AMANDA

ANTARCTIC MUON AND NEUTRINO DETECTOR ARRAY

Simulation Tools

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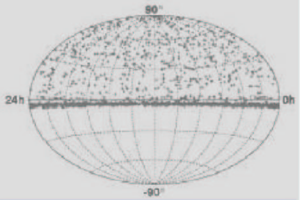
October 7, 2003

VLVνT Workshop

Amsterdam



Basic aspects of simulation:

- to simulate the detector response to processes generating light in the detection medium

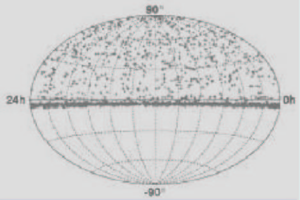
- physics generators generate events for signal and background simulations

- propagators propagate photons and leptons through matter

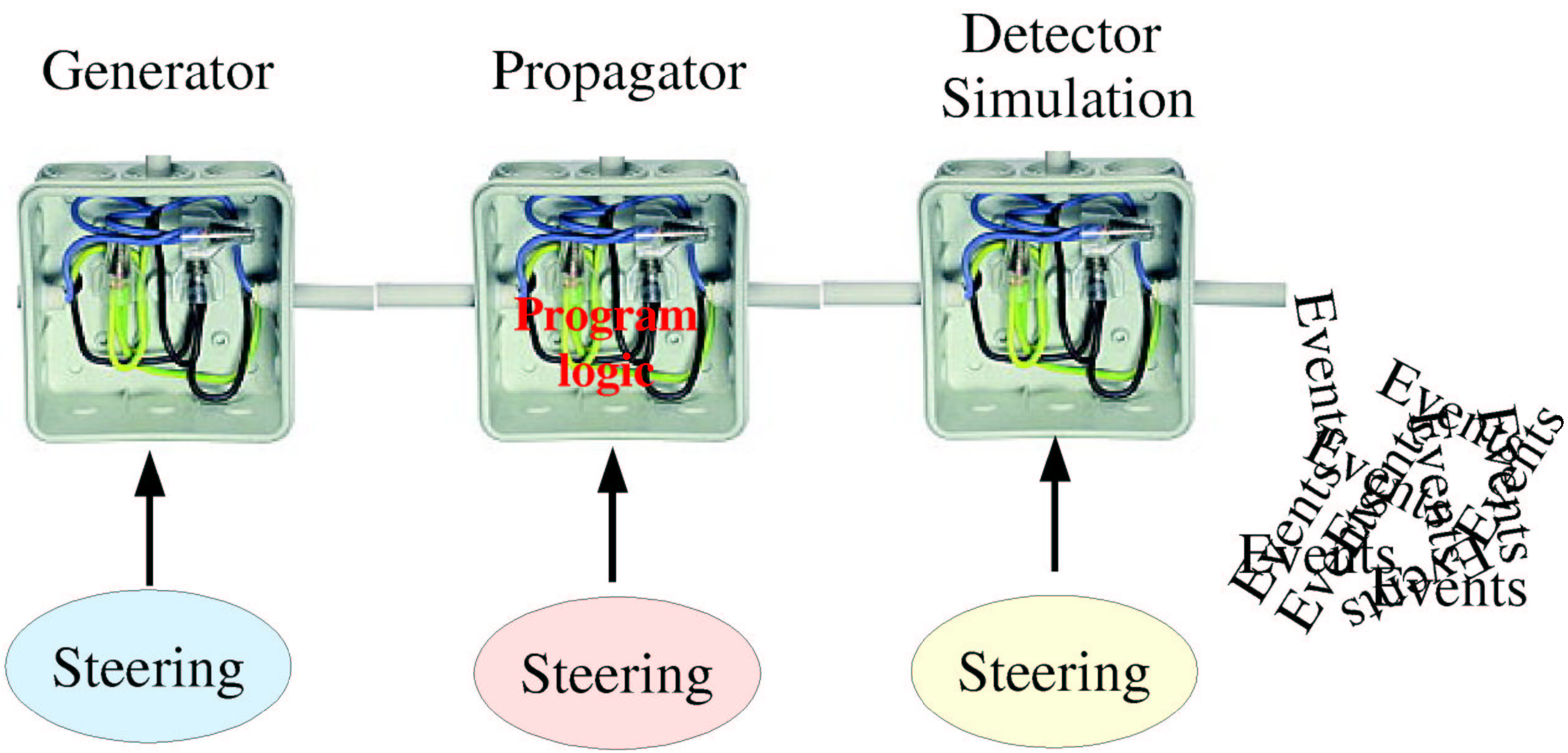
- the detector simulation includes all important aspects of the specific hard- and software implementation of the real detector

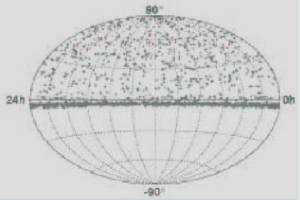
- a comparison of results of the simulation to the experiment has to be possible at all important steps of an analysis

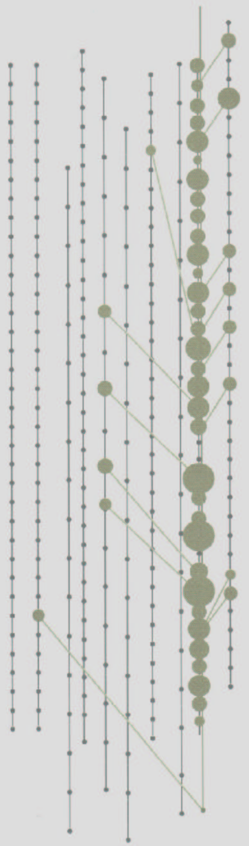
- the simulation needs to be fast enough to enable analyses with the allocated resources (detail ↔ speed)



Framework 'connects' the different parts together,
via *memory*, *files*, *tcp/ip:*







Physics sources:

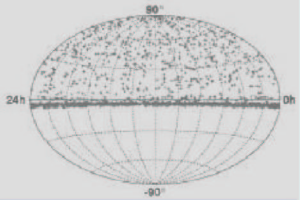
- Cosmic Rays; $p \rightarrow \pi, K \rightarrow (e), \mu, \nu_{\mu,e}$ $\geqslant$ 800 GeV
- Neutrino Sources; AGN, GRB, atm., Wimps $\geqslant$ 10 GeV
- Fast monopoles

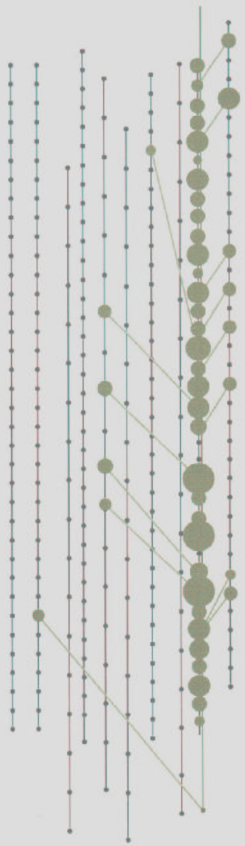
Propagating of:

- Neutrinos, Muons, Taus through earth and ice
- Photons through medium (results kept in archives)

Detector response to:

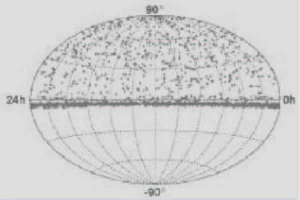
- 'Point like' electro-magnetic energy depositions
- Hadronic energy depositions
- 'Track like' light sources
- Lasers and other light sources

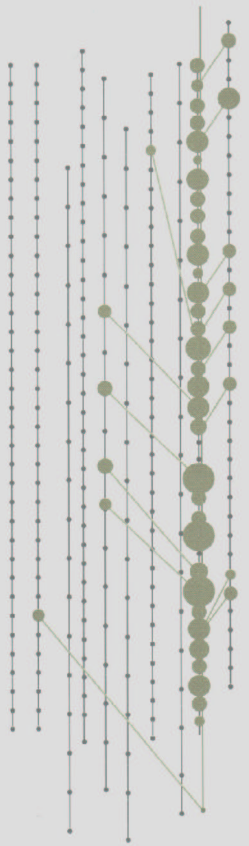




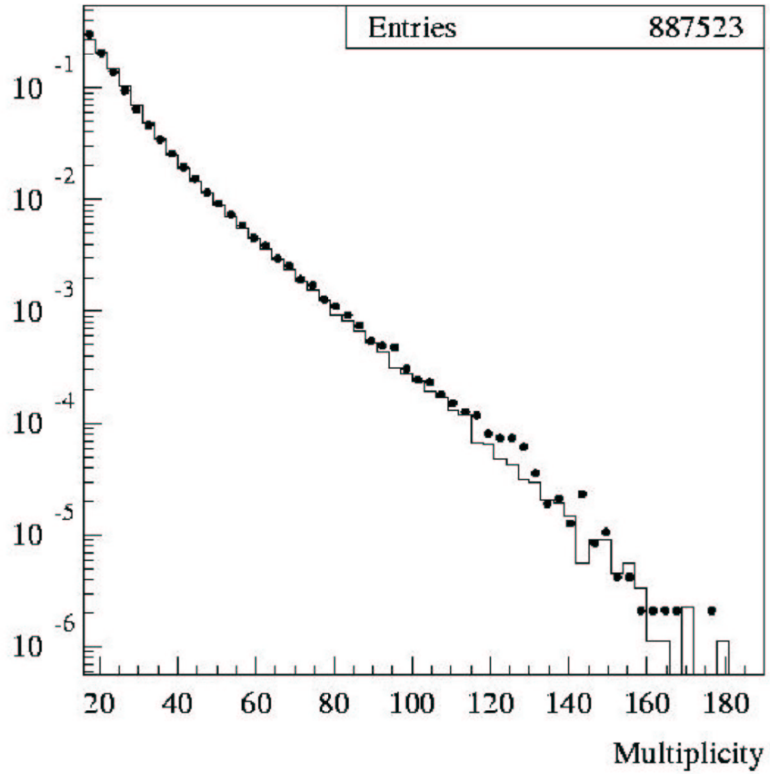
Cosmic Rays -- Corsika

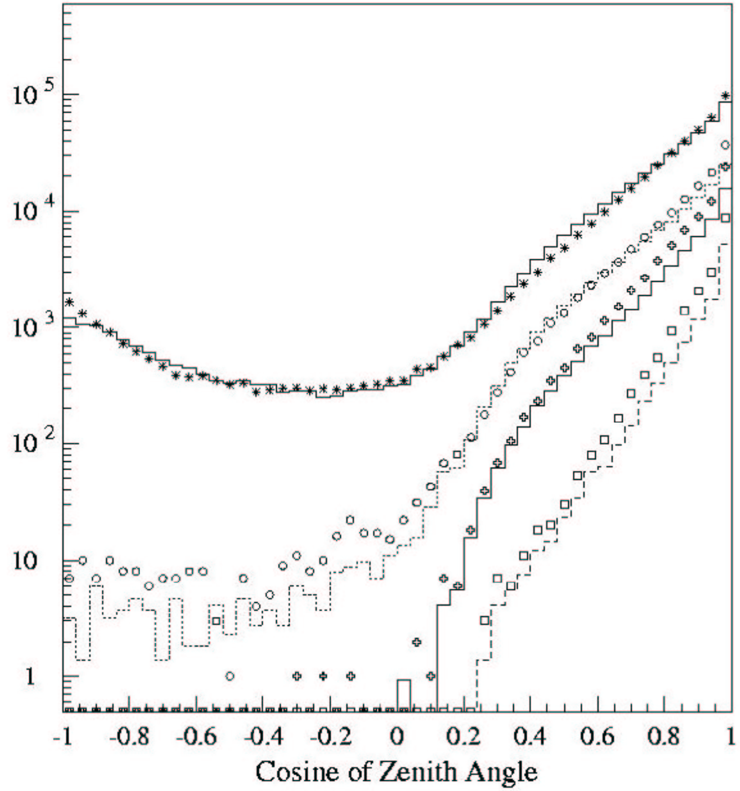
- modifed for AMANDA, atmosphere, horizontal events
- using QGSJET
- generate μ-bundles on ice surface
- simulate full primary spectrum (acc. Wiebel-Sooth)
- not used for atm. ν-generation
- not used to generate EM part of air shower
- oversampling by modifying impact parameter and azimuth angle



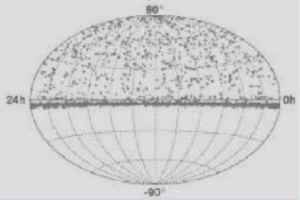


Simulations with Corsika





Comparison of atm. air shower simulation and experimental data

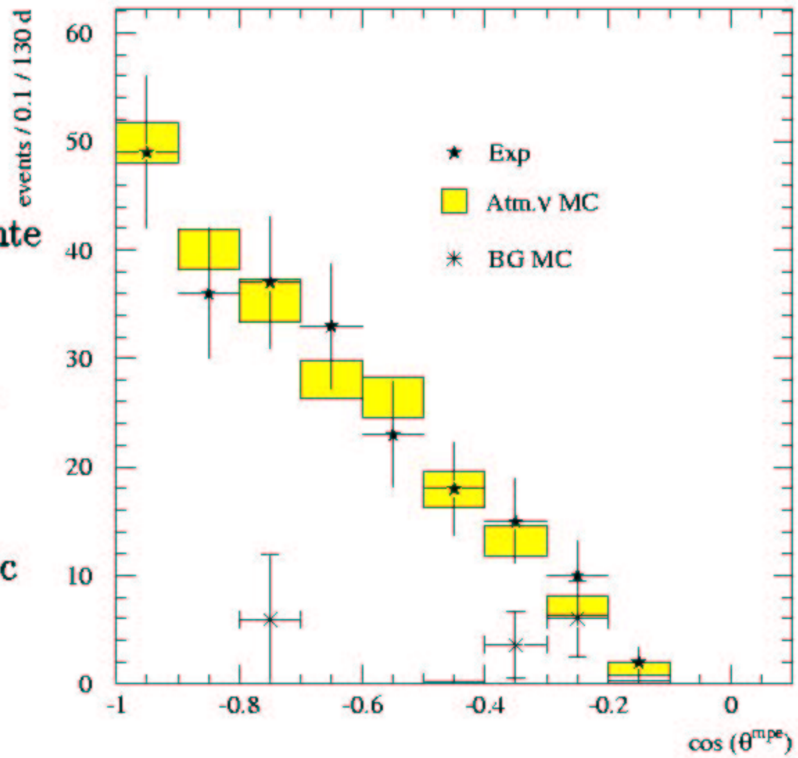


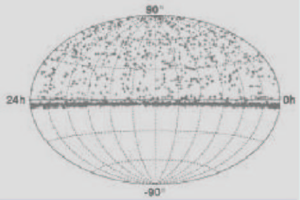
Neutrino Generators

nusim (astro-ph/9607140)

- muon-neutrino generator
- parton distribution from Martin et.al and Frichter et.al
- results consistent with Gandhi et.al (Neutrino Interactions at UHE)
- efficent due to event weighting
- not usable above ~10^{16} eV

'97 atm. neutrinos

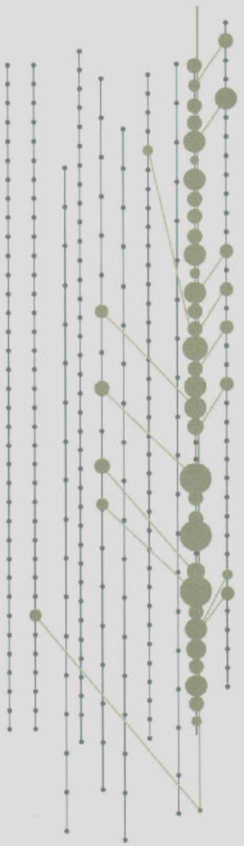


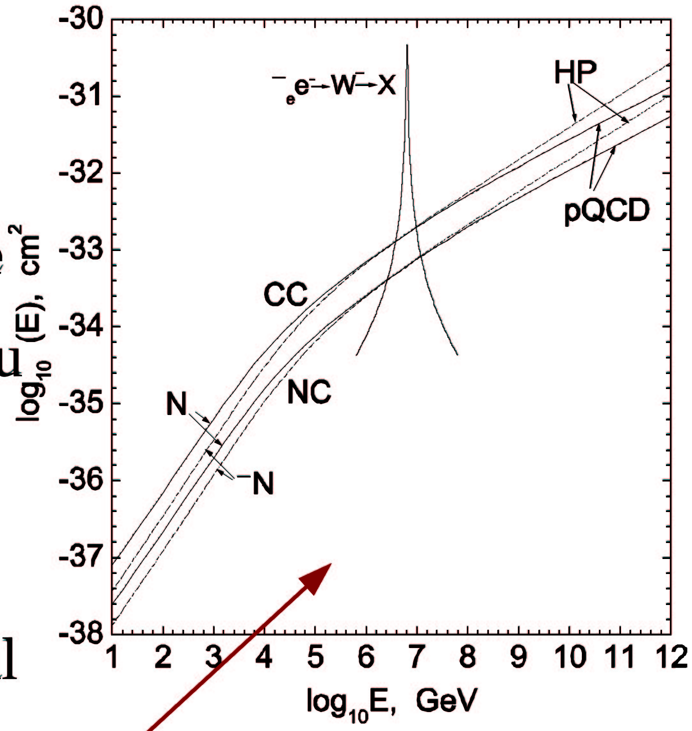


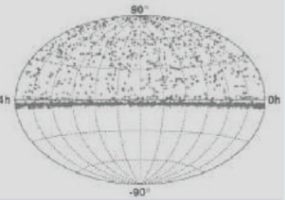
Neutrino Generators

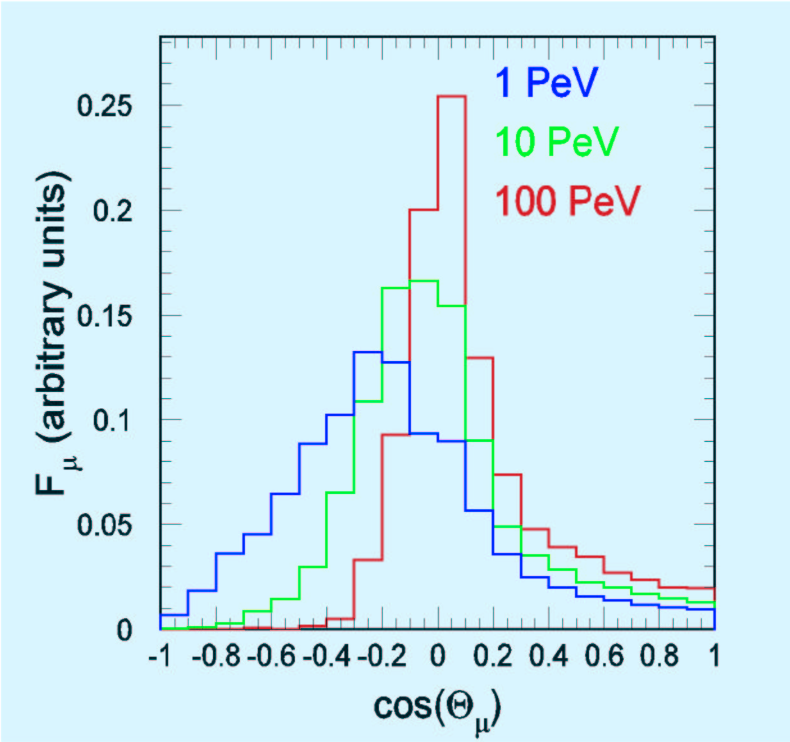
ANIS ICRC 2003 M. Kowalski

- All flavor generator $\nu_{e,\mu,\tau}$
- Includes relevant SM processes
  CC, NC (CTEQ5), Glashow resonance
- Includes regeneration NC and CC nutau
- Secondary neutrinos are tracked
- Angle neutrino-lepton simulated
- Flexible and fast, as x-section and final states are stored in tables
- Works at highest energies due to implemented extrapolations of x-section



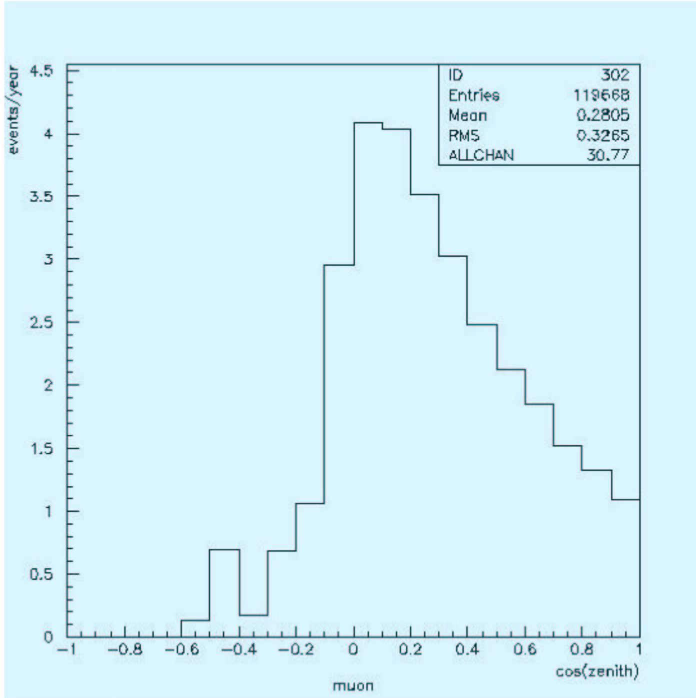


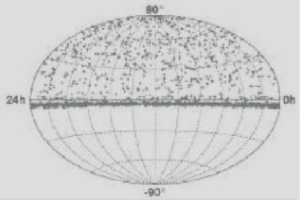




μ's from monoenergetic ν's at the detector

Events from E^{-2} ν_μ's for UHE analysis after all cuts





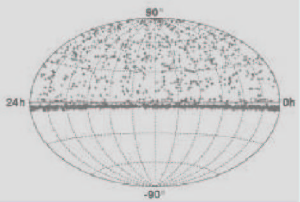
MMC - muon and tau propagation

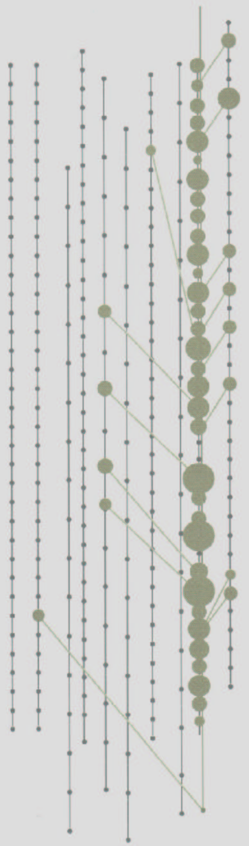
- Result of extensive comparison of different codes
- Can propagate muons/taus through all kinds of materials
- Uses newest x-section formulars
- x-sections are easily exchangable
- Works over the full energy range (<-> mudedx, propmu)
- Minimizes computational errors -> tracking over large distances
- Two different modes:

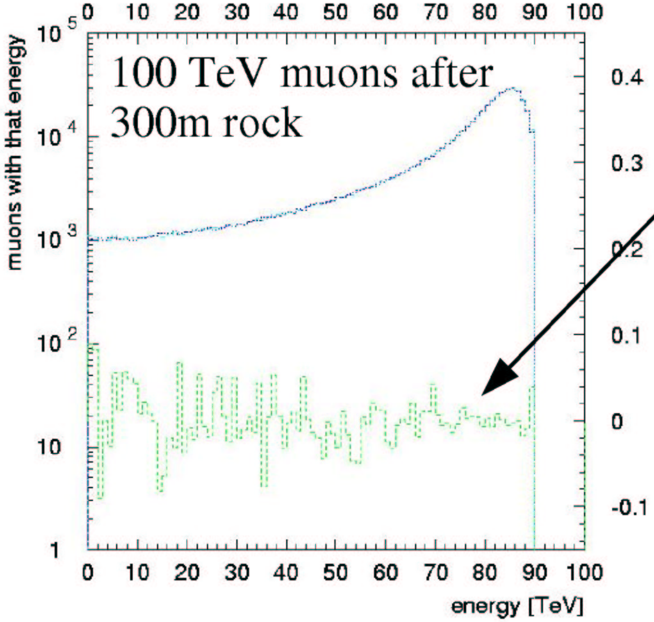
  Solve integrals to calc elosses on the fly (slow)

  Use parametrizations (fast)

http://lisa.physics.berkeley.edu/~dima/work/MUONPR/

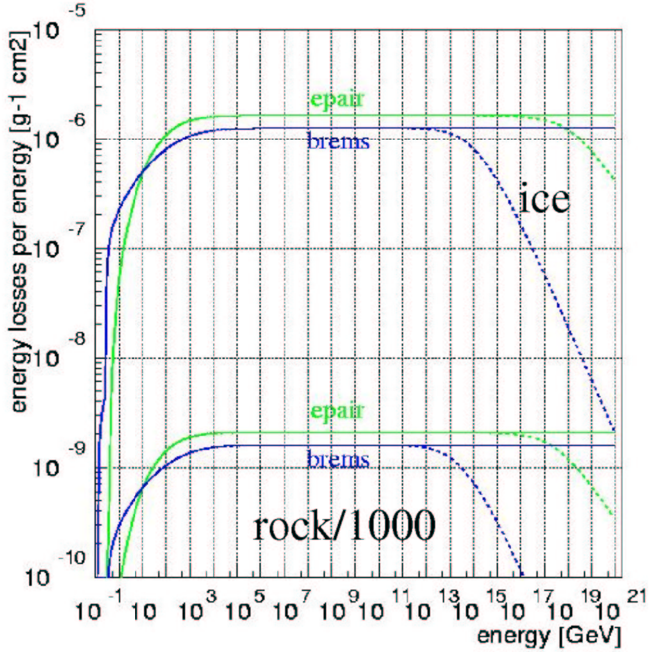


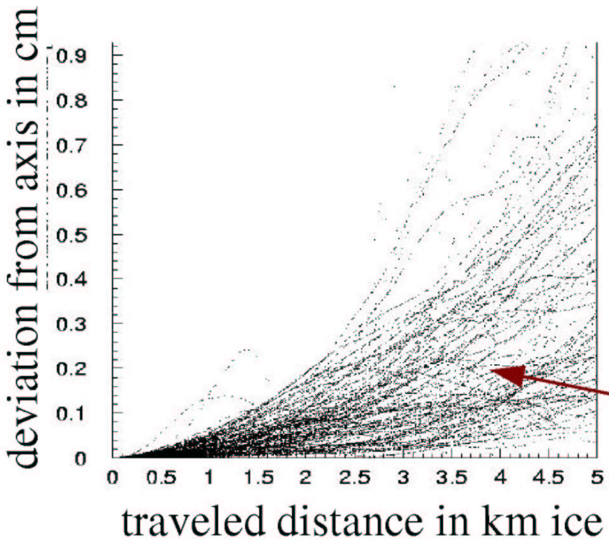




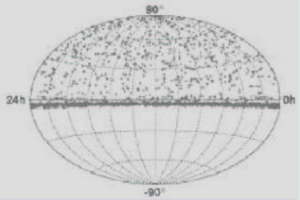
rel. error: parametrisation on/off

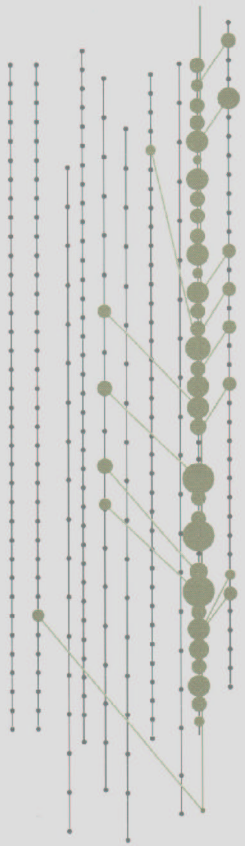
LPM effect





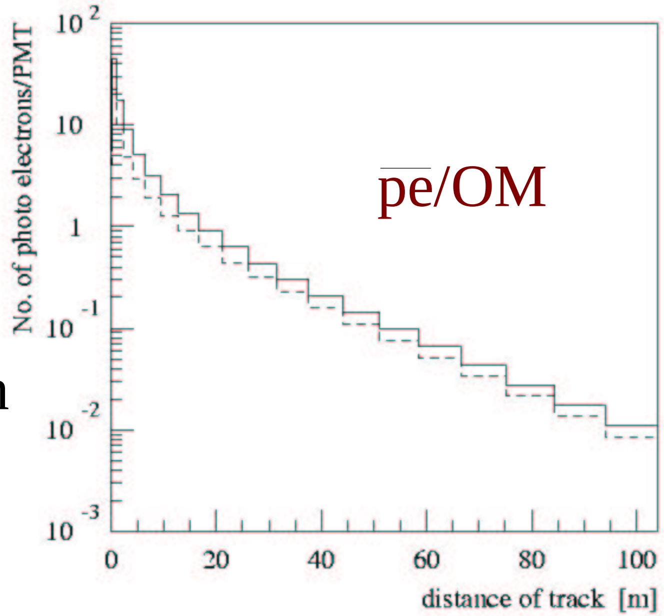
Moliere scattering with
10 TeV muons



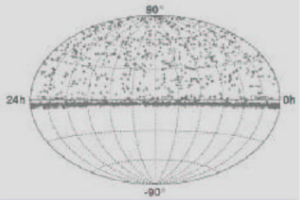


PTD

- Propagates photons through homogeneous ice
- No intrinsic ice layers
- Different OMs may see different ice
- Absorption is function of wavelength
- Includes OM acceptance simulation (wavelength, angular acceptance)

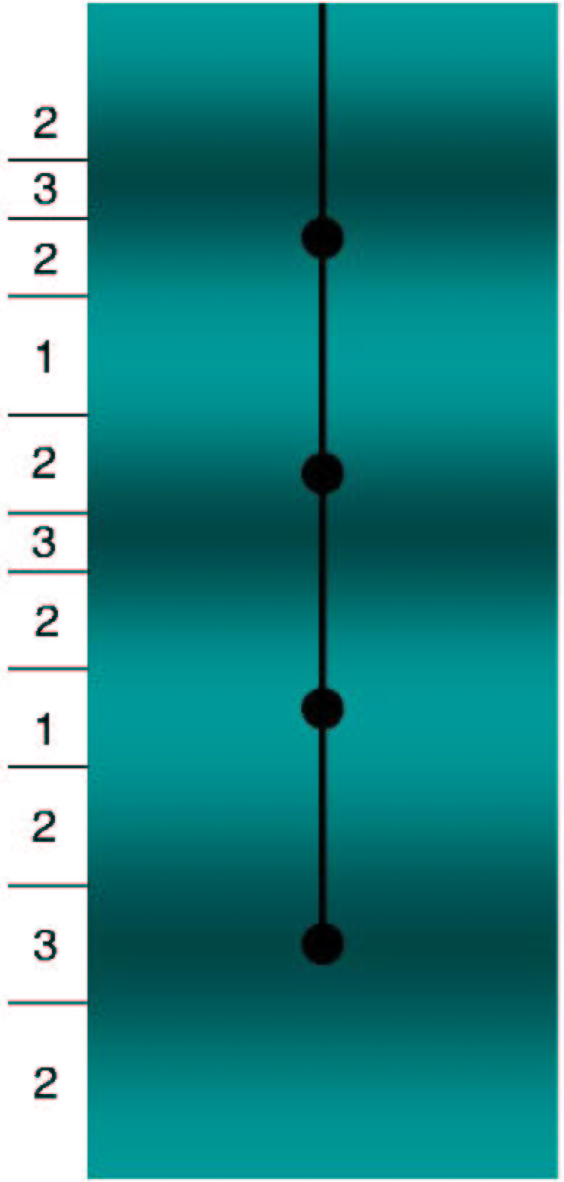


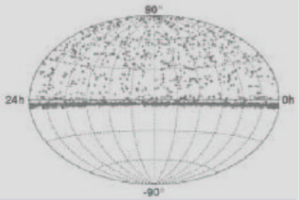
- Few, small tables (for amplitude and arrival time distribution)
- Fast
- Generic interface exists

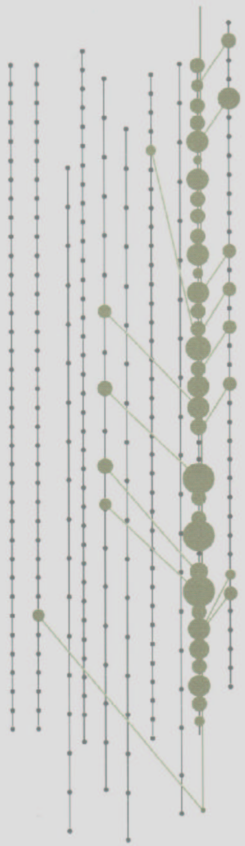


Photonics

- Generically includes variying ice properties
- Each OM sees full effect of medium on photons
- Wavelength dependencies included in scattering and absorption
- More tables (i.e. larger memory req.)
- Slower
- Detailed
- Generic interface exists







Detector Simulation Amasim

- Detailed simulation of the AMANDA detector hardware
- Uses PTD or Photonics results stored in archives for photon yield and arrival time simulation
- 18+ parameters per OM to simulate hardware behavior
- Examples:

  Individual pulse shapes for OMs

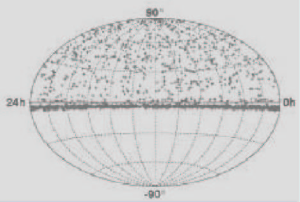
  Different gains and amplification behavior in the two channels of the surface amplifier

  Individual noise rates

  Saturation behavior

  Afterpulsing

  Trigger gates, etc.....
- Three trigger implemented: Multiplicity, String, Random
- Constantly maintained and updated



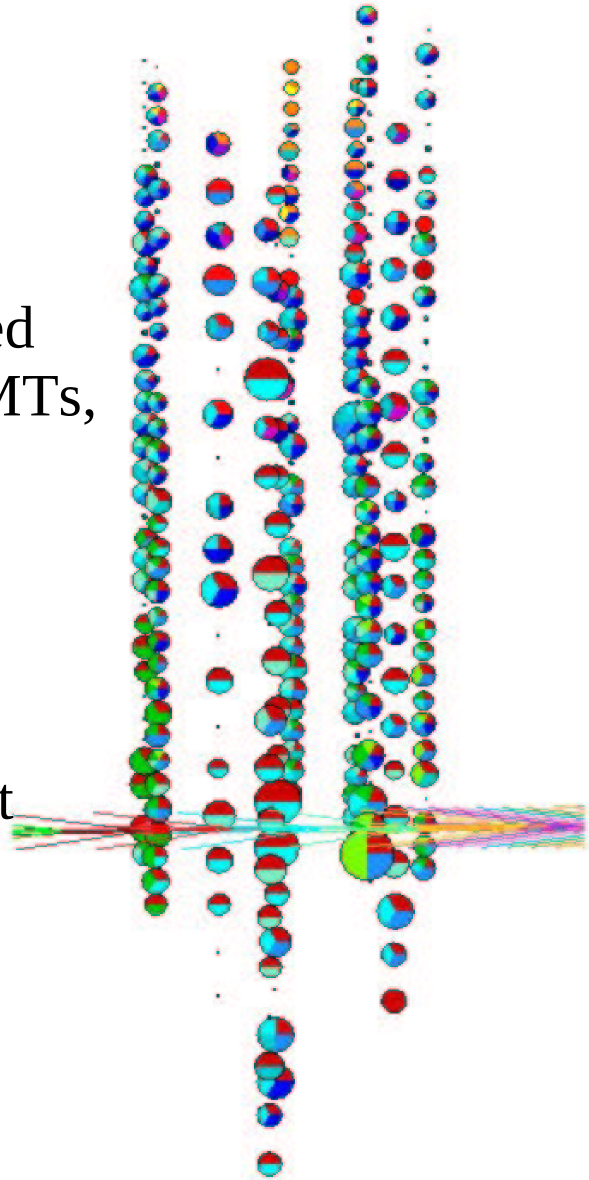
Detector Simulation Amasim

Amasim includes hardware effects needed to simulate EHE events (saturation of PMTs, amplifiers, overrun of electronics,...)

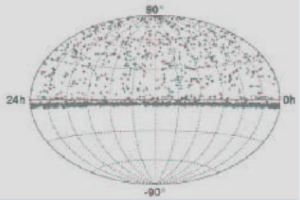
Amasim is tested against exp. data at low and at the highest energies

Amasim is tested against calibration light sources

Amasim is used to simulate IceCube (neglecting hardware details)



10^{19} eV event



Simulation Tree

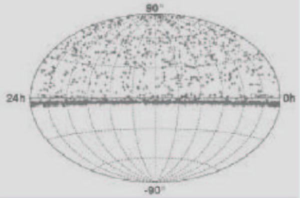
To generate large sets of simulated data the programs and steering files are arranged in a directory structure

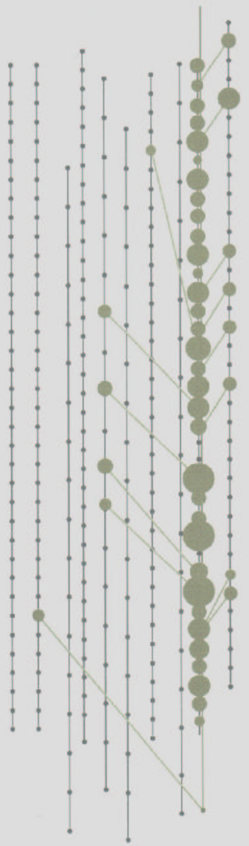
The user selects the generator, detector configuration and number of events and the scripts send jobs to the queuing system.

The structure contains error checking for failed runs

This system is used for the massproduction on 300-400 cpus

Currently we are not limited by cpu availibility to do our analysises.





IceCube situation

Requirements change (larger, more complex detector,...)

Learned a lot with AMANDA

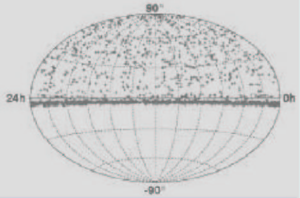
Need to be able to simulate at least 3 different detectors:

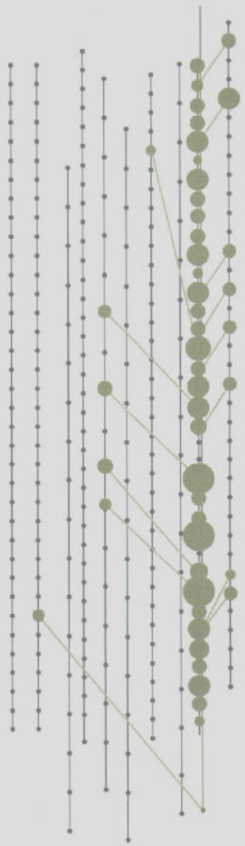
IceTop, AMANDA, deep Ice

IceTop requires simulation of em part of air shower

$\Downarrow$

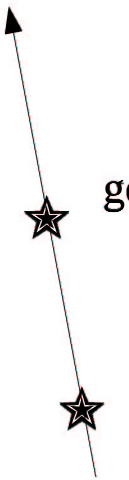
Write new framework and new detector MC



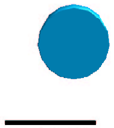


Detector Simulation (...the way IceCube will go)

Can be split into 'generic' and specific part



some
geometry
calc



amp

arrival time(s)

Source
of
photons

'field'
of
photons

Trigger

ATWD

String Processor

Flash ADC

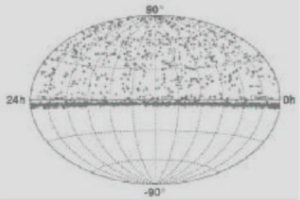
DAQ

TDC

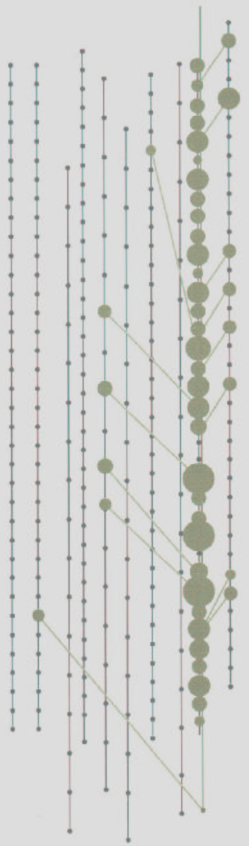
↓

Hits, Times, Amplitudes

Events



Summary



AMANDA has a simulation environment that covers the full energy spectrum and all possible physic signals

Tools have been extensively checked against exp. data and different AMANDA configurations

Proofed to be fit for massproduction given our resources

AMANDA tools were used to project IceCube

IceCube uses the AMANDA experience to set up a better environment (i.e. frame, detector MC)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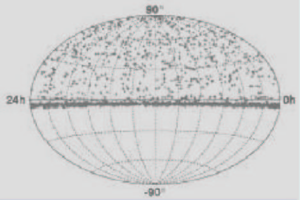
90°
24h
0h
-90°