

European Strategy for Neutrino Oscillation Physics – II
CERN, 14-16 May 2012

PINGU – An IceCube extension for low-energy neutrinos

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PINGU Collaboration
14.05.2012

ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS



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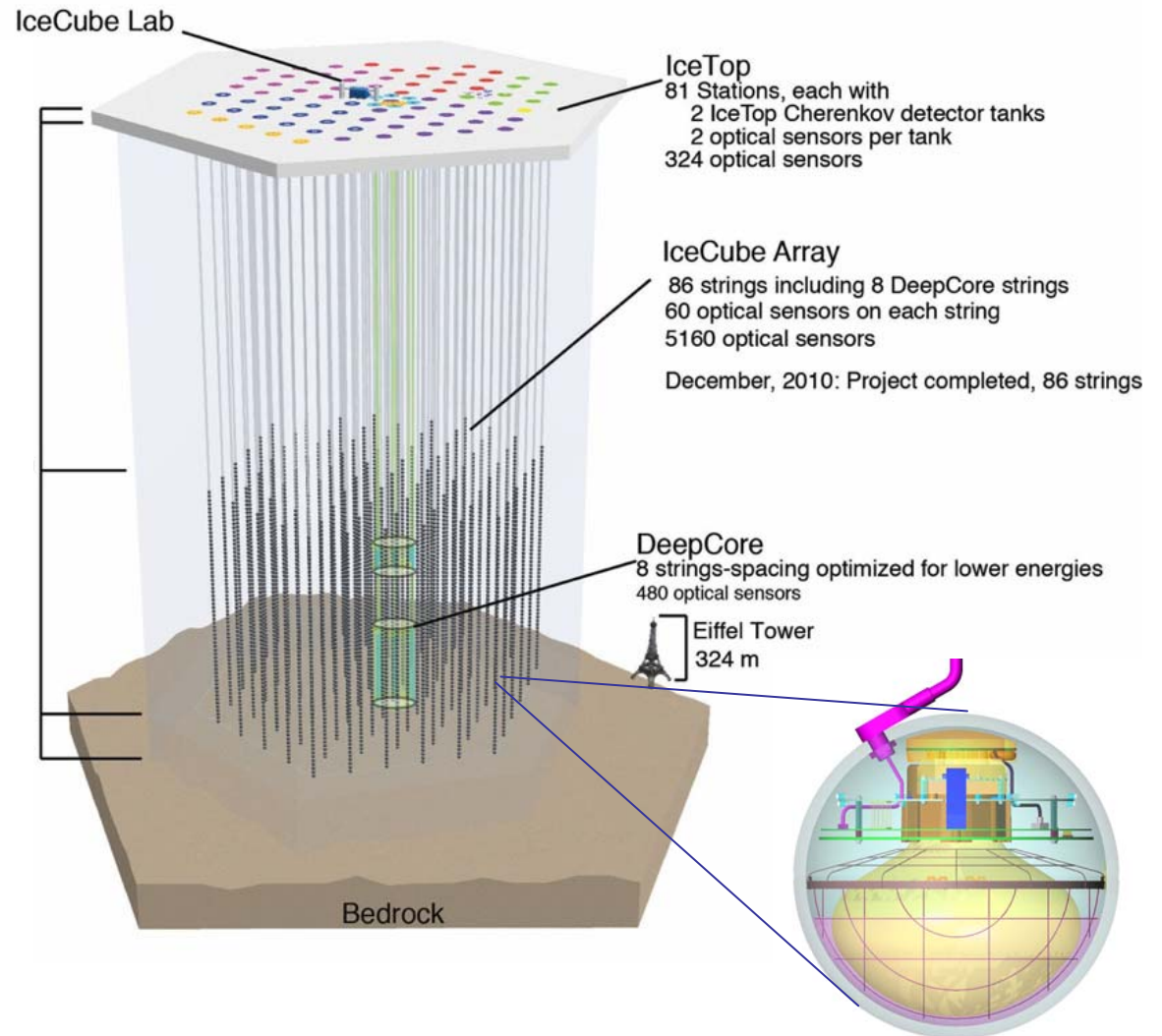


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IceCube as of May 2012

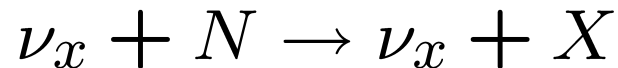
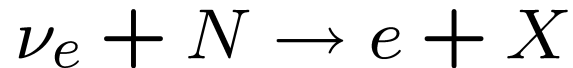
- 86 strings altogether
 - 125 m horizontal spacing
 - 17 m vertical spacing
 - One 10-inch PMT per Optical Module
- Deep Core
 - Densely instrumented region
 - clearest ice
 - atmospheric muon veto by IceCube
 - 15 strings, 6 of them:
 - 72 m (horizontal)
 - 7 m (vertical)
 - High-QE PMTs
- First Deep Core results emerging



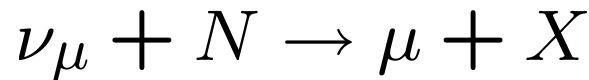


A first Deep Core result

- Identification of cascades, mainly from

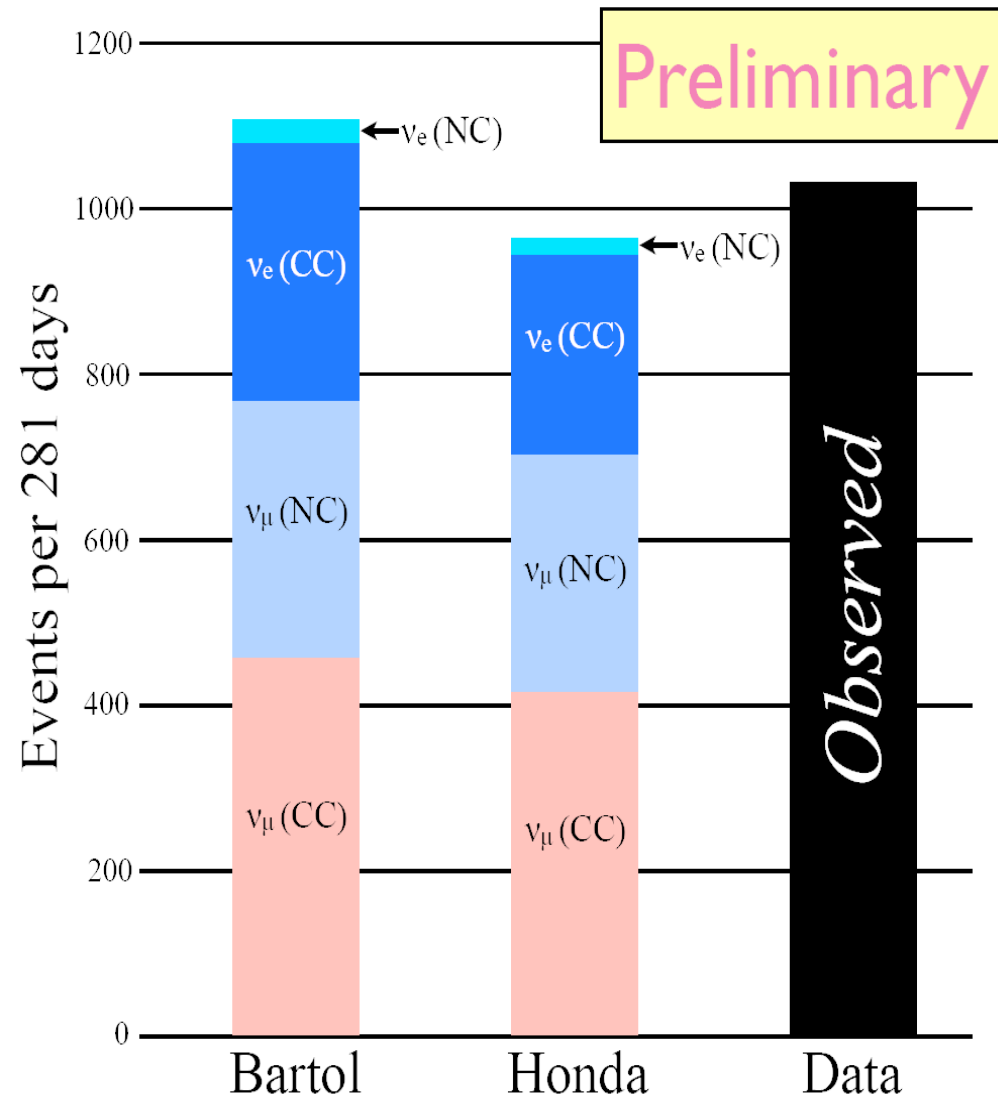


- Main background:



with short μ track

- Very difficult in IceCube
- Success in Deep Core!
(see arXiv:1201.0801)





What we learn from Deep Core

- A close look at neutrino events above $O(10 \text{ GeV})$; event identification and reconstruction possible.
- The atmospheric muon veto works well.
- New physics results (see also arXiv:1112.1053):
 - Flavour composition of atmospheric neutrinos
 - Neutrino oscillations (ν_μ disappearance)
 - Neutrino oscillations (ν_τ appearance)
 - ...

In the
pipeline

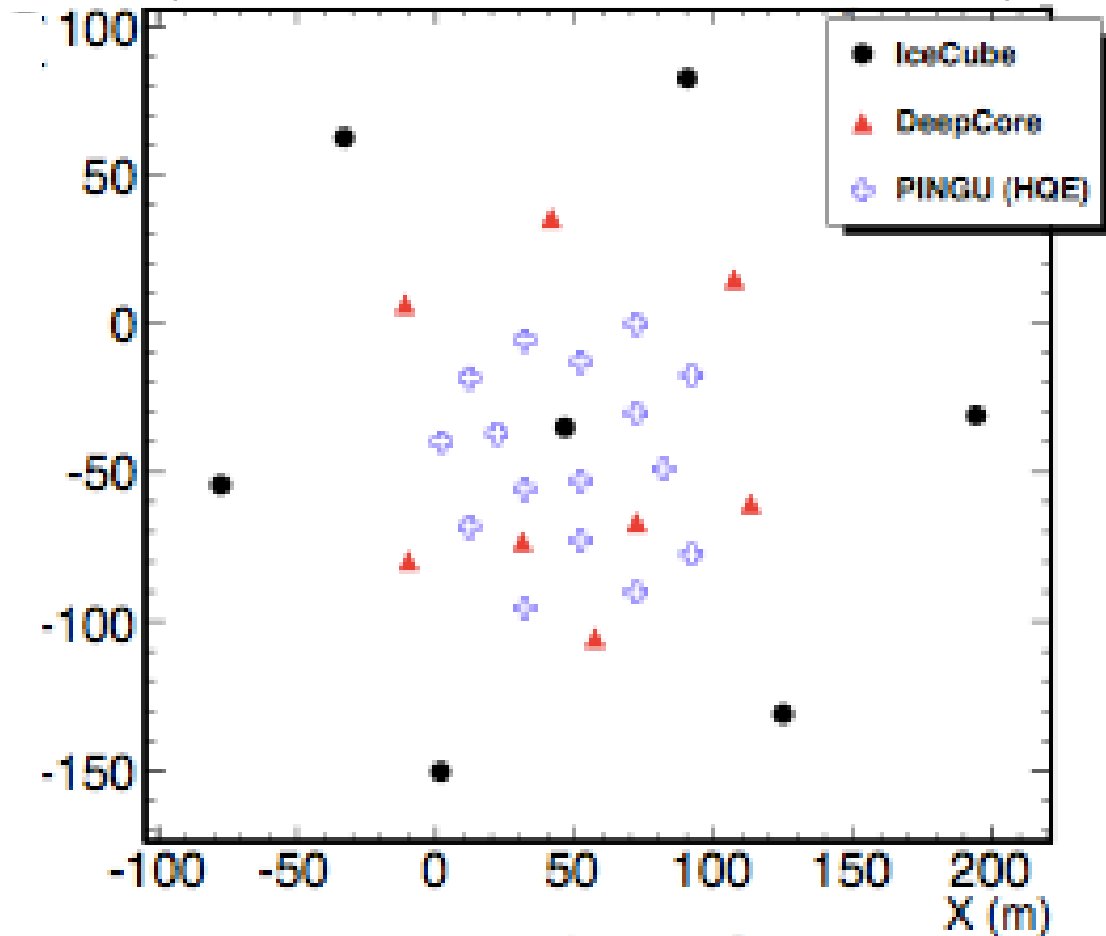
Can we build on this success and
go one step further?
→ The PINGU project



The PINGU fact sheet

- Phased IceCube Next-Generation Upgrade
- Add 20 strings in Deep Core region
- Expected energy threshold at 1 GeV
- R&D opportunity for future developments
- IceCube plus further groups

PINGU geometry
(more compact version also studied)





Physics opportunities with PINGU

Theorists are very interested:

Alexei Smirnov

Walter Winter

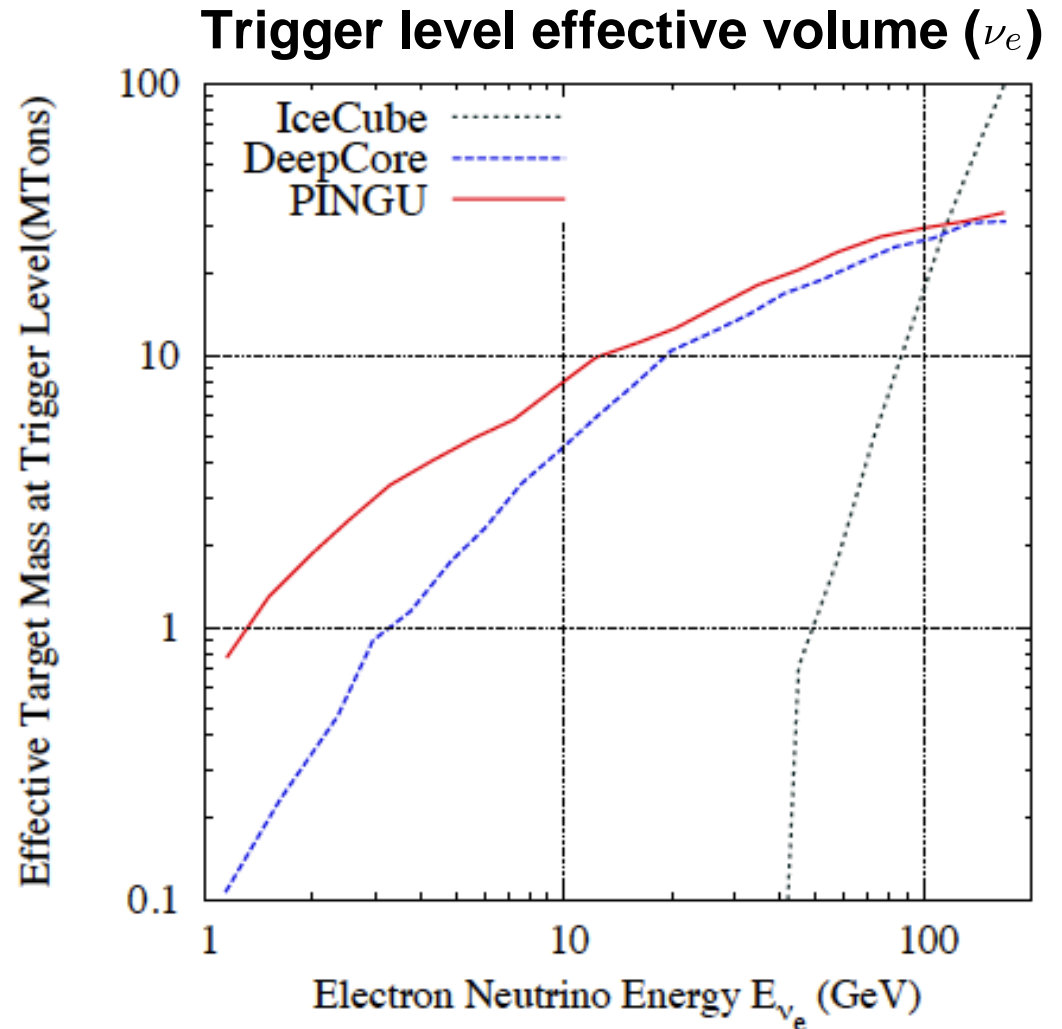
...

- Neutrino physics:
 - Oscillations (in particular deviation of 2-3-mixing from maximal)
 - Mass hierarchy
 - Sterile neutrinos
 - Additional option: Neutrino beam-line to PINGU
 - CP violation ??
- Indirect Dark Matter searches
- Supernova neutrinos
- ...



Sensitivity example

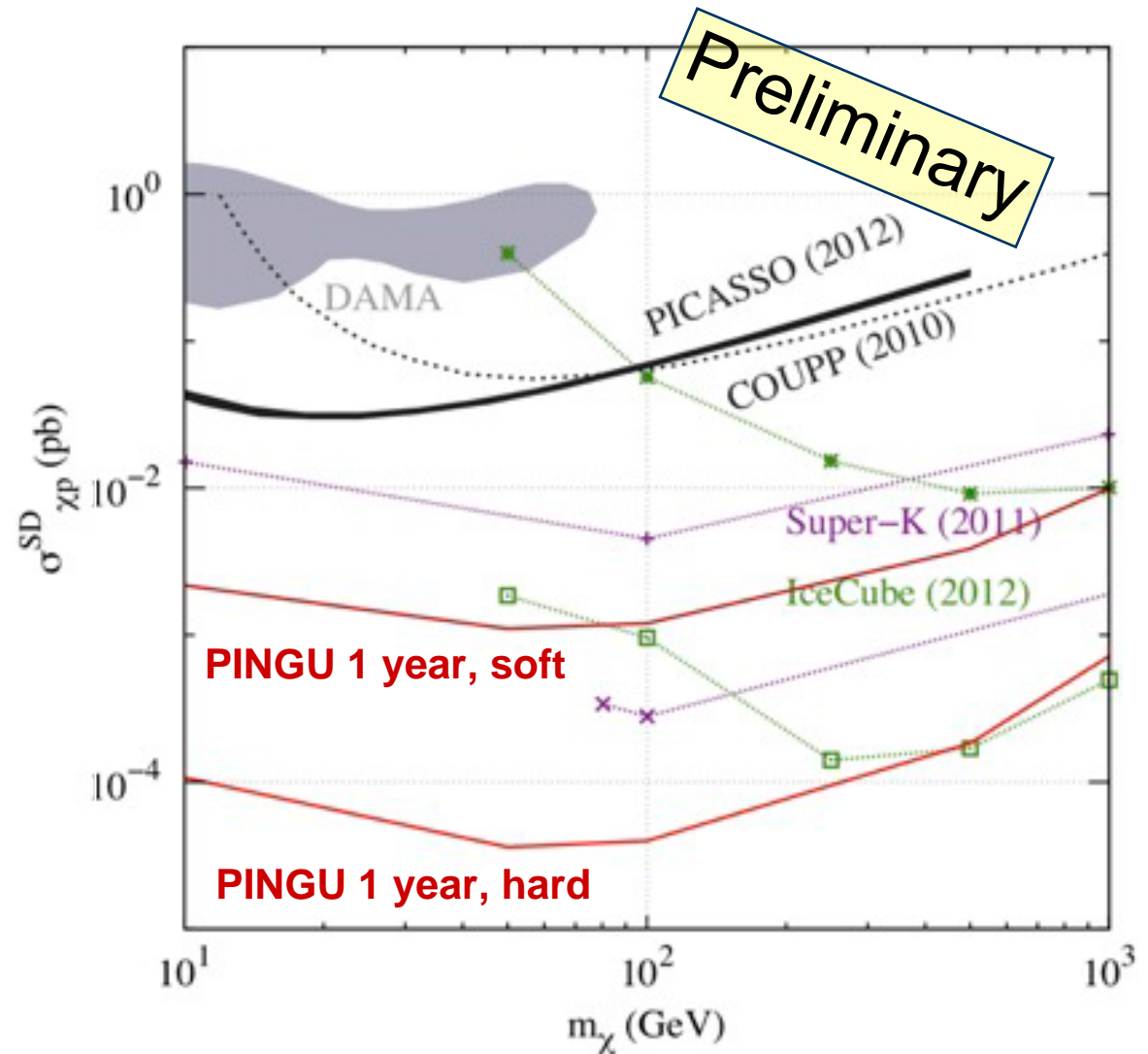
- Study sensitivity to ν_e
- Particularly important for WIMP searches (low atm. background)
- Improved trigger level sensitivity compared to Deep Core (factor 2-10 at 1-10 GeV)
- Even more at analysis level
- Megaton-scale effective volume





WIMP searches

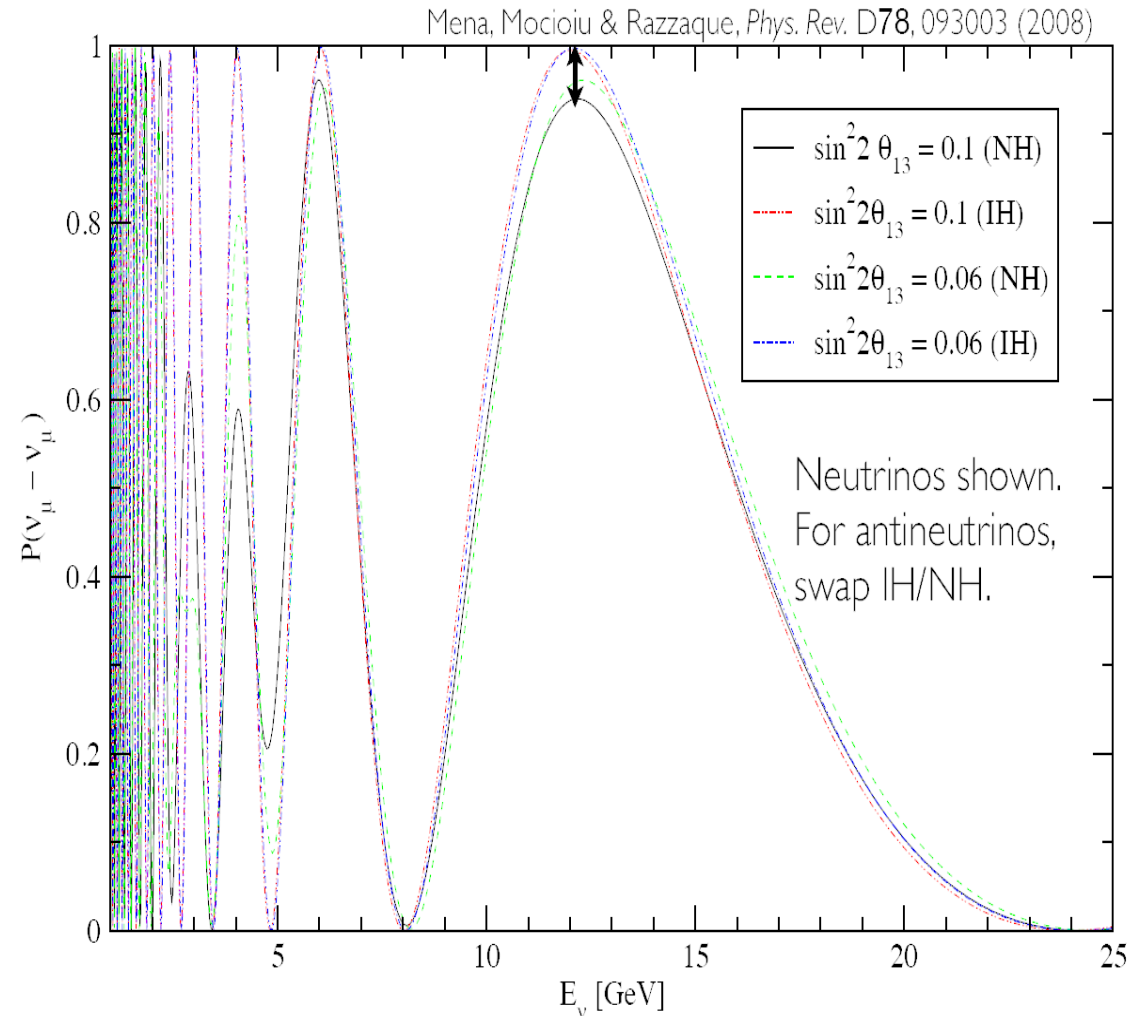
- Expected exclusion limits for spin-dependent cross section
- Assumptions see C.Rott, JCAP(2011)029
- Atmospheric muons not yet included
- Low-mass WIMP region in reach





Mass hierarchy (atmospheric ν)

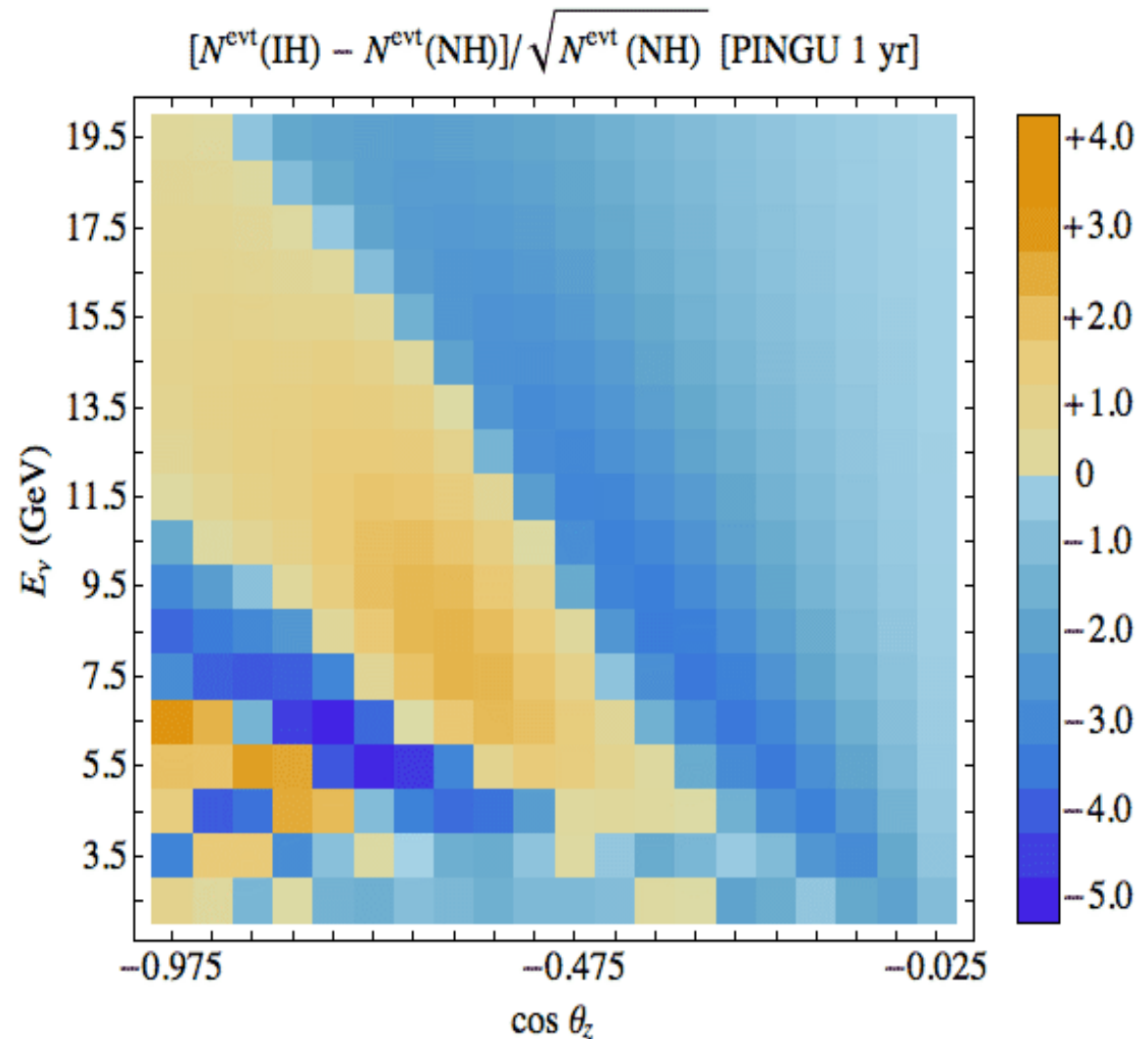
- MSW effect in Earth induces $\nu/\bar{\nu}$ difference in ν oscillations
- Note: first maximum for $\mu \rightarrow \mu$ is at 12 GeV for $L = d_{\text{Earth}}$
- Could be measurable since $\sigma(\nu) \approx 2\sigma(\bar{\nu})$ at these energies
- Advanced analysis: “oscillograms” (Alexei Smirnov)





Mass hierarchy oscillogram

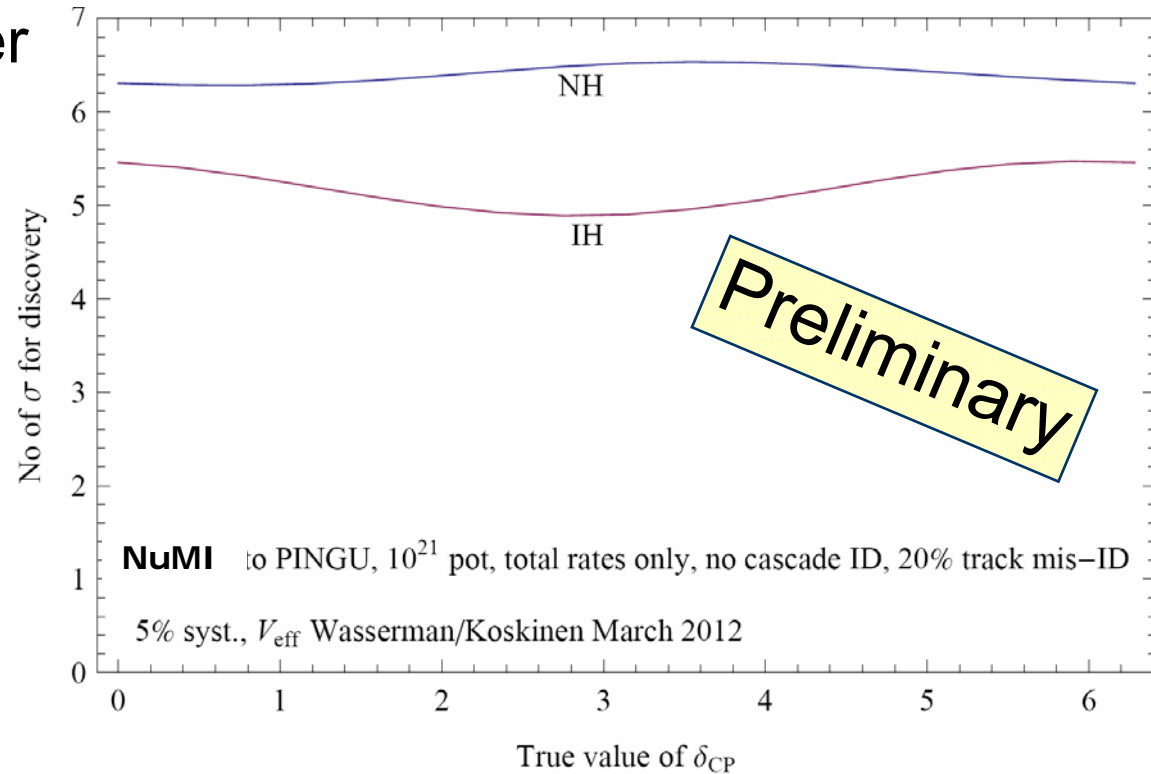
- Expected signal significance in energy vs. zenith
- Required energy and directional resolution appear to be realistic
- Analysis and plot courtesy of Alexei Smirnov





Mass hierarchy with a accelerator beam

- Idea by Walter Winter
- Accelerator beam (beta, super, ...) provides clean initial state
- Hierarchy measurement could be possible using event counts only
- Requires beam pointing to the South Pole

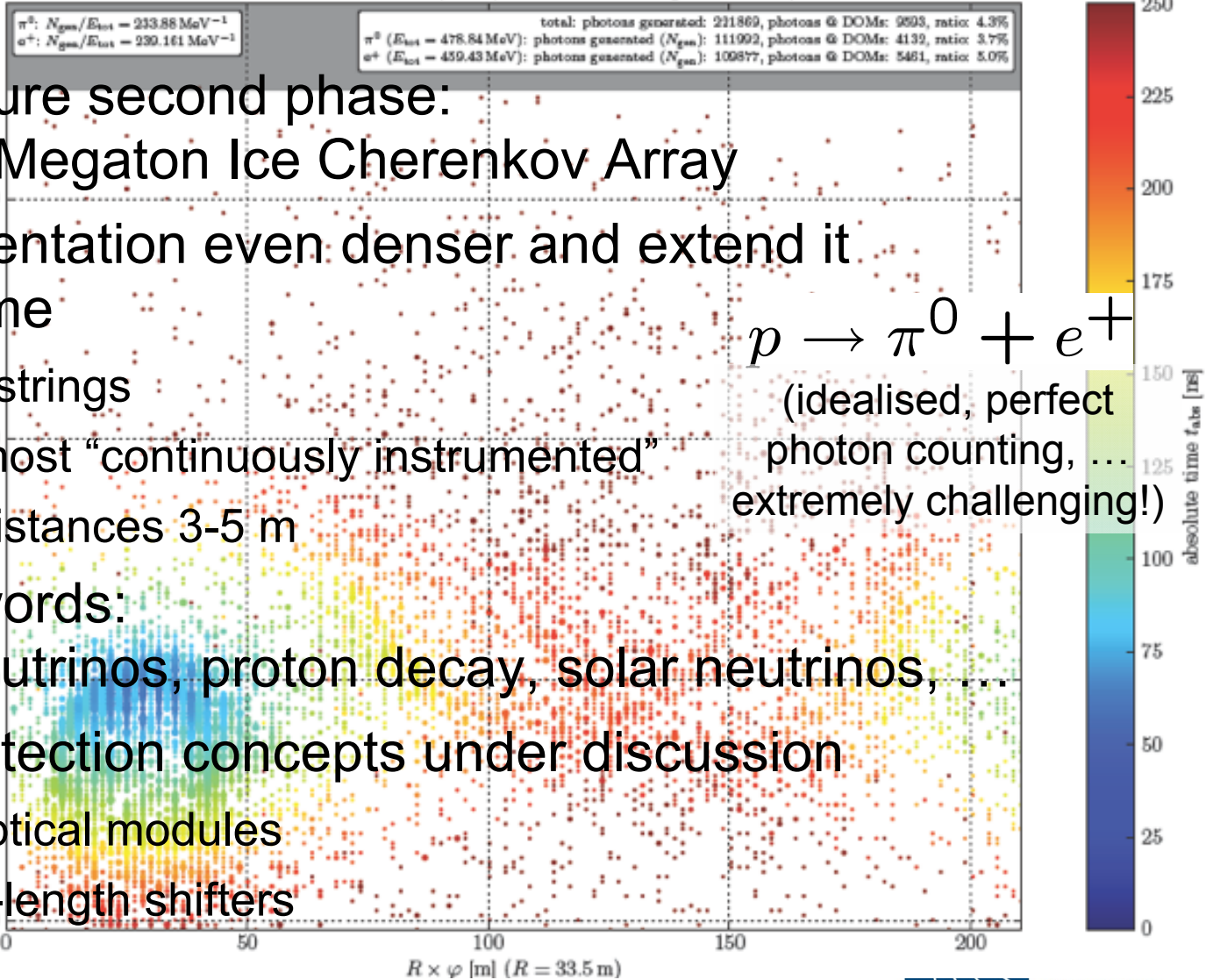




MICA – a long-term vision

(run 1 event 2) perfect photon counting (all photons $\lambda \in [265 \text{ nm}; 675 \text{ nm}]$)

IceCube coordinates, ref. depth ($z = 0$) is 1948.07 m; $N_{\text{string}} = 40$; $d_{\text{DOM};z} = 1 \text{ m}$; $N_{\text{DOM}} = 7040$

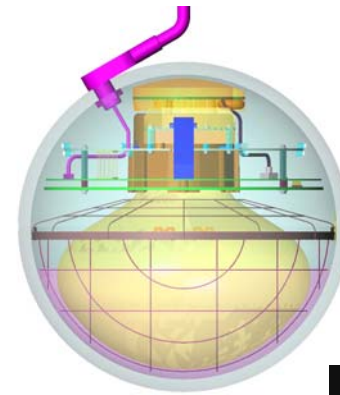


- Vision of a future second phase: MICA = Multi-Megaton Ice Cherenkov Array
- Make instrumentation even denser and extend it to larger volume
 - Several 100 strings
 - Vertically almost “continuously instrumented”
 - Inter-string distances 3-5 m
- Physics key words: Supernova neutrinos, proton decay, solar neutrinos, ...
- New photo-detection concepts under discussion
 - Multi-PMT optical modules
 - Use of wave-length shifters

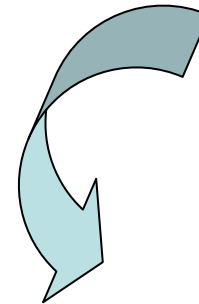


R&D in PINGU

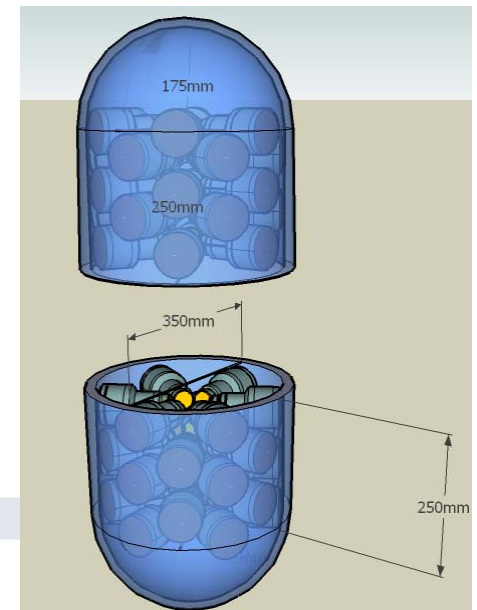
- PINGU offers opportunities for R&D towards MICA
- Example: Optical Module with many small PMTs
- Advantages:
 - Increased photocathode area per OM
 - Precise single-photon counting
 - Directionality
 - Intra-OM coincidences
- Prototype in preparation



KM3NeT:
31 3" PMTs
in 17" sphere



PINGU:
3"-PMTs in
cylindrical
vessel





Status and next steps

- Active collaboration, growing interest (IceCube plus further groups)
- Simulation studies are ongoing, need to be extended and refined
- Hardware aspects of PINGU construction are being investigated
- Letter of Intent for PINGU envisaged for fall 2012
- Proposal to funding agencies:
 - Coordination between partner countries
 - Likely in 2013
- ... meanwhile investigate MICA potential ...



Summary and Outlook

- The PINGU project targets at an extension of the Deep Core concept (even denser instrumentation in the deep clear ice)
- Neutrinos with energies as low as 1 GeV will be accessible
- Promising physics prospects:
Neutrino oscillations, mass hierarchy, WIMPS, ...
- PINGU will provide a platform for R&D activities towards a huge low-energy installation (MICA)
- Expected time line for PINGU:
2012 Letter of Intent;
2013 Proposal