

Response of AMANDA-II to Cosmic Ray Muons

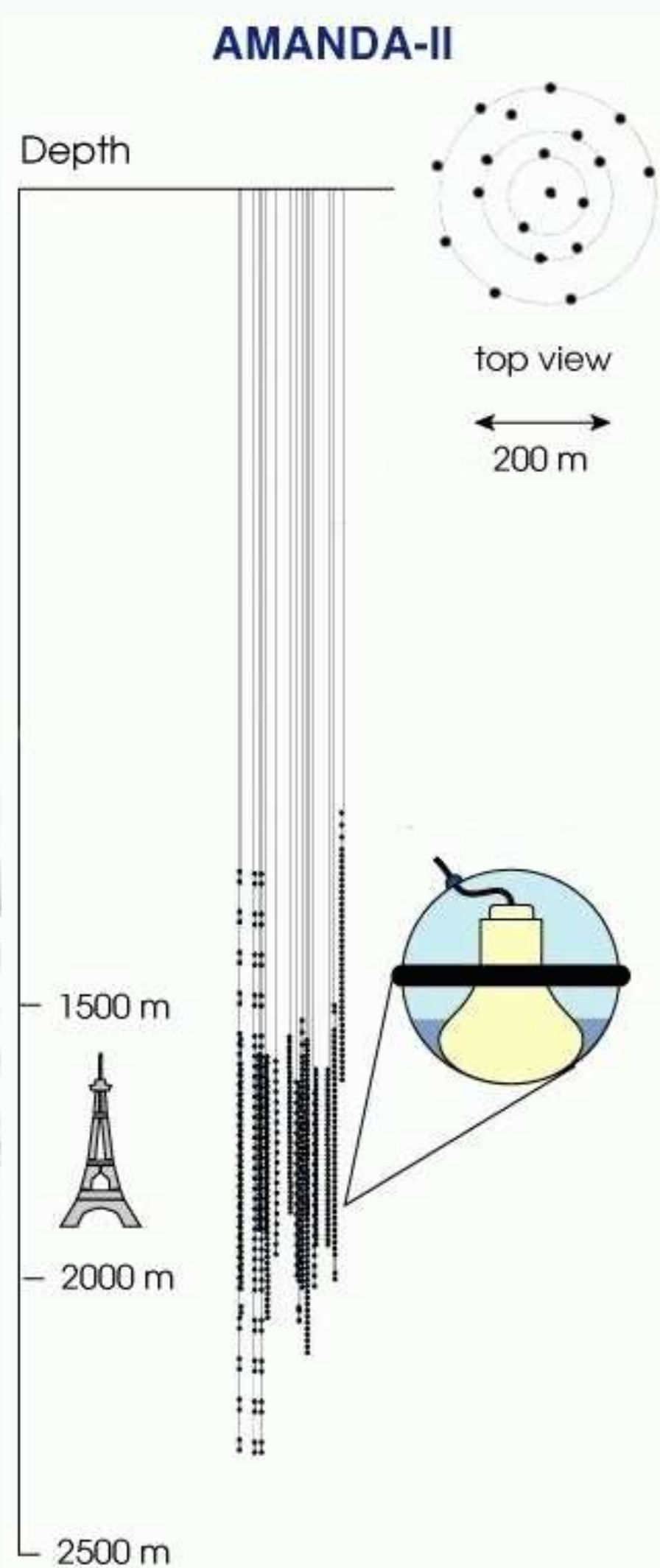
Paolo Desiati¹ for the AMANDA Collaboration and for Karen Bland²

1. Dept. of Physics, University of Wisconsin, Madison, WI, U.S.A.
2. Dept. of Physics, University of Wisconsin, REU Summer Student 2002

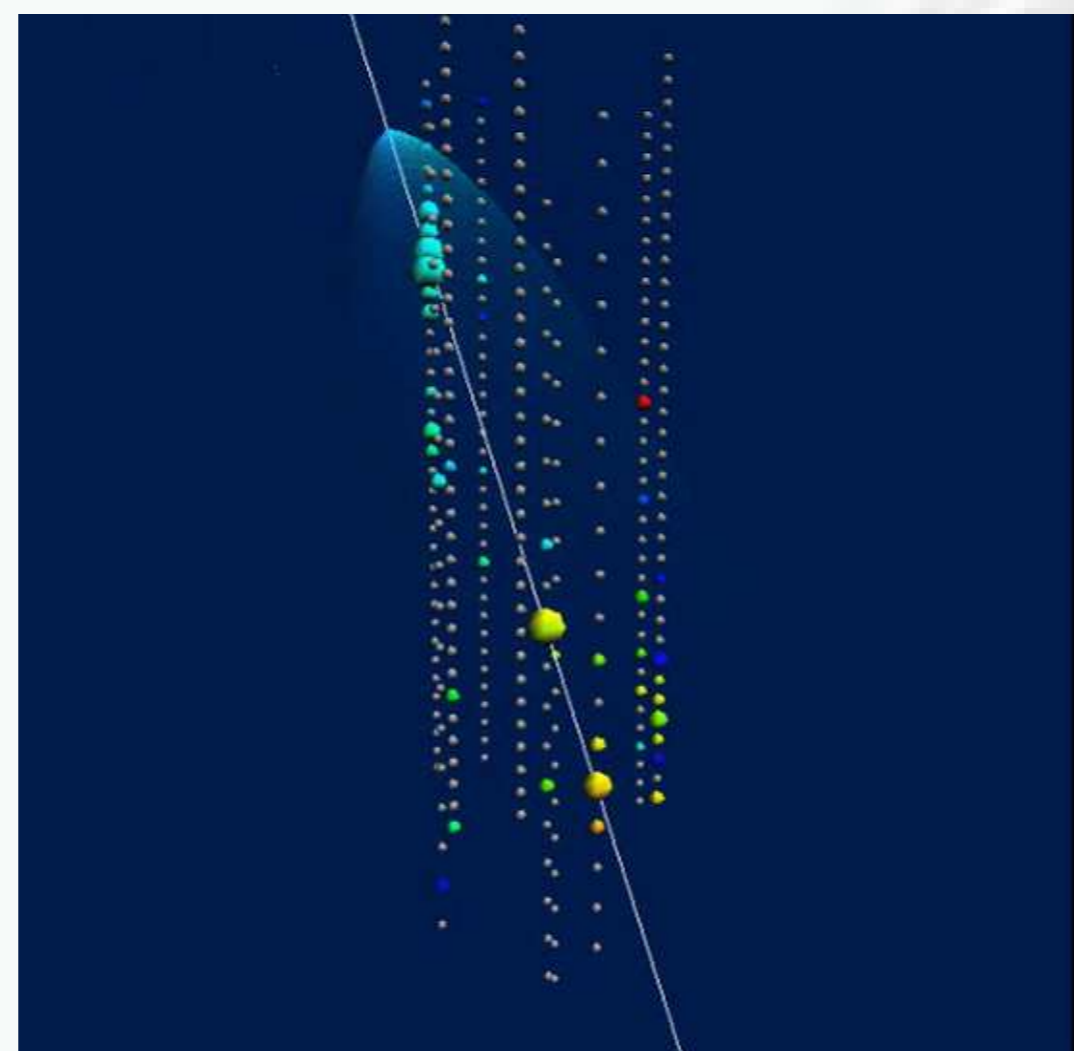
Abstract

The high flux of down-going muons detected by the AMANDA-II neutrino telescope is used as a test beam to check the experimental systematics and to improve the knowledge of its response. This work shows the result of an effort to get a better understanding of AMANDA-II performance, an improved data filter as well as event reconstruction. The preliminary experimental down-going muon angular and depth intensities are compared with Monte Carlo prediction, other experimental results and theoretical calculations. A good agreement is found within systematic uncertainties.

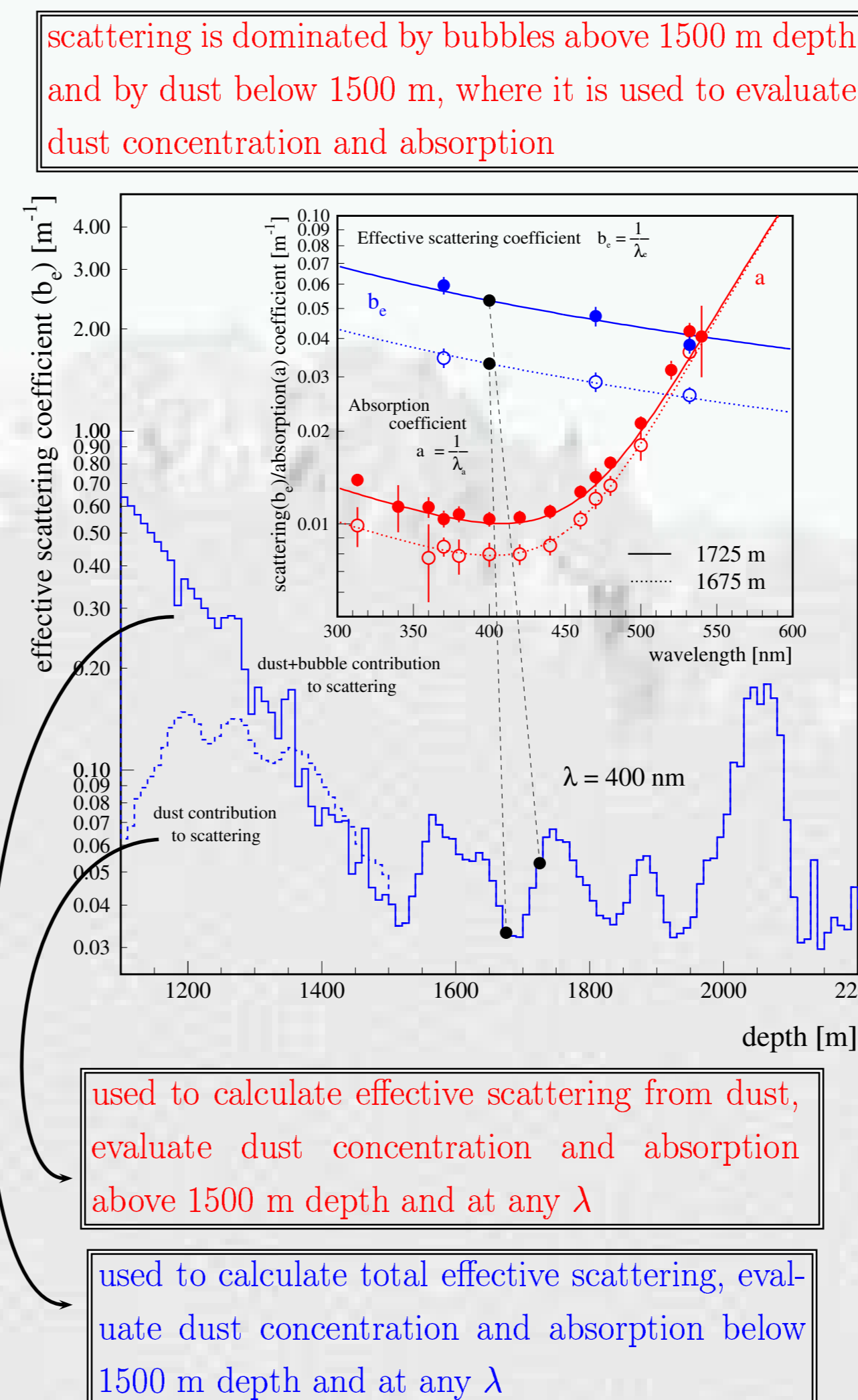
The Detector



- AMANDA-II, situated at the Geographic South Pole, was completed in the antarctic summer 1999/2000
- AMANDA-II contains 677 Optical Modules (OMs) deployed in 19 strings, most of them at depths 1500-2000 m
- Charged particles propagating through the ice, emit Cherenkov light which is detected by the OMs. Track reconstruction is based on time recorded by the OMs



The Optical Properties of Ice



- The optical properties of ice are not homogeneous, but change with depth. We can think of several horizontal ice layers, each with given optical properties
- Different concentrations of dust in the layers produce a modulation of the scattering and absorption lengths of light.
- At AMANDA-II depths and at $\lambda = 400$ nm (the maximum optical sensitivity) we have

$$\text{average absorption length } \lambda_a \approx 110 \text{ m}$$

$$\text{average effective scattering length } \lambda_e \approx 20 \text{ m}$$

- Systematic uncertainties include the following

$$\sim 10\% \text{ on measured scattering/absorption lengths}$$

$$\sim 20\% \text{ on OM light collection efficiency}$$

$$\sim 10\% \text{ on properties of refrozen ice surrounding the OMs}$$

Simulation Data

- The primary event generation is done using CORSIKA v6.020, with QGSJET01 interaction model, South Pole altitude and average atmosphere profile. A multi-component primary cosmic ray energy spectrum and composition (Wiebel-Sooth, B. 1998, PhD Thesis WUB-DIS 98-9, BUGH Wuppertal, Germany) is used.
- Propagation of muon events through the ice is performed taking into account all relevant energy losses (Chirkin D., Rhode W., 2001, Proc. XXVII ICRC HE220, Hamburg, Germany)
- The detector response is fully simulated to reproduce the experimentally detected events (Hunertmark S., 1999 DESY-PROC-1-1999)

- The Cherenkov photon propagation through ice was modeled to create multi-dimensional tables of density and arrival time probability distributions of the photon flux.
- The optical properties of OMs and glacial ice are included in the simulation of photon propagation
- A detected event corresponds to a realization of a majority trigger of at least 24 hit channels within 2.5 μ s

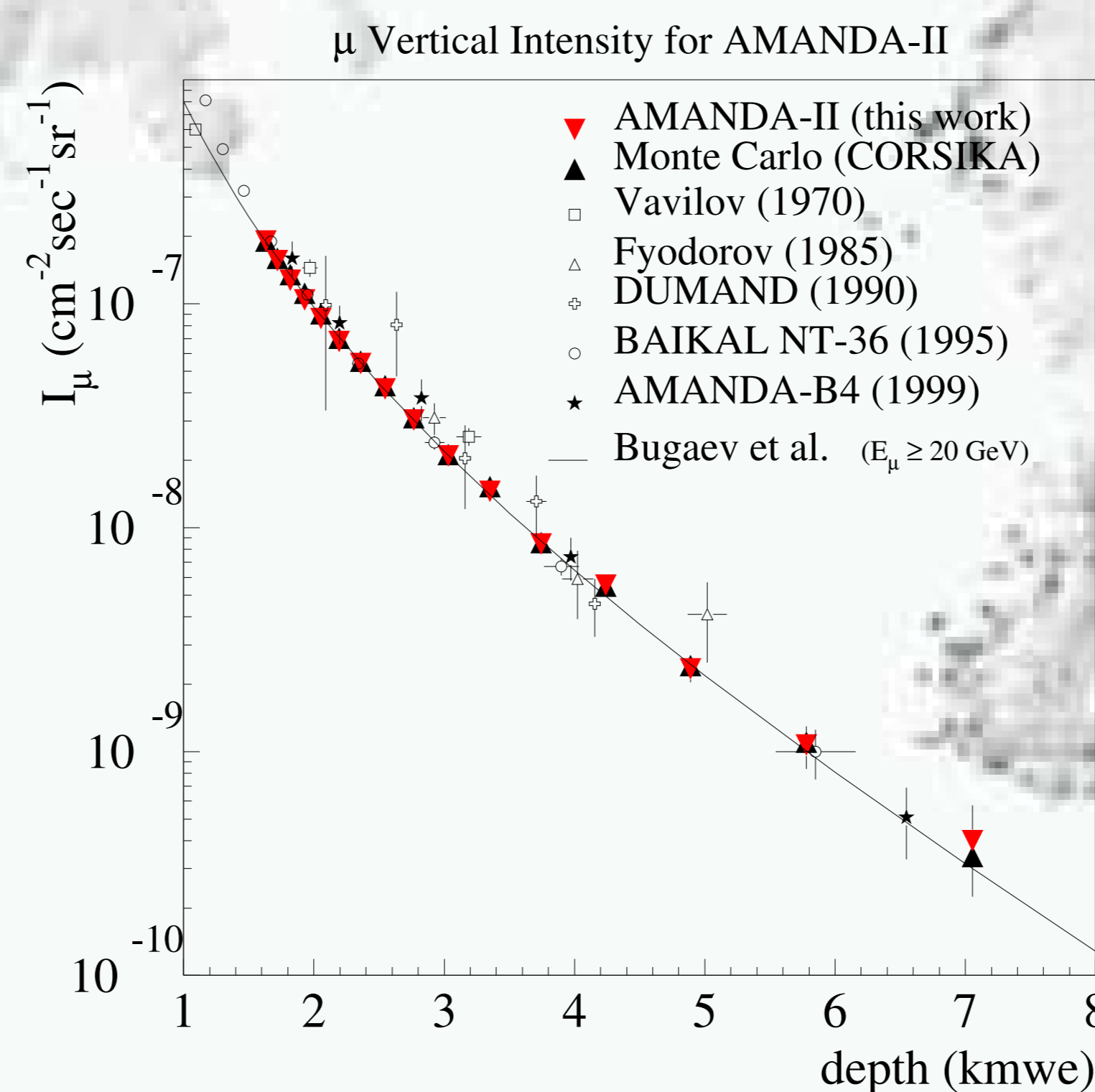
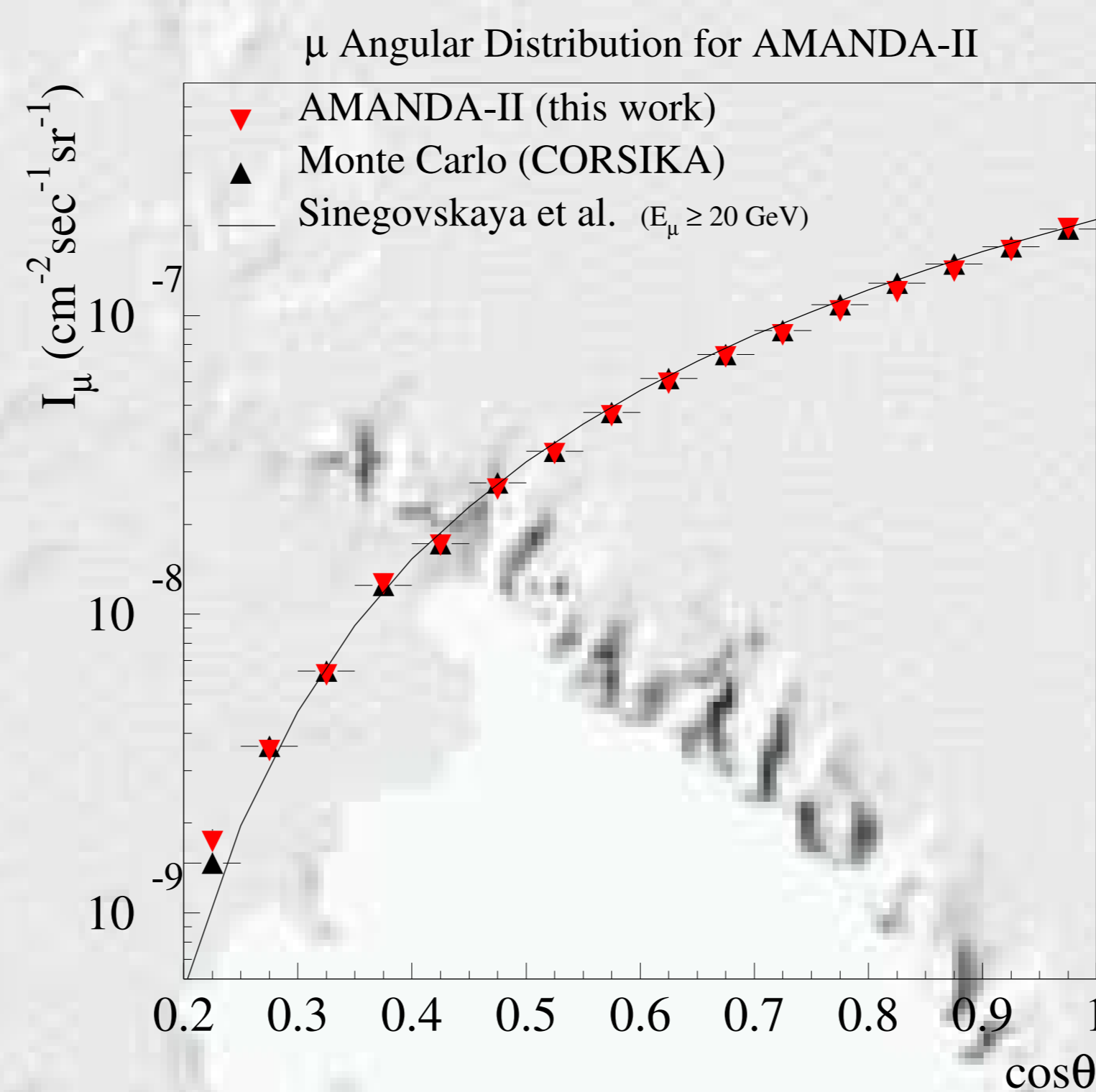
Experimental Data

- Presented here is the down-going muon data taken during the year 2000 and down-scaled by a factor of 500. A total of approximately 10 hours live-time is used for this analysis.

Systematic Uncertainties

- Simulated trigger rate is $\sim 30\%$ lower than experimental one
- This is due to the overall uncertainty in the optical properties of the ice and of all OM transparent media

The Results



Data Filtering and Reconstruction

- The data filtering and reconstruction is identical for both simulation and experimental data

- The OMs which are dead or have anomalous transient behavior are removed
- A time calibration corrects for the signal propagation time through the cables

- A muon track time likelihood reconstruction is applied to the events, which takes into account the average optical properties

- Due to limited reconstruction resolution, additional criteria are used to improve the event quality
- A good likelihood value, a smooth hit distribution along the reconstructed track, a relatively long distance between first and last hit along the track
- Angular resolution: $\delta\theta \sim 1.5^\circ$ at $\cos\theta=1$ and $\delta\theta \sim 2.4^\circ$ at $\cos\theta=0.2$
- Possible to neglect angular inter-bin correlations, given the proper bin choice

The Procedure

- Calculate the detector acceptance in each angular bin with simulation
- Perform bin by bin acceptance correction on experimental data
- Get angular and vertical distributions averaged over muon multiplicities, with event multiplicity evaluated with the simulation
- Compare acceptance-corrected experimental distribution with simulated true distributions, with other experimental results and with theoretical predictions.
- In the figures acceptance-corrected distributions are normalized to the most vertical point.