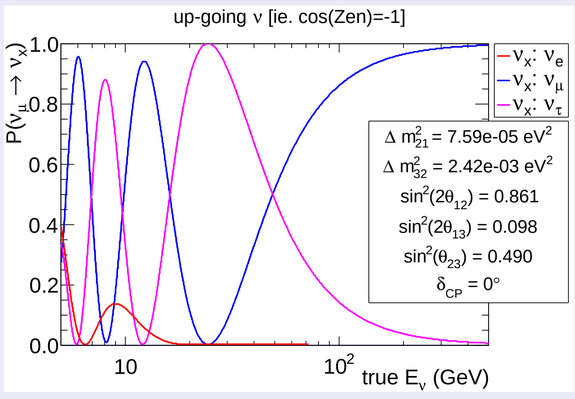
Sensitivity to ν_τ appearance with DeepCore and PINGU

João Pedro Athayde Marcondes de André* for the IceCube-PINGU Collaboration
Penn State University, Department of Physics, University Park, PA 16802
*jpa14@psu.edu

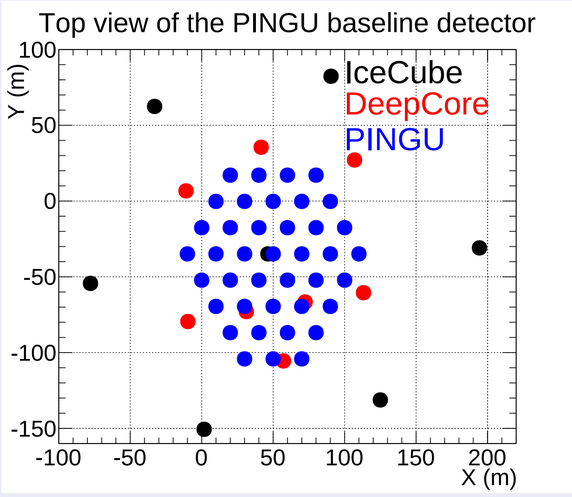
Neutrino oscillations



- At E_ν ~25 GeV and up-going ν:
  - Small $\nu_\mu \to \nu_e$ oscillation probability
  - ν_μ disappearance close to maximal
  - First ν_τ appearance maximum
- Decreasing Zenith angle will reduce the first oscillation maximum energy
- Decreasing E_ν, the ν_τ CC cross-section rapidly decreases

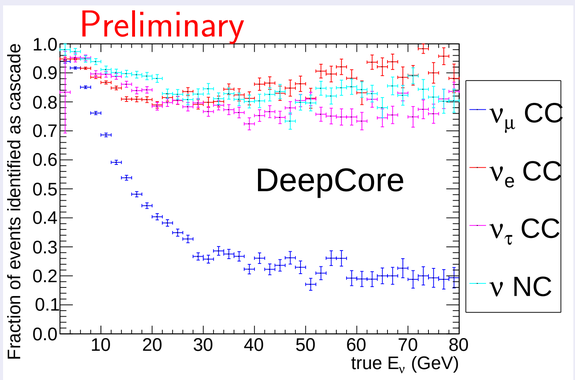
DeepCore vs PINGU

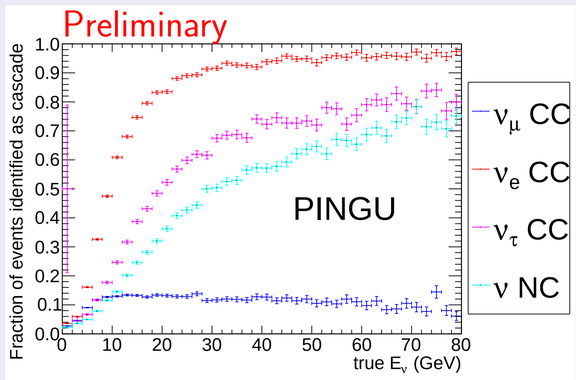
- PINGU [1]: upgrade to IceCube/DeepCore
  - lower energy threshold from ~15 GeV to ~5 GeV
  - PINGU baseline geometry: 40 strings, 20 m horizontal string spacing, 60 optical modules/string
- Why ν_τ appearance signal in PINGU is clearer than DeepCore?
  - at ν_τ appearance energies:
    - ★ improved reconstruction quality
    - ★ improved particle identification (PID)



Event selection

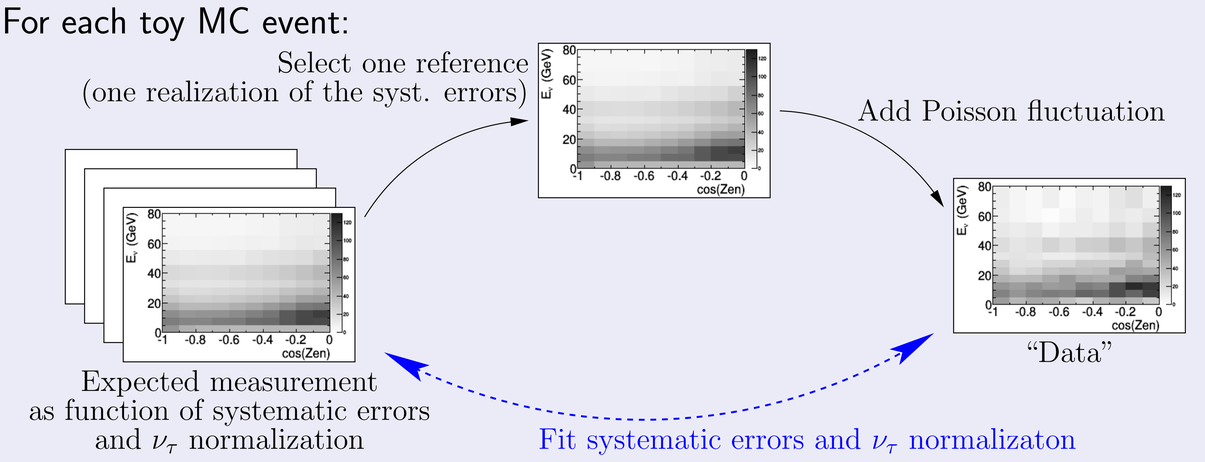
- Reject atmospheric μ
  - For DeepCore, use similar cuts as for ν_μ disappearance analysis [T1]
  - For PINGU, use same cuts as for ν mass hierarchy (NMH) analysis [1, P075]
- Select cascade-like events (reject ν_μ CC and ν_τ CC with muonic τ decay [17%])
  - Use BDT classification [1, P368] to distinguish tracks and cascades
  - PID optimization different for DeepCore and PINGU





Method to estimate sensitivity for ν_τ appearance

- Use toy MC to simulate possible measurement
- For each toy MC event:



- Fitting procedure uses Gaussian priors for systematic errors and flat prior for ν_τ normalization (between -0.5 and 1.5)
  - Unphysical region added to improve minimizer behaviour

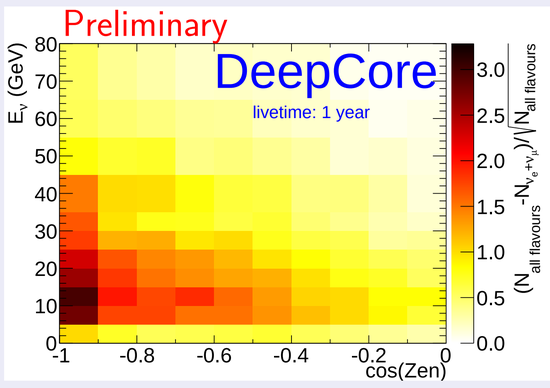
References

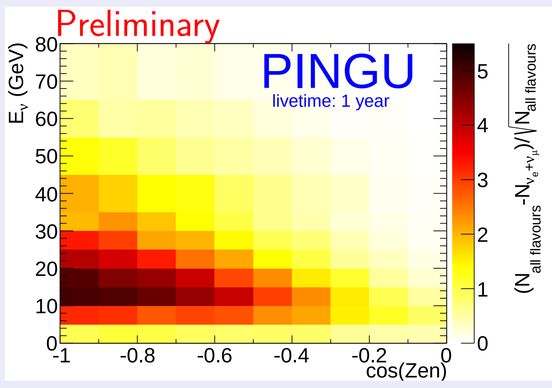
[1] M. G. Aartsen, et al. [IceCube-PINGU Collaboration], arXiv:1401.2046 [physics.ins-det].
[2] M. Honda, et al., Phys. Rev. D 75, 043006 (2007) [astro-ph/0611418].
[3] G. Giordano, O. Mena and I. Mocioiu, Phys. Rev. D 81, 113008 (2010) [arXiv:1004.3519 [hep-ph]].

Related posters

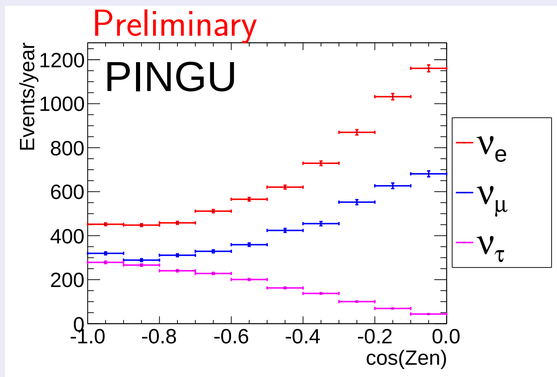
[P368] T Arlen, JPAM de André, et al., *Event reconstruction and particle identification for low energy events in DeepCore and PINGU*
[P075] L Schulte, T Arlen, S Böser, et al., *Calculating PINGU's Sensitivity to the Neutrino Mass Hierarchy*
[P162] M Jurkovic, et al., *New calibration methods for IceCube, DeepCore and PINGU*

Signature of ν_τ appearance





- Maximal significance for **up-going** events with reconstructed energy of 10-20 GeV
- Difference between 10-20 GeV and 25 GeV due to outgoing ν from τ decay
- Background events concentrated at horizon (ν flux larger at horizon)

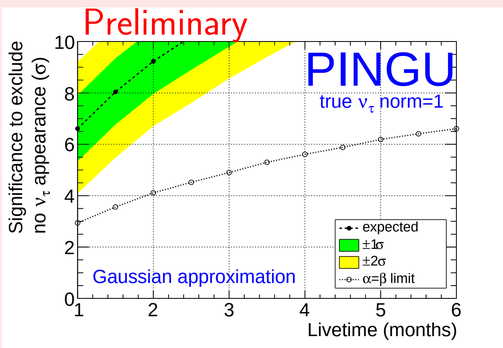


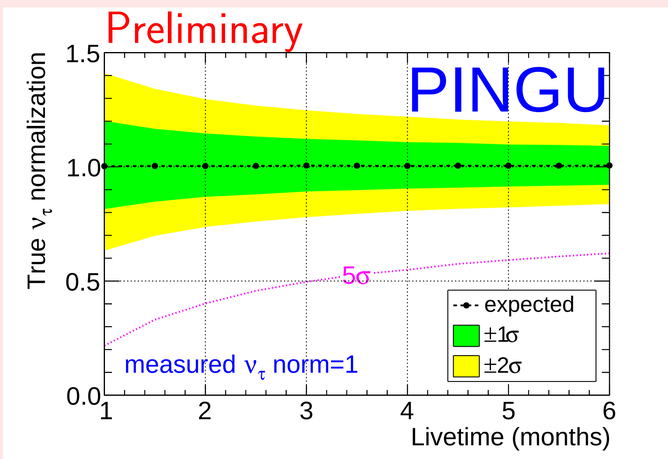
Flavour	Exp. number of events/year/10^3 DeepCore	PINGU
Background: $\nu_e + \nu_\mu$	36.0	11.2
Signal: ν_τ	2.1	1.7
Signal/Background	6%	15%

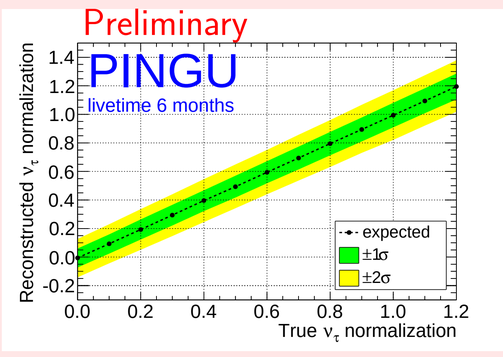
Systematic errors considered for PINGU

	Gaussian prior	reference
ΔM^2	$(2.42 \pm 0.08) \cdot 10^{-3}$ eV^2	NMH [1, P075]
$\sin^2(\theta_{23})$	0.490 ± 0.023	NMH [1, P075]
Normalization	±15%	NMH [1, P075]
ν_e/ν_μ flux normalization	±2%	Honda'06 [2]
$\bar{\nu}/\nu$ cross section normalization	±15%	NMH [1, P075]
Spectral index of ν_μ flux	±0.05	ν_μ disappearance [T1]
Energy scale	±2%	NMH [1, P075]

Expected sensitivity for PINGU (with systematic errors)







- 5σ exclusion of no ν_τ appearance expected with 1 month of data
- ~10% precision in ν_τ normalization after 6 months

Status for DeepCore

- Finalizing atmospheric μ rejection cuts
- Optimize analysis to improve expected sensitivity
  - optimize PID selection
  - constrain systematic errors with data outside ν_τ appearance region
  - refine treatment of systematic errors using full detector simulation to consider ice model uncertainty and optical module efficiency
- Will perform analysis with 3 years of the full IceCube data

Related presentations

[T1] JP Yanez, *Atmospheric Results from IceCube/DeepCore*
[T2] D Grant, *Future Atmospheric Measurements with PINGU*

PENNSTATE 1855

PSU ν_τ appearance

PINGU Letter of Intent

NEUTRINO2014
XXVI International Conference on Neutrino Physics and Astrophysics
June 2-7, 2014, Boston, U.S.A.