Neutrino reconstruction for PINGU

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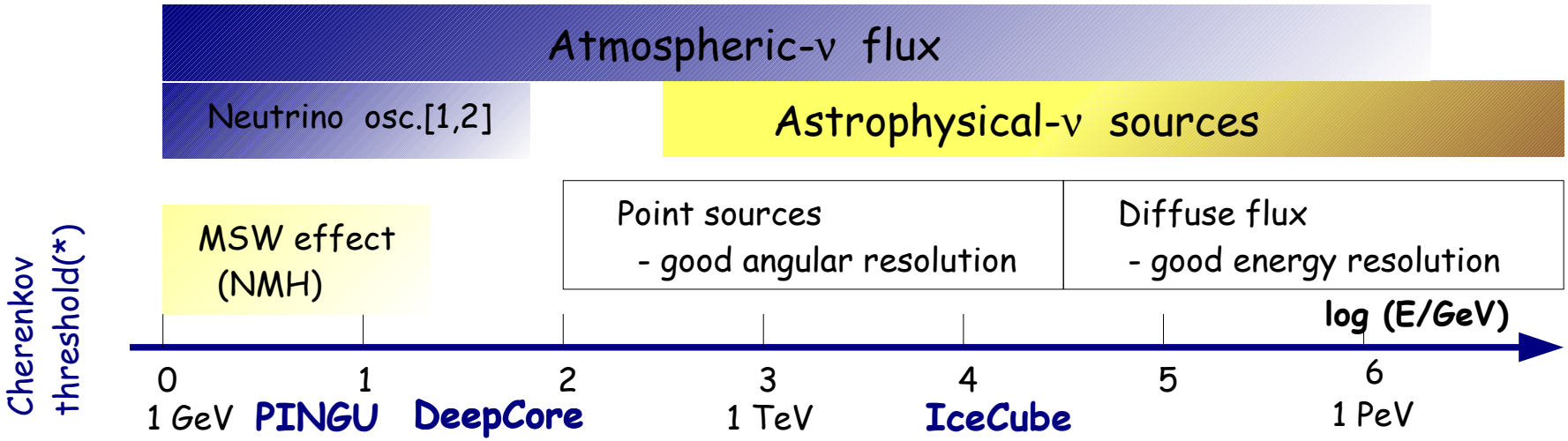
for the IceCube collaboration & PINGU

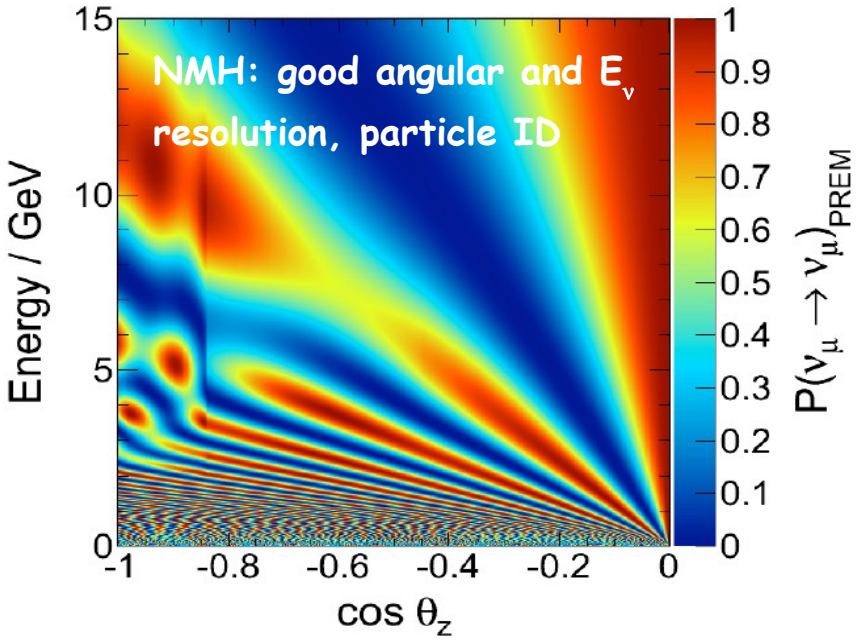
MANTS Meeting
14-15 October 2013 Garching, Germany

HELMHOLTZ GEMEINSCHAFT

DESY

IceCube/DeepCore/PINGU





* Cherenkov threshold $E_{th} > [n/(n^2-1)^{1/2}] \times m$

for $n_{ref} \sim 1.3$ (water/ice) :

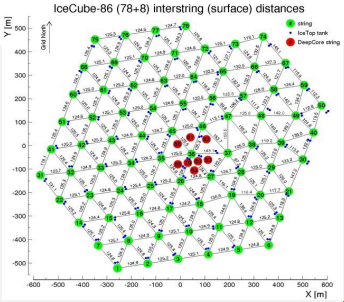
$E_e > \sim 0.8$ MeV, $E_\mu > \sim 160$ MeV

[1] Antares collaboration, Phys.Lett. B714 (2012) 224 [1206.0645]

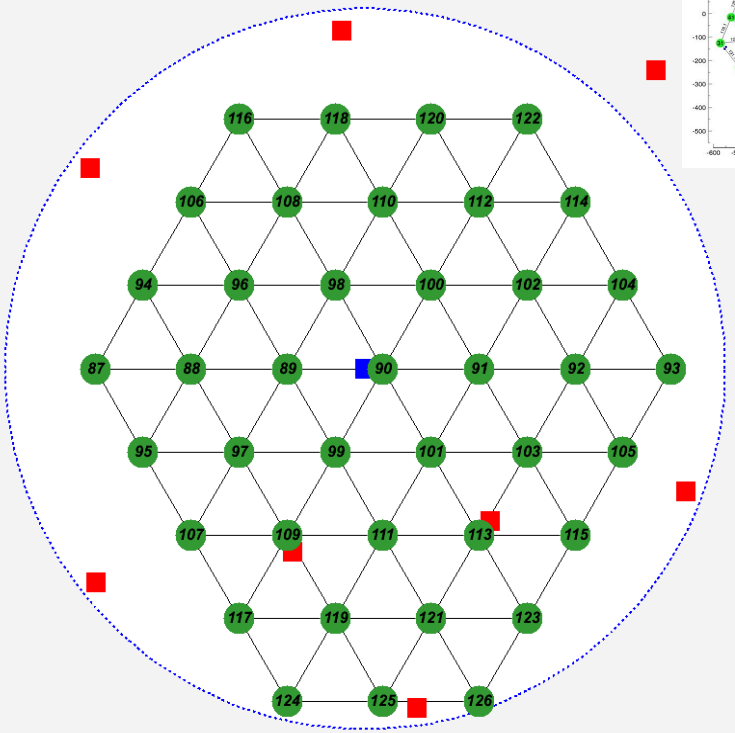
[2] IceCube Collaboration, Phys. Rev. Lett. 111(2013), 081801 [1305.3909]

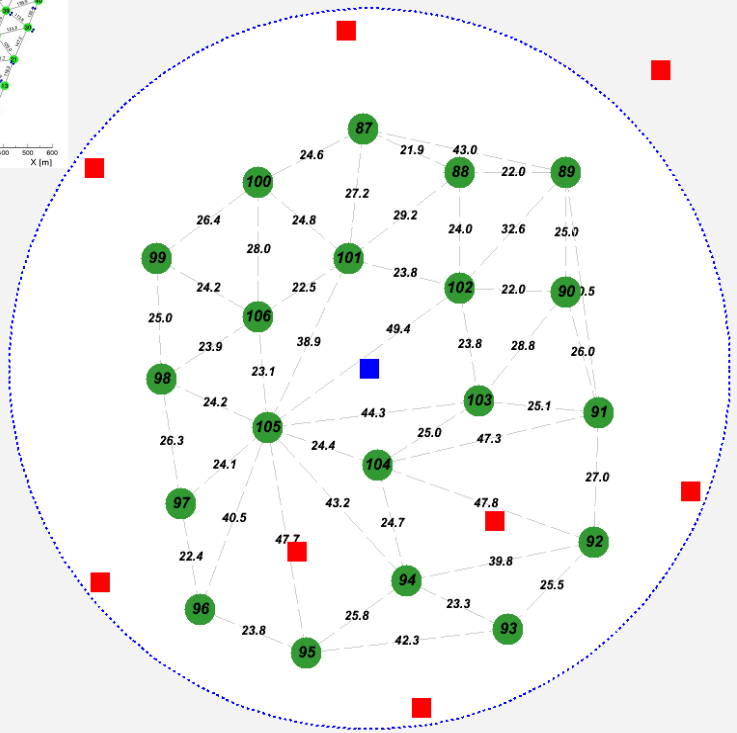
PINGU configurations

40 string configuration (v15)



20 string configuration (v6)



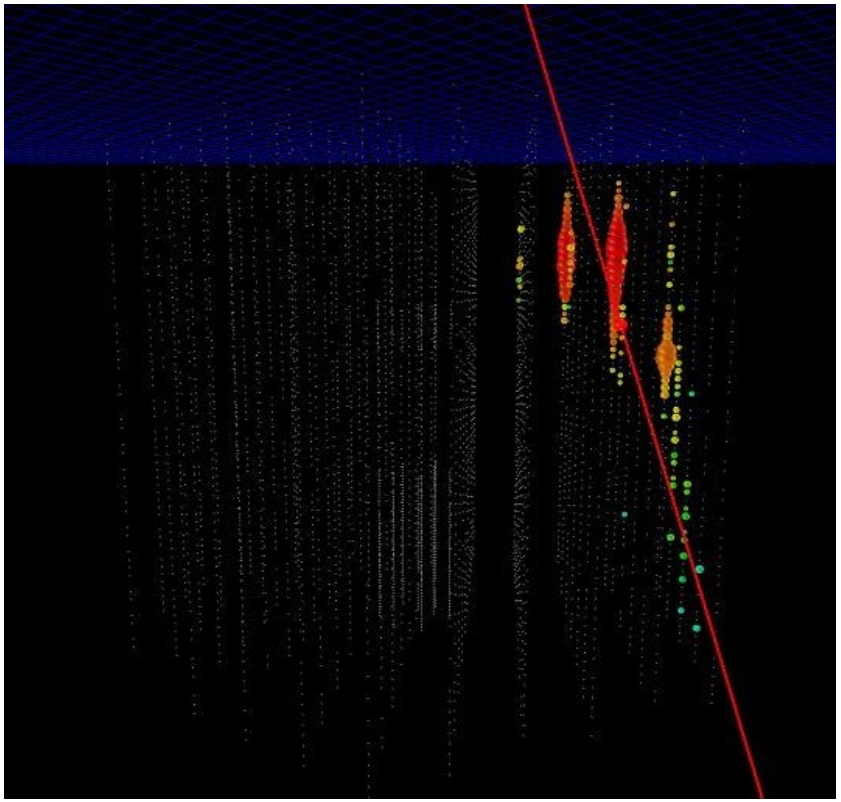


Closest distance between 2 strings: 20 m.
(same for all strings in this configuration)

IceCube string #36 is indicated by a blue square. Red squares: 8 DeepCore strings
Radius of the Circle, around IceCube String #36 is R=75 m. ρV_{PINGU} ~ 5 Mton

Track reconstruction in IceCube

- ν_μ-CC and atmospheric-μ reconstruction in IceCube: "infinite track" approximation.
- PDF based reconstruction[1] includes best knowledge of calibrated detector and medium(ice) optical properties.
- The PDF is calculated with respect to "seed track" wich is obtained with first guess pattern recognition[2].



[1] AMANDA Collaboration (J. Ahrens et al.), NIM. A524 (2004) 169
Muon track reconstruction and data selection techniques in AMANDA
[2] IceCube Collaboration (M.G. Aartsen et al), arXiv:1308.5501
Improvement in fast particle track reconstruction with robust statistics

Reconstruction for PINGU

- Level 2 (L2) reconstruction:
  Standard IceCube/DeepCore reconstruction of the triggered/filtered events:
  - Hit cleaning algorithms
  - Various IceCube algorithms for track, vertex and energy reconstruction: SPE, MPE, FiniteReco, . . ., Monopod

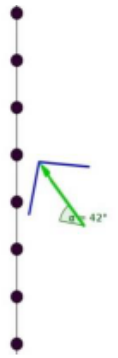
- L2 reconstruction for DeepCore events where modified and updated for the PINGU MC data.

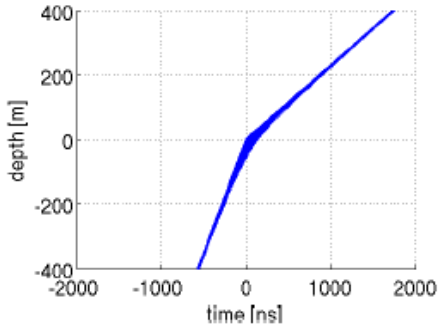
- Level2 reconstruction for PINGU includes additional algorithms:
  - SANTA [DESY]
  - IgelFit [Bonn U.]
  - HybridReco [PSU]

SANTA

SANTA*: find direct hits, build observables

- Number of direct hits → **quality criterion**
- Hyperbola projection orientation → **zenith angle**
- **Limit impact of ice properties**



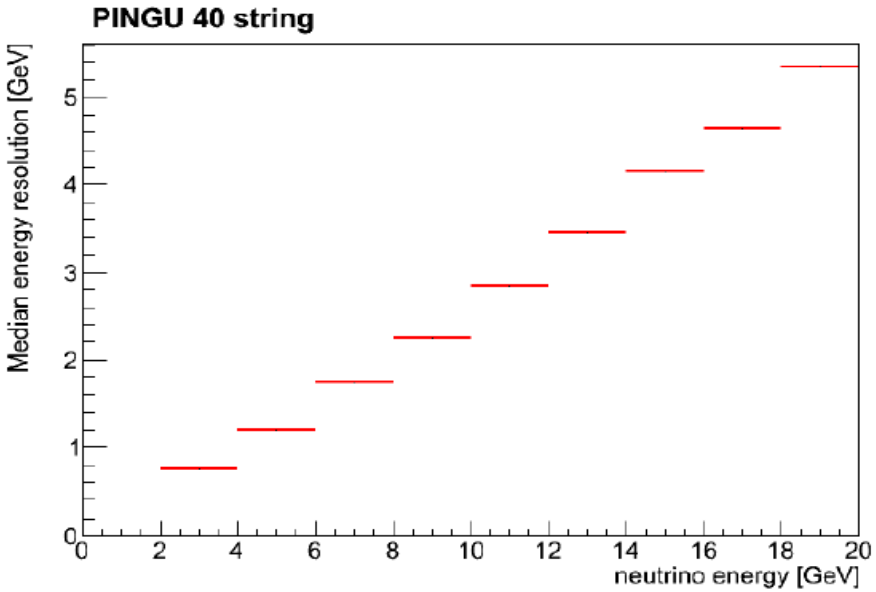


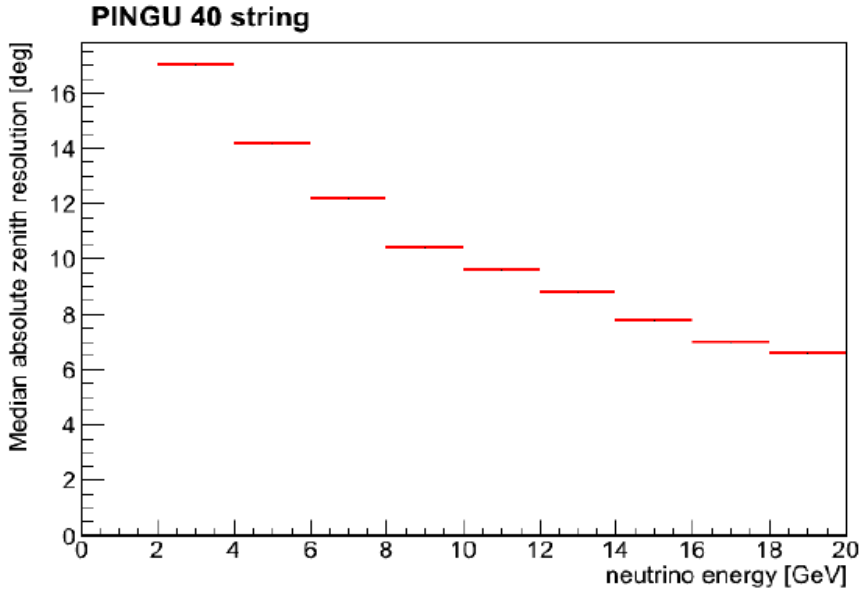
Idea developed in collaboration with J. Brunner (Astropart.Phys.34:652-662,2011), based on the BB-fit
*Single-string **ANT**ares inspired **A**lgorithm

- Used in current analysis of PINGU sensitivity
  [talk by A.Gross, MANTS-2013, 14/10/2013]

SANTA

- Energy and angular resolution obtained for PINGU MC events reconstructed with SANTA (direction) amd Monopod(energy)

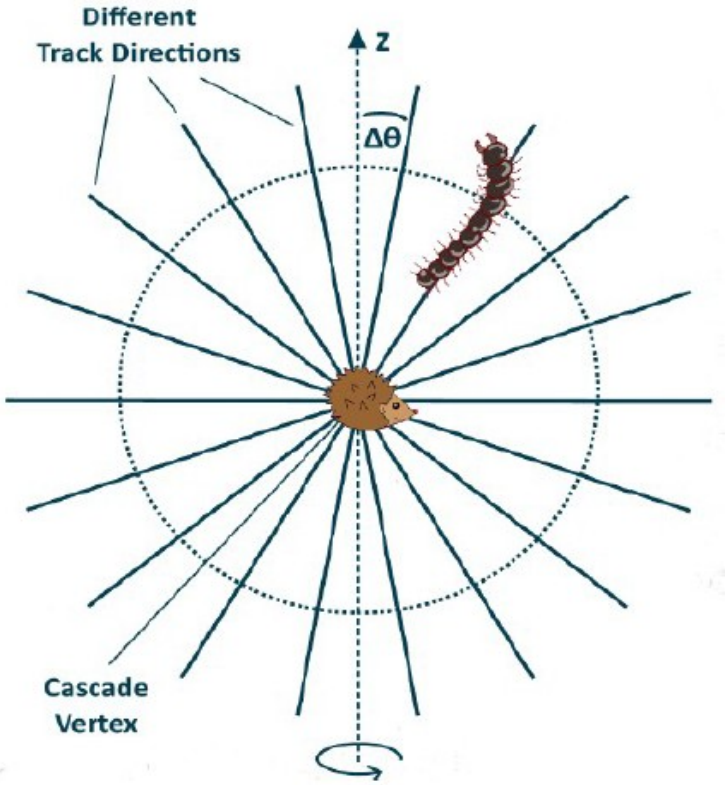




A.Gross, presentations at ICRC-2013 (Rio de Janeiro) and VLVnT-2013 (Stokholm) .

IgelFit

- Divides sphere around a vertex in N-segments/tracks (N=128 by default) .
- In each segment IceCube PDF-based reconstruction is applied.
- Requires vertex coordinates as a "seed"



Currently studies:

M. Day (UW) – for DeepCore data

HybridRECO

- muon neutrino-CC event reconstruction with 8-parameters:
  - neutrino interaction vertex and time (x_0, y_0, z_0, t_0)
  - $\mu(\nu)$ direction: $\cos\Theta$, ϕ
  - μ-energy (defined from length l_μ) and cascade energy (E_x)

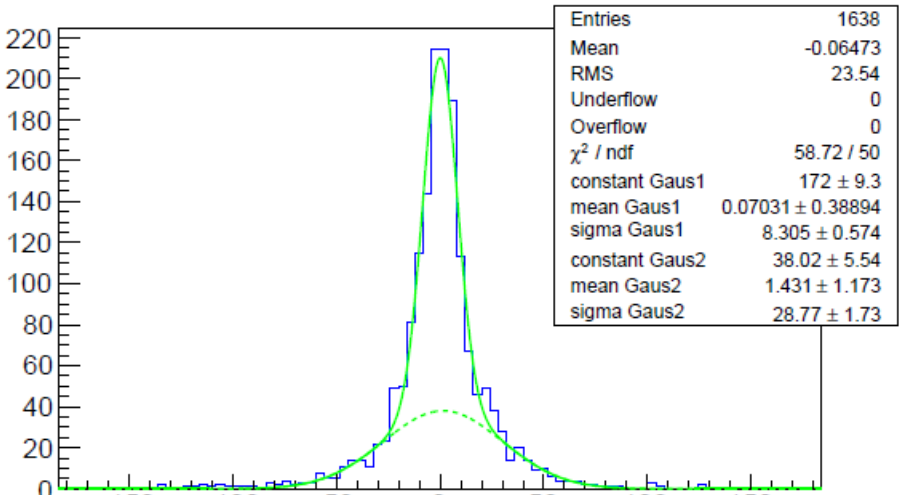
- Requires PDF / depends on the knowledge of ice properties.
  - Current PINGU MC simulations use SPICEMie.
  - PDFs are calculated from SPICE 1.

- Relatively slow, different minimization and LH-scan algorithms tested:
  - MINUIT algorithms
  - Markov Chain(MC): Vanilla Metropolis-Hastings MCalgorithm
  - MultiNest algorithm[1]

[11 F. Feroz et al, arXiv< 0809,3437

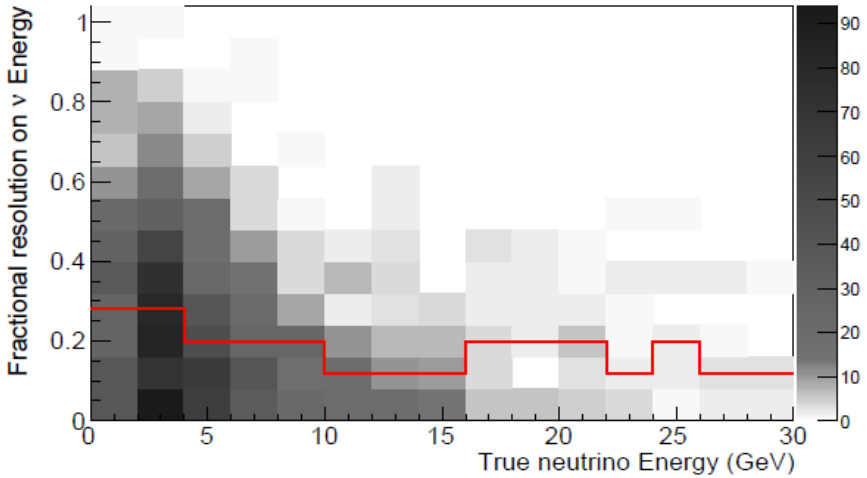
MultiNest algorithm

João Pedro Athayde Marcondes de André @IceCube meeting, Munchen 2013

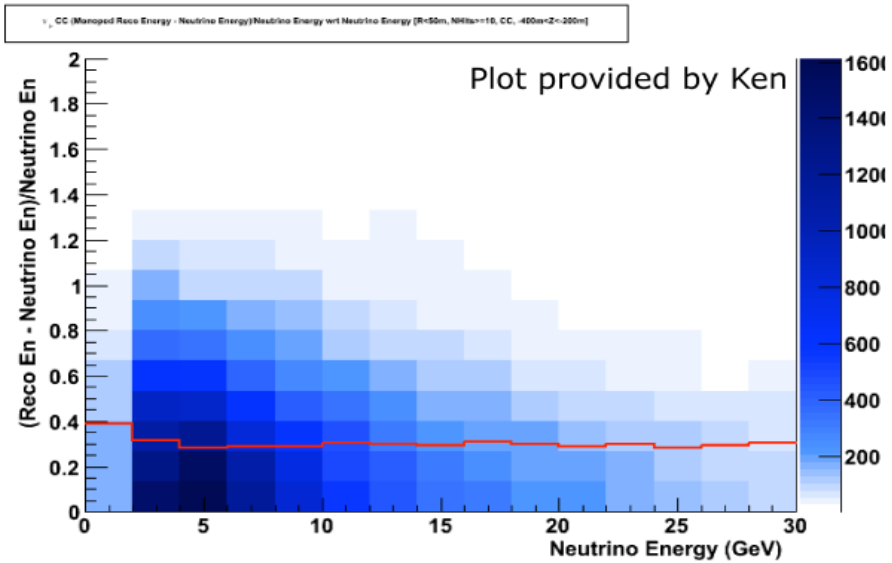


- Zenith angle resolution of less than 10° for most events
- Inner Gaussian contains about 57% of the events

Energy resolution of neutrino events reconstructed with HybridReco/Multinest (bottom left) and Monopod (bottom right)



Red line shows median value of the resolution



Atmospheric ν-flux and event selection

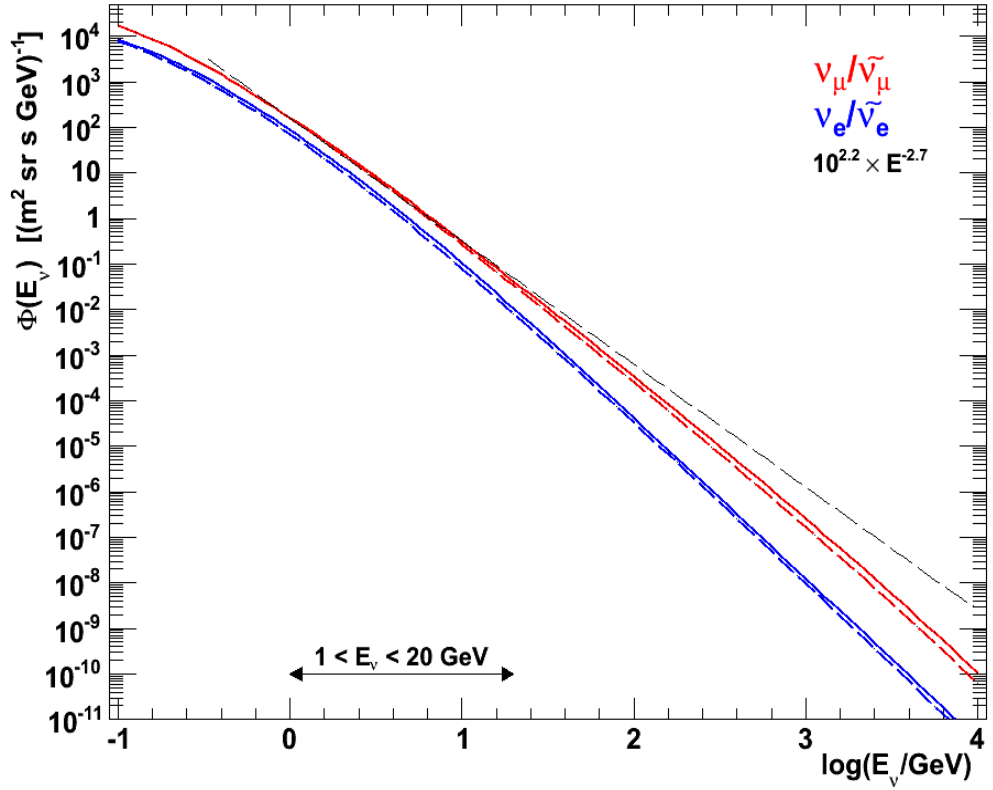
Atmospheric neutrino flux ("neutrino beam"):

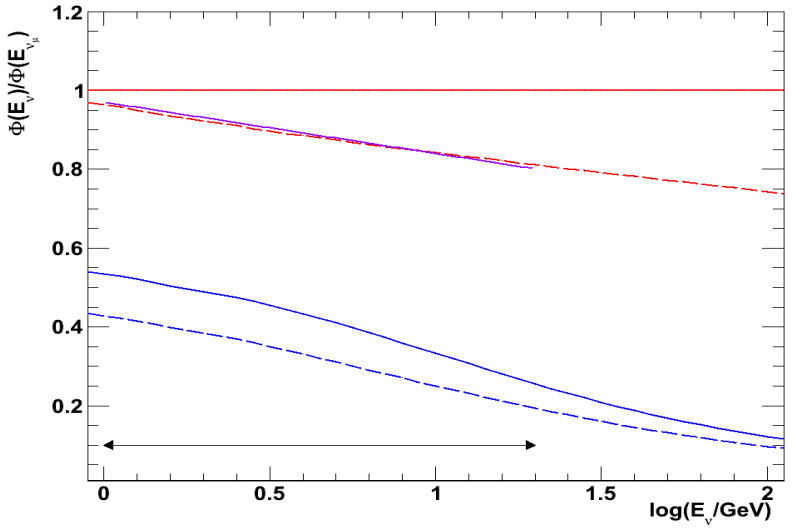
M. Honda et al. Phys. Rev. D 83, 123001 (2011) [arXiv:1102.2688]

"Improvement of low energy atmospheric neutrino flux calculation using the JAM nuclear interaction model"

HKKM fluxes: *http://www.icrr.u-tokyo.ac.jp/~mhonda/nflx2011/index.html*

6 sites: Frejus, Gran Sasso. INO, Kamioka, Soudan, Sudbury





Atmospheric-ν flux content (normalized to ν_μ-flux)

DESY

ν-event separation (PID)

- ν_μ-CC events ("track like") at low energy (E < ~20 GeV) will be contaminated with ν-NC and electron and tau neutrino CC ("cascade") like events. PID-methods could help to separate these events.

- Method based on the "superluminal" hits for the separation of track and cascade type neutrino events studied in PSU.
(talk by Ty. DeYoung)

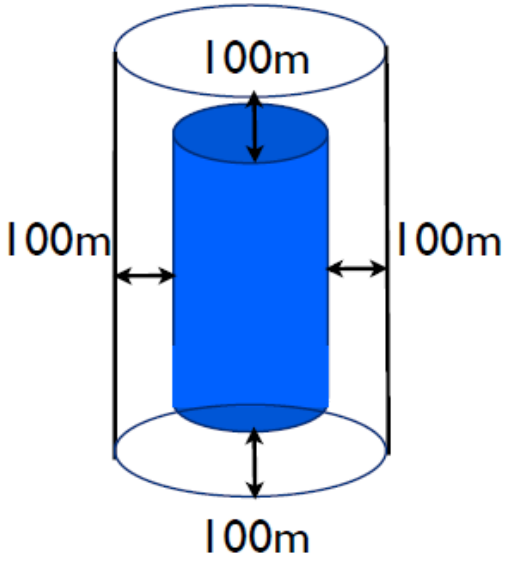
- Another method is based on the variables from collider experiments for PID in the DeepCore/PINGU.
Currently under development in NBI by M.Jørgensen.

Current PINGU MC data

- All PINGU MC data sets produced with GENIE.-GEANT-CLSIM* (/data/sim/PINGU/2012/triggered/GENIE-in-ice) are copied and stored at DESY. (* Ken Clark, GPU/WestGrid system)

- Largest statistics of simulated data: v15 (40 str., 60 PDOM)
  neutrino energy range: 1-80 GeV, E^{-2}

	ν_e	ν_μ	ν_τ
Simulated($x10^8$)	3.75	8.0	3.75
Triggered ($x10^6$)	0.428	1.250	0.102



Simulation volume for PINGU events

- All triggered events from PINGU v15 are reconstructed with "standard" reconstruction ("PINGU L2" including SANTA, Monopod)

Summary and outlook

- Level2 reconstruction scripts for PINGU MC events based on standard IceCube/DeepCore algorithms and few new methods were set and tested. The PINGU reconstruction is working at different sites in USA/Canada and Europe.

- Current algorithms used in the reconstruction of ν-direction (SANTA) and E_ν (Monopod) provide sufficient angular and energy resolution for the NHM determination .

- New promising methods for the neutrino direction and energy reconstruction with improved resolutions were presented at the IceCube meeting last week.

- Work is in progress to adapt IceCube tables and algorithms developed for high energy neutrinos evens to lower energies..

The IceCube Collaboration & PINGU

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Fonds de la Recherche Scientifique (FRS-FNRS)
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