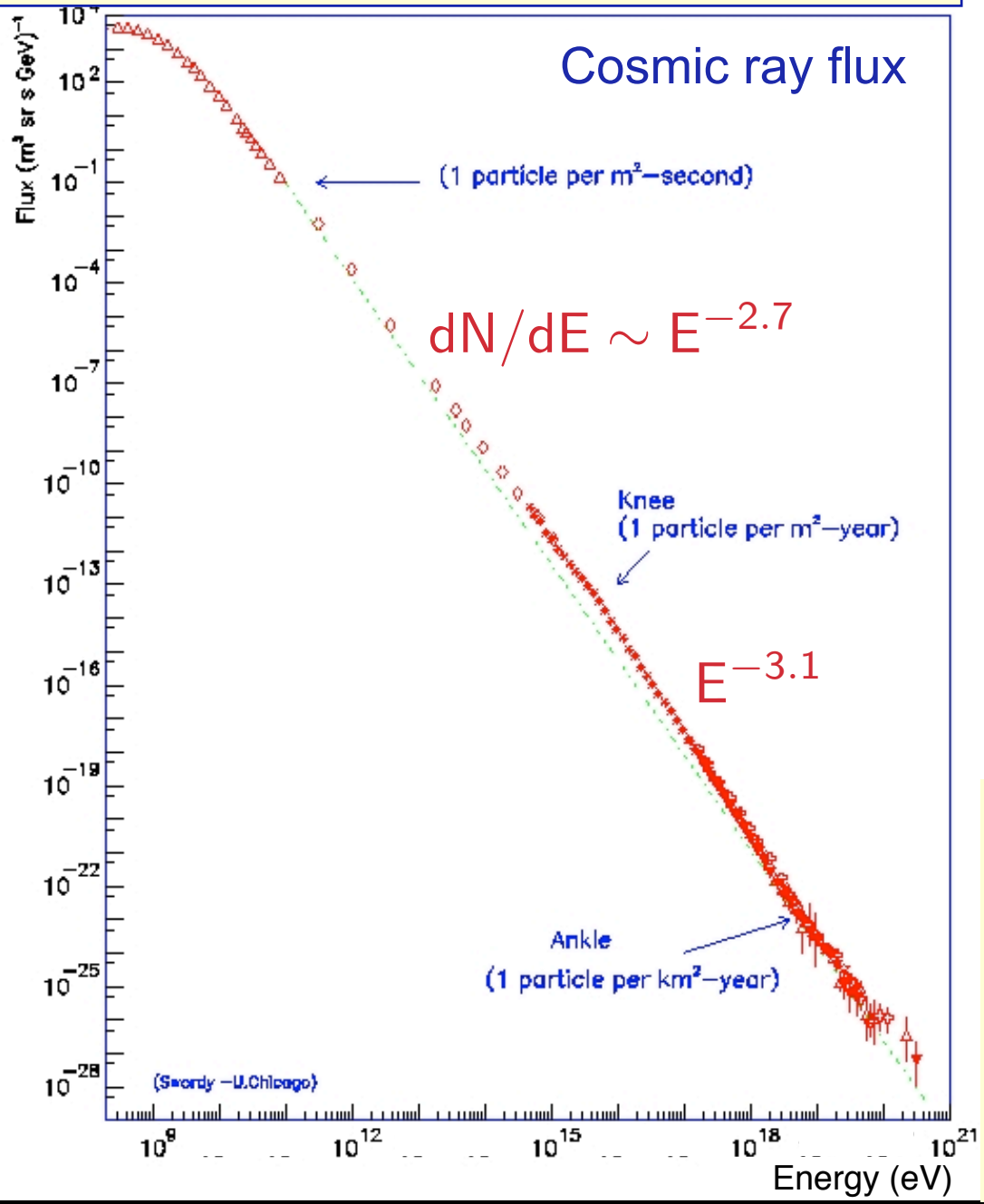
MonteCarlo studies started
(also at DESY)

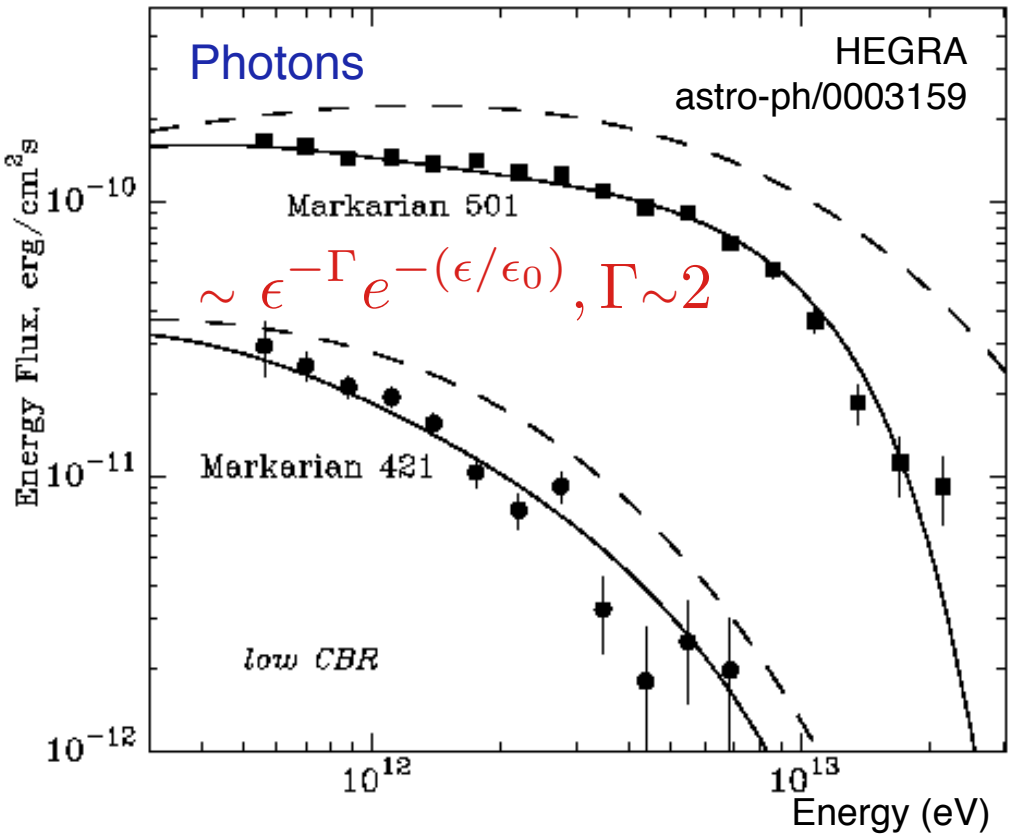
EeV Neutrino detection with a 4-string array?
Maybe, if λ_{abs} = 6 km: Array 3



2 km spacing, 1.5 km strings, 4 strings, Veff = 75 km^3

Neutrino Astro-Physics

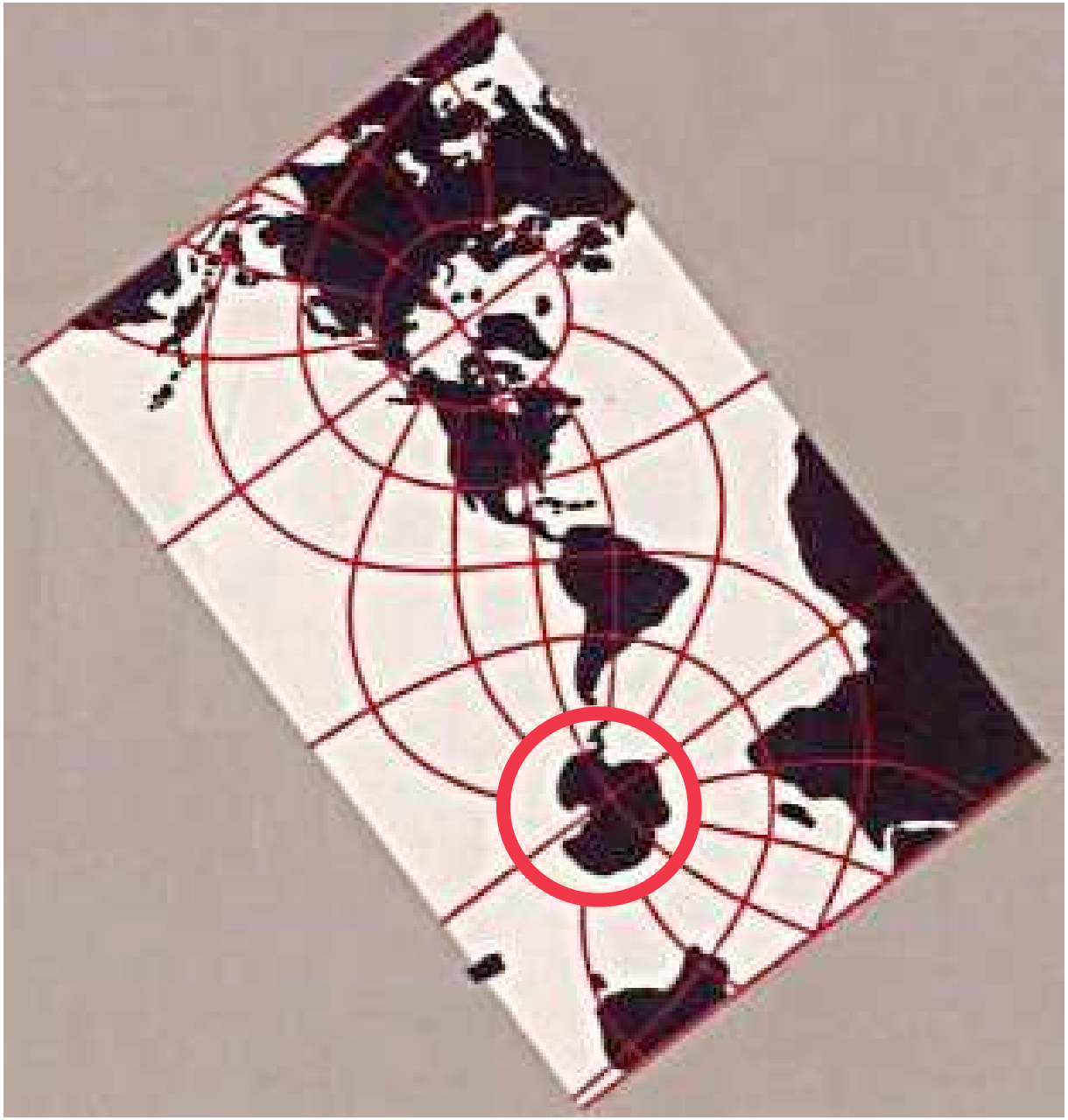




see also the latest γ results by CANGAROO and HESS on RXJ 1713.7-3946 (π^0) and by MILAGRO on Crab and 3EG J0520+2556

- Cosmic rays with energy >TeV observed - are there neutrinos?
- What are the neutrino sources: correlation with supernovae, blazars, quasars, gamma ray bursts... and/or WIMPs ?

The AMANDA Collaboration



Europe

VUB-IIHE Brussel
ULB-IIHE Bruxelles
Université de Mons-Hainaut
Imperial College London
DESY Zeuthen
Gutenberg Universität Mainz
Bergische Universität Wuppertal
Stockholms Universitet
Uppsala Universitet
Kalmar Universitet

The Americas

Bartol Research Institute
UC Berkeley
LBNL Berkeley
Univ. Simón Bolivar Caracas
UC Irvine
UW Madison
PennState
UW River Falls

~150 members

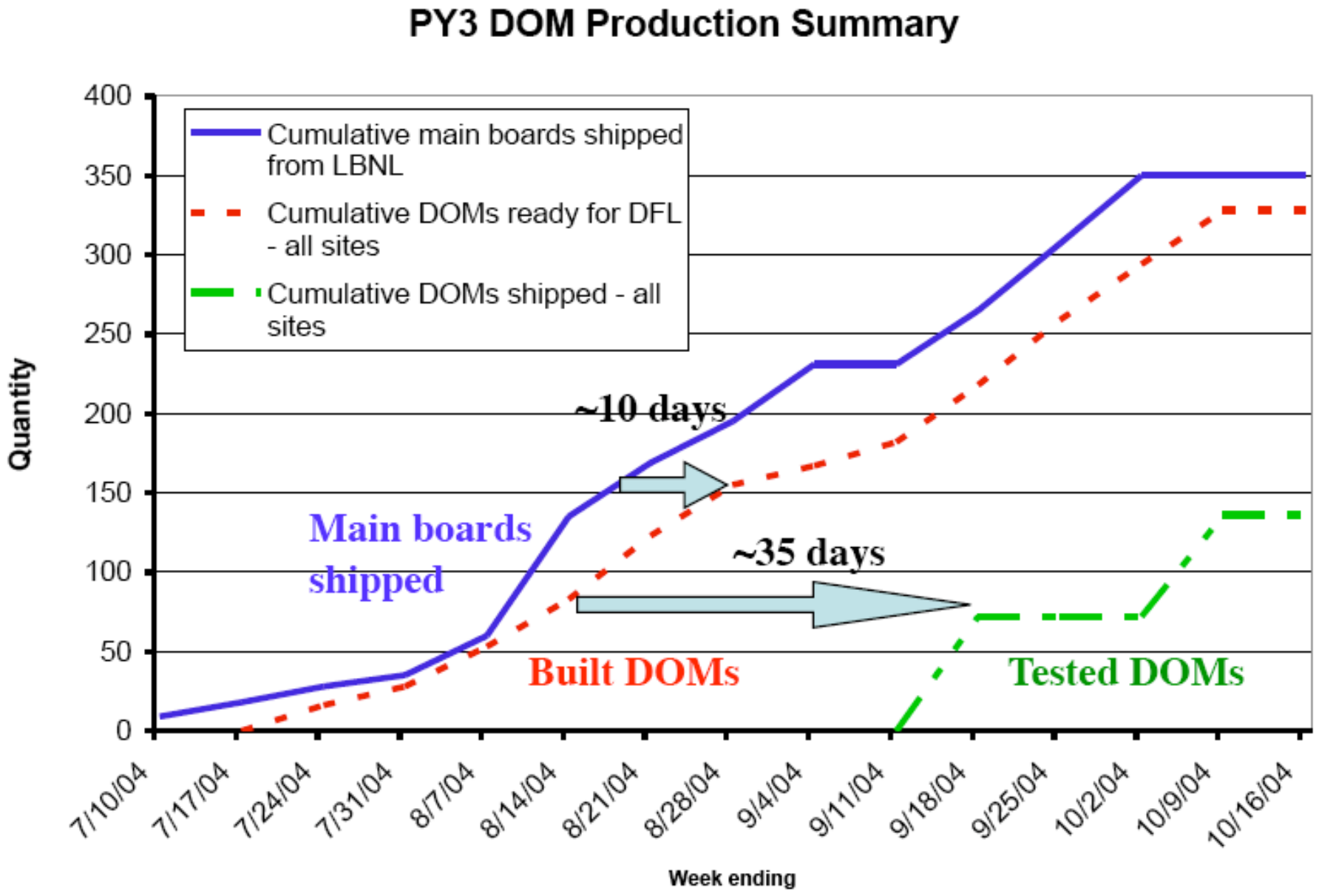
The Baikal Collaboration

Russia – Germany

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

~45 authors

DOM production



Average slope (rate) after startup: ~150/month