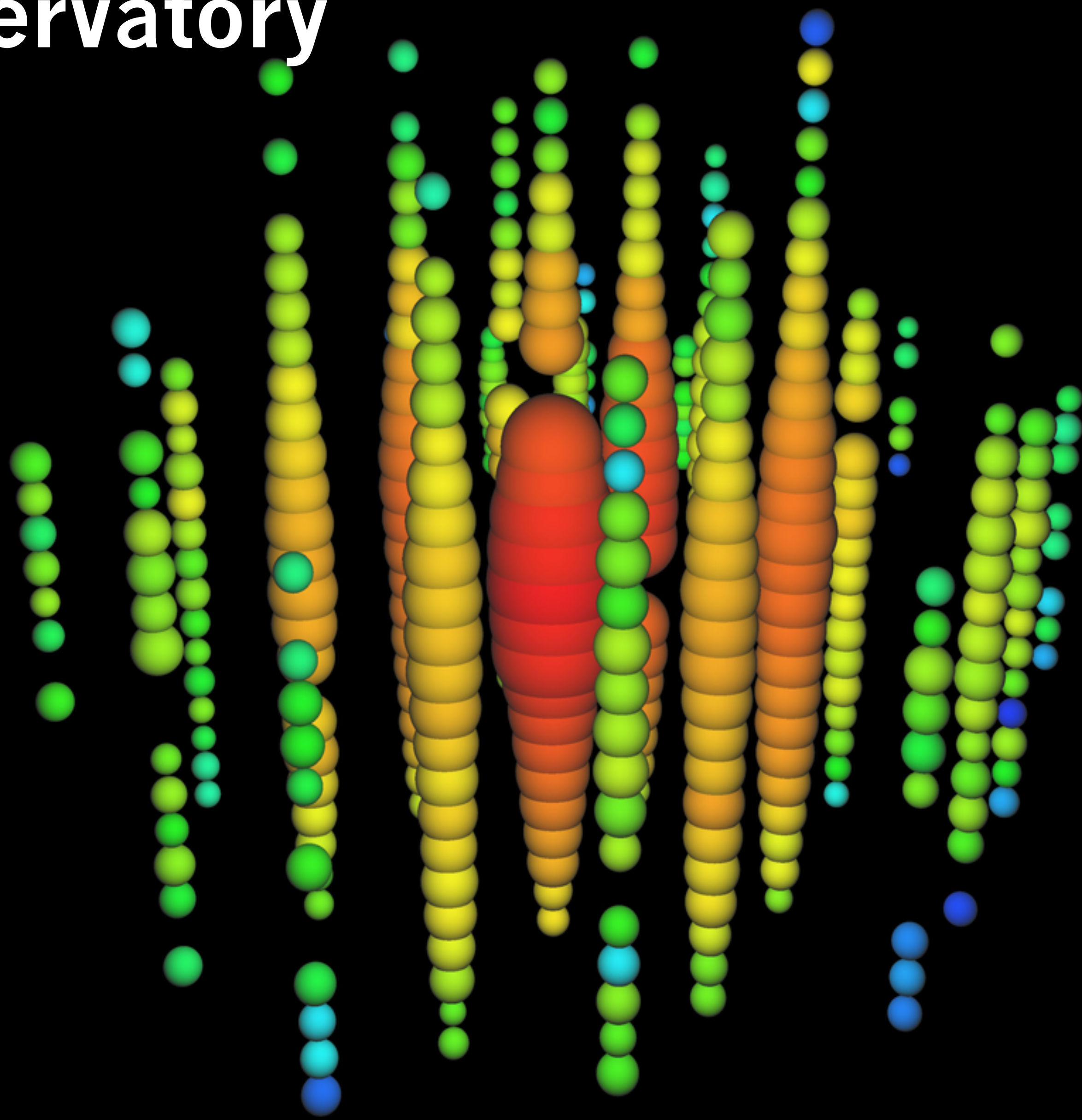
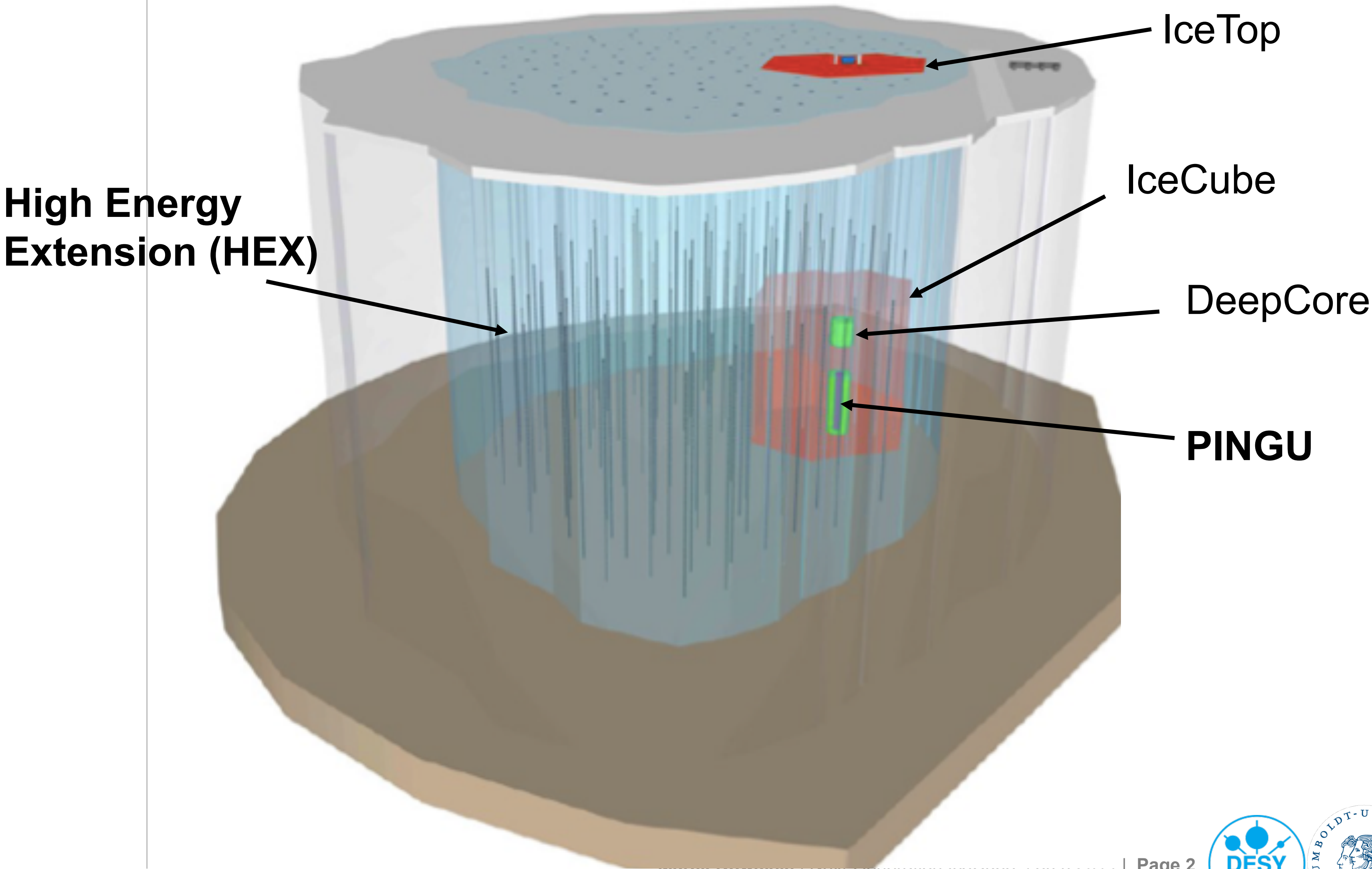
Next Generation IceCube Neutrino Observatory



Marek Kowalski
KIT, 30.9.2014

Next Generation IceCube (NGIC)



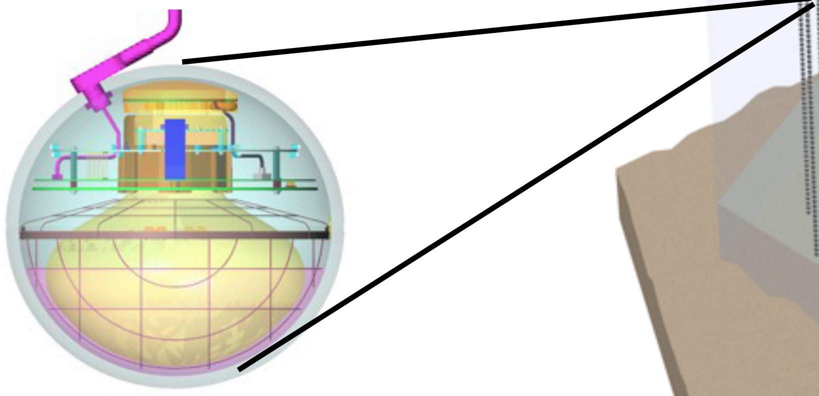
The IceCube Neutrino Observatory

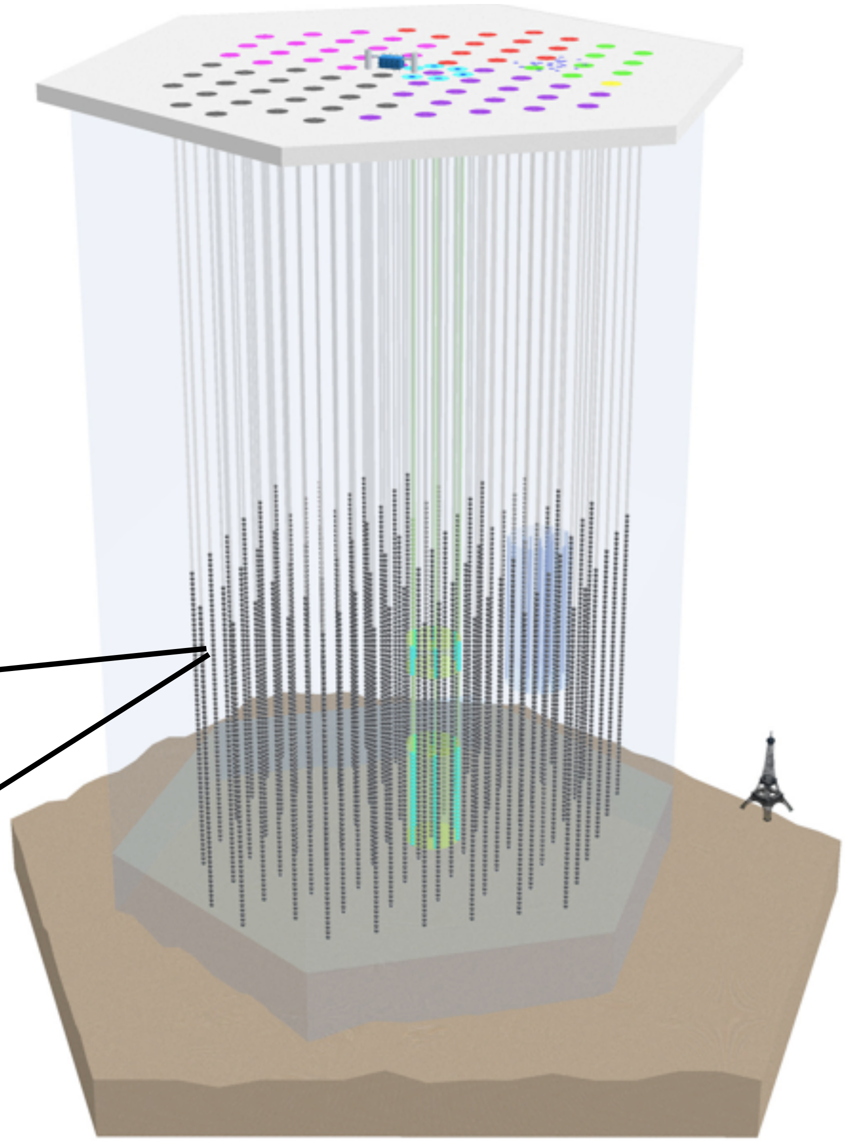
IceCube

- 86 Strings, 5360 DOMs
- E_{thresh} ~ 100 GeV

➔ astrophysical neutrinos

digital optical module (DOM)
housing 10 inch PMT



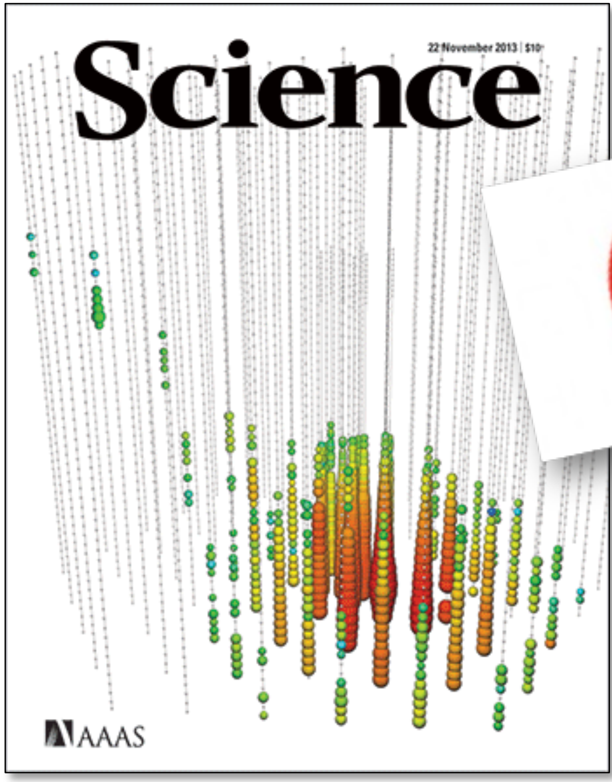


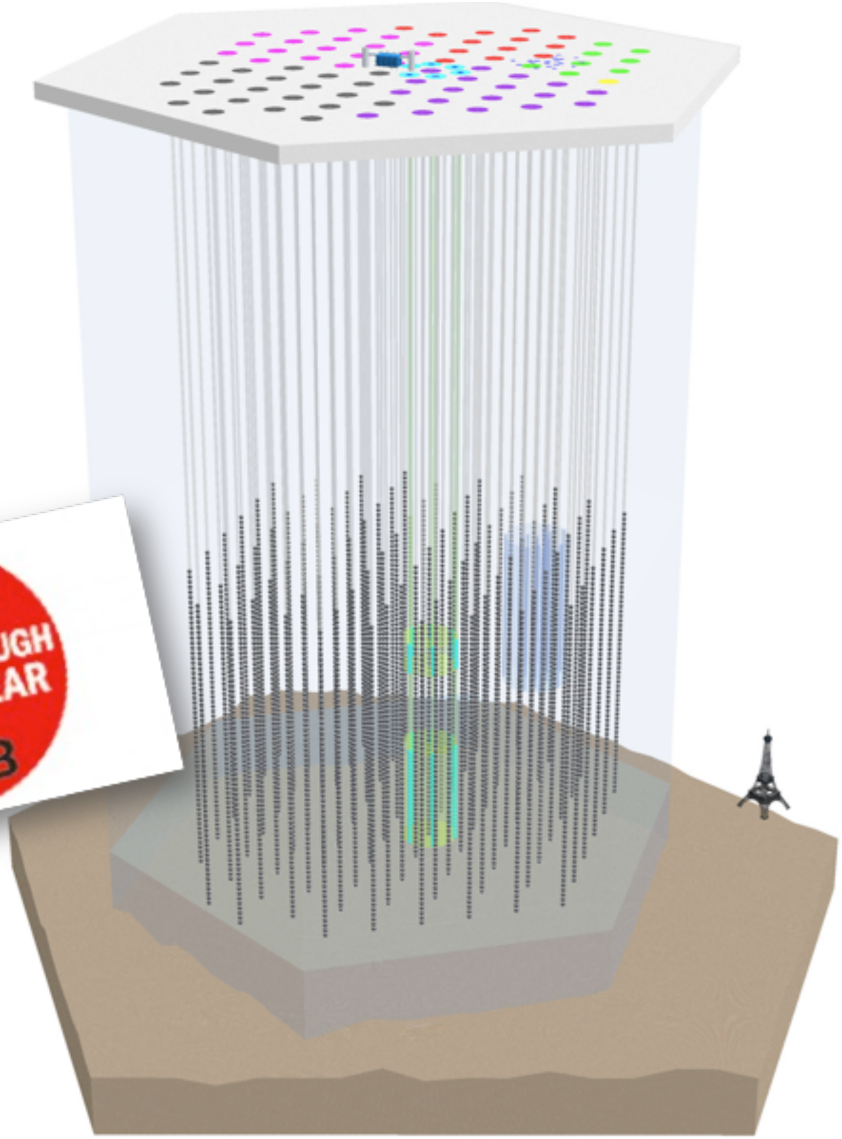
The IceCube Neutrino Observatory

IceCube

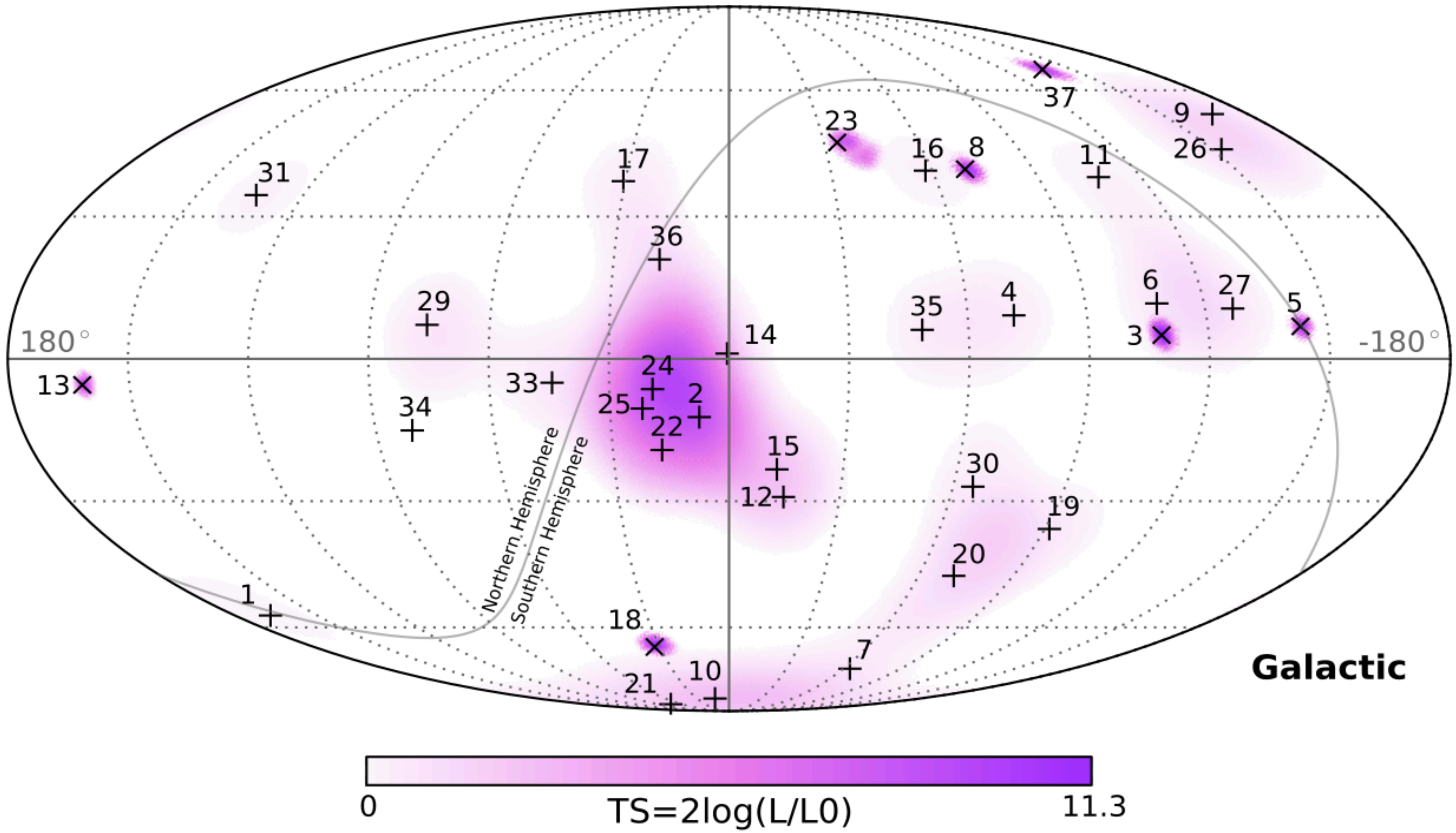
- 86 Strings, 5360 DOMs
- E_{thresh} ~ 100 GeV

➔ astrophysical neutrinos



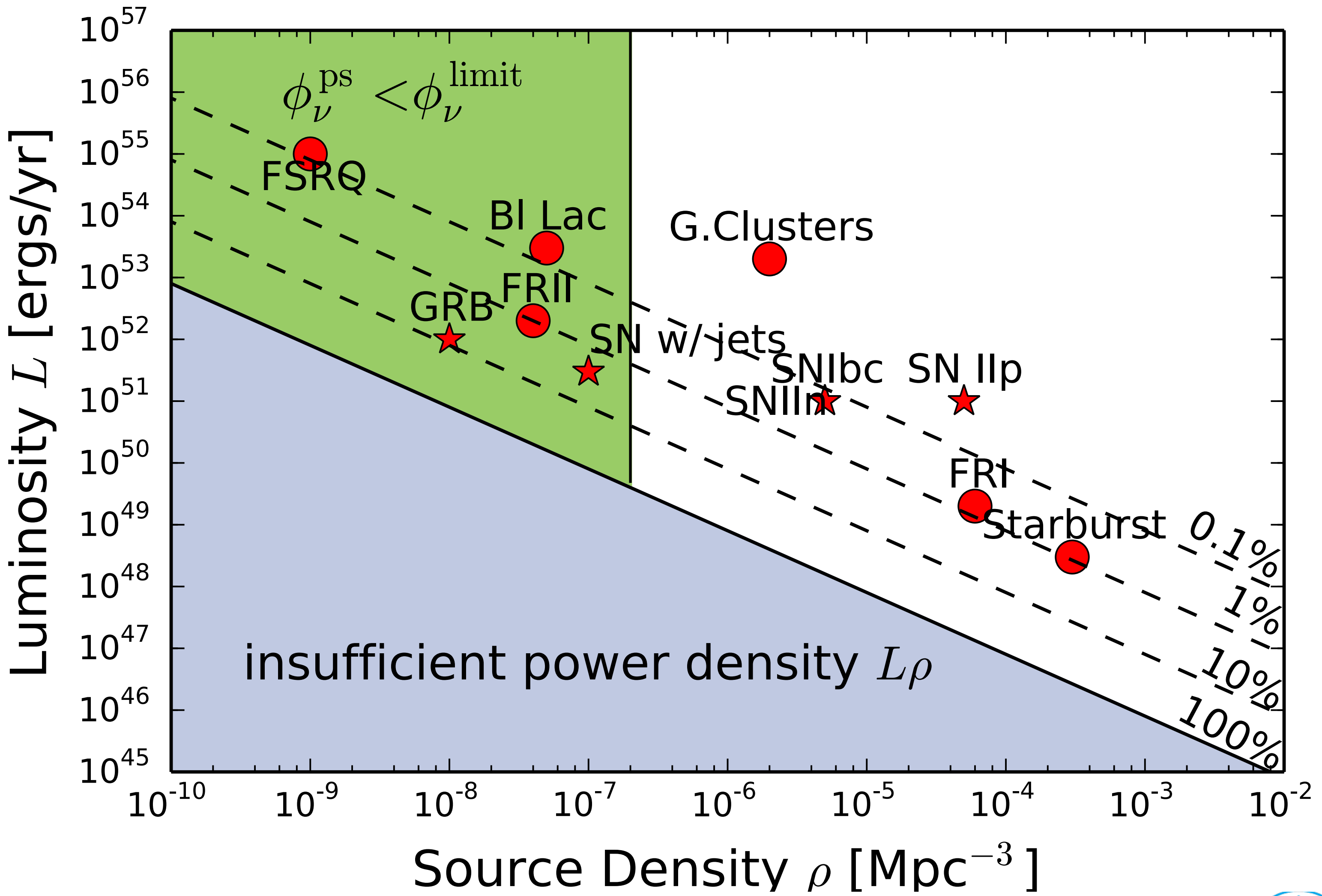


Extragalatic origin of cosmic neutrinos?

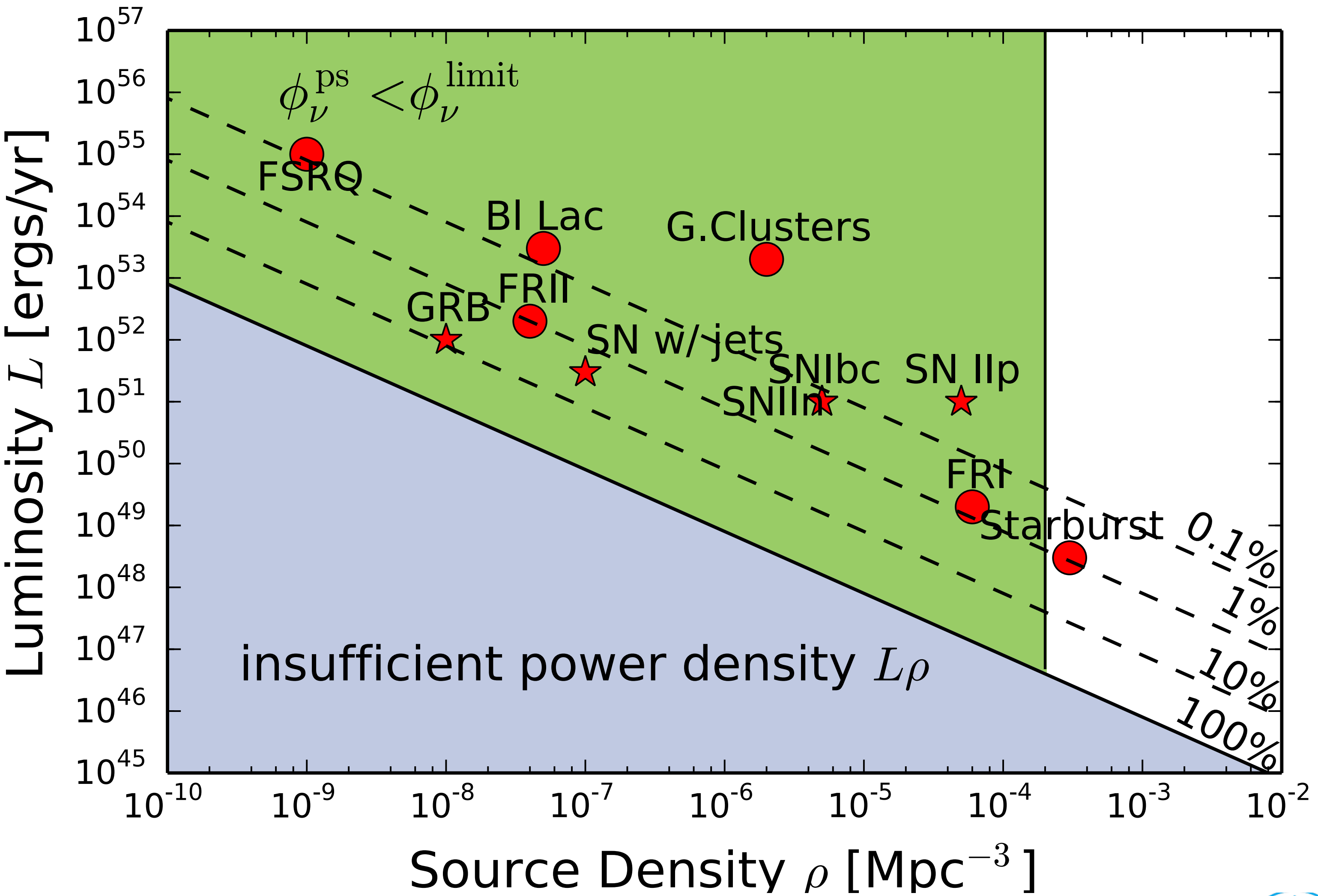


IceCube, PRL 2014

Current Sensitivity



Current Sensitivity x 10

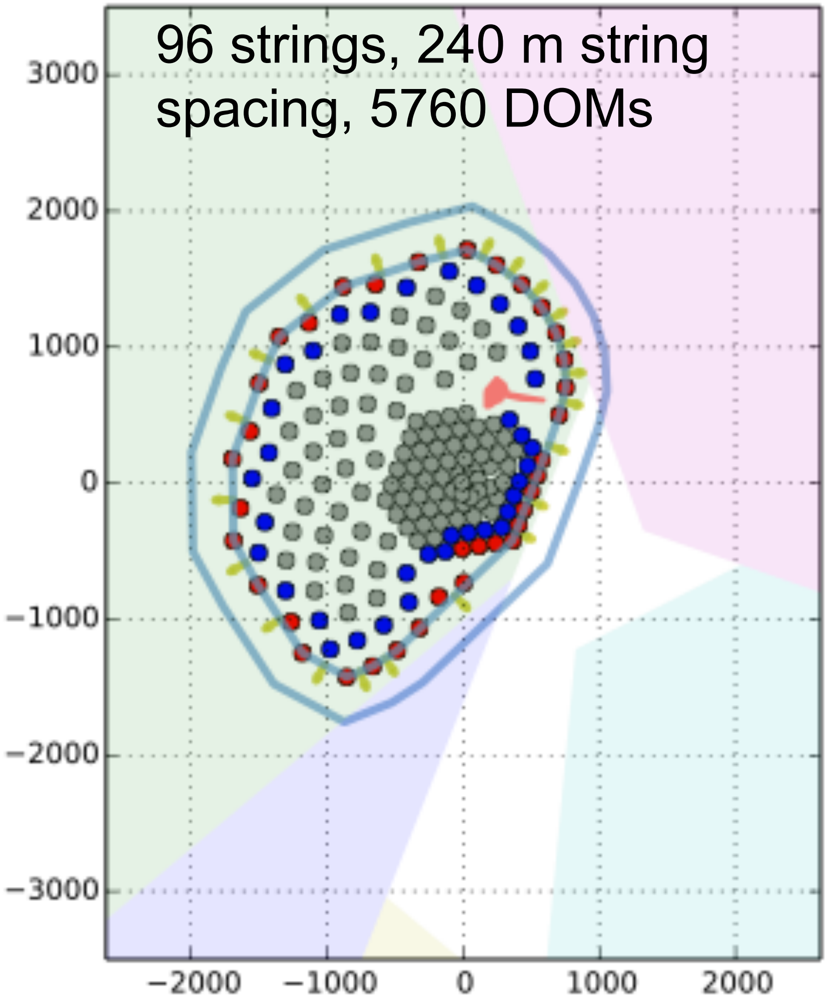


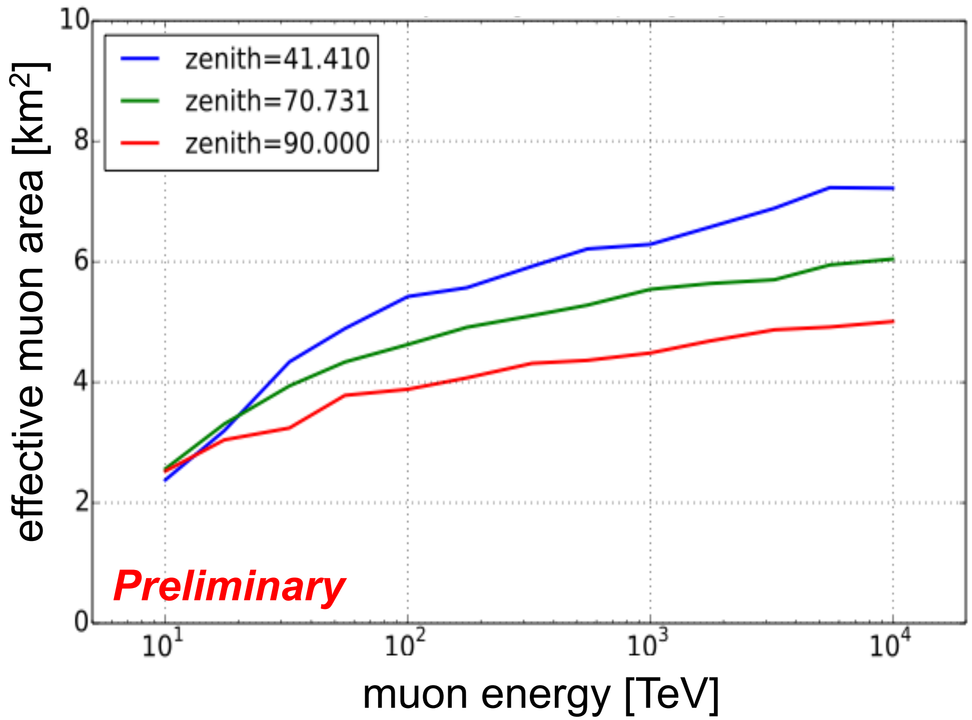
Current Sensitivity x 10

More science:

- ✧ Neutrino flavor composition
  - ⟶ probing the conditions at origin
- ✧ Spectral shape
  - ⟶ connecting to cosmic rays
- ✧ Cosmogenic neutrinos
  - ⟶ composition and prop. of UHE cosmic rays
- ✧ Galactic sources
  - ⟶ PeVatron accelerators

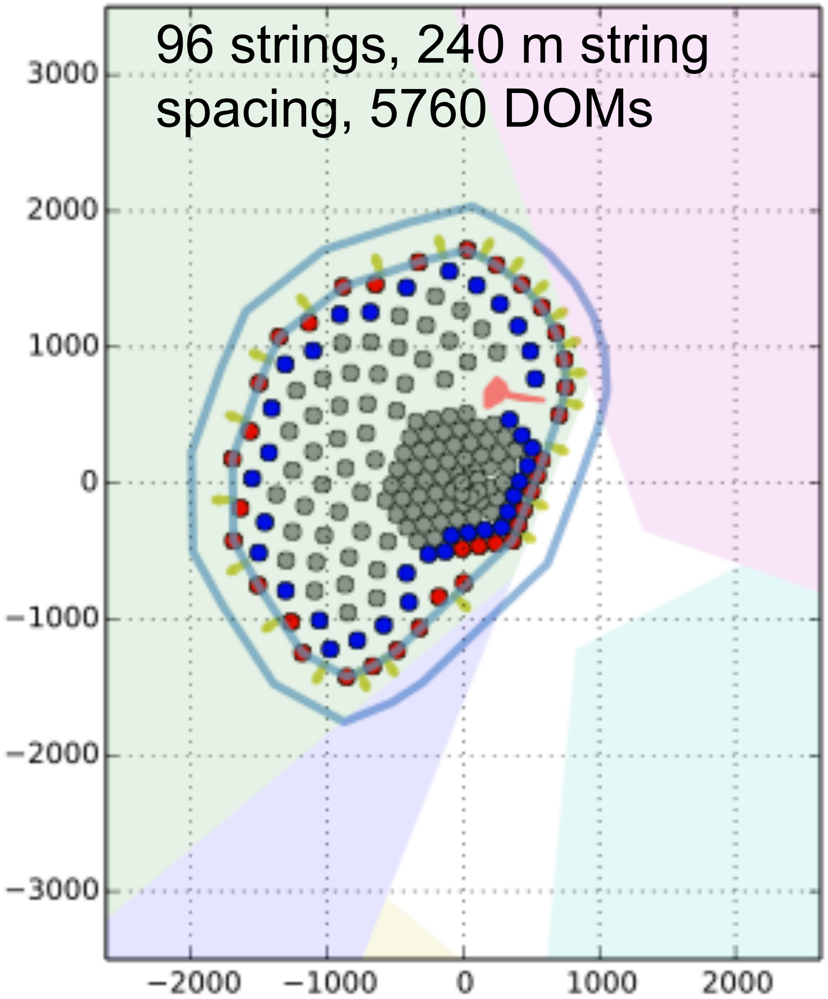
Configuration studies

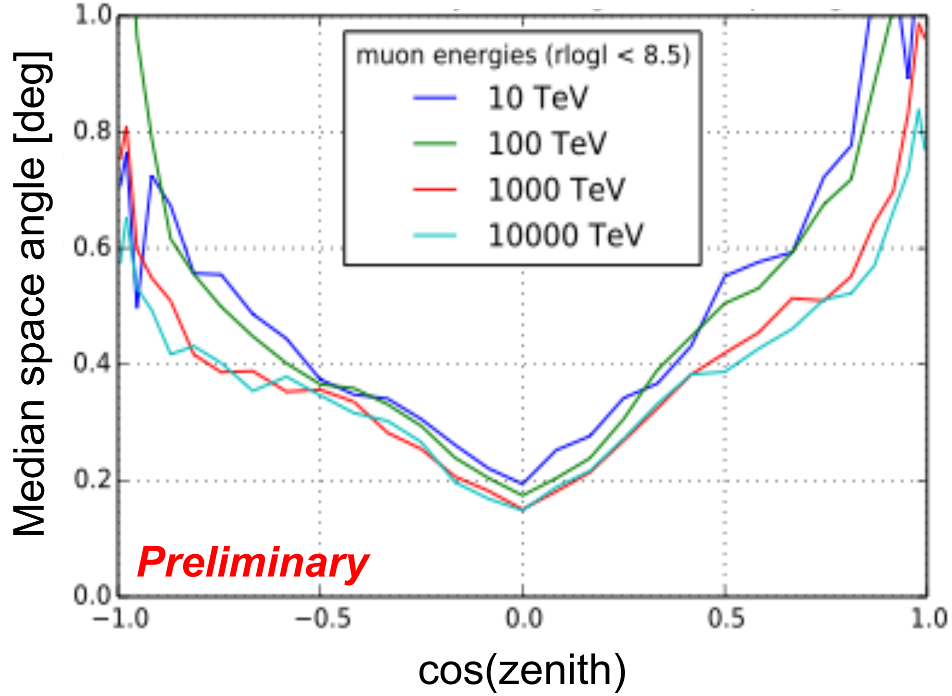




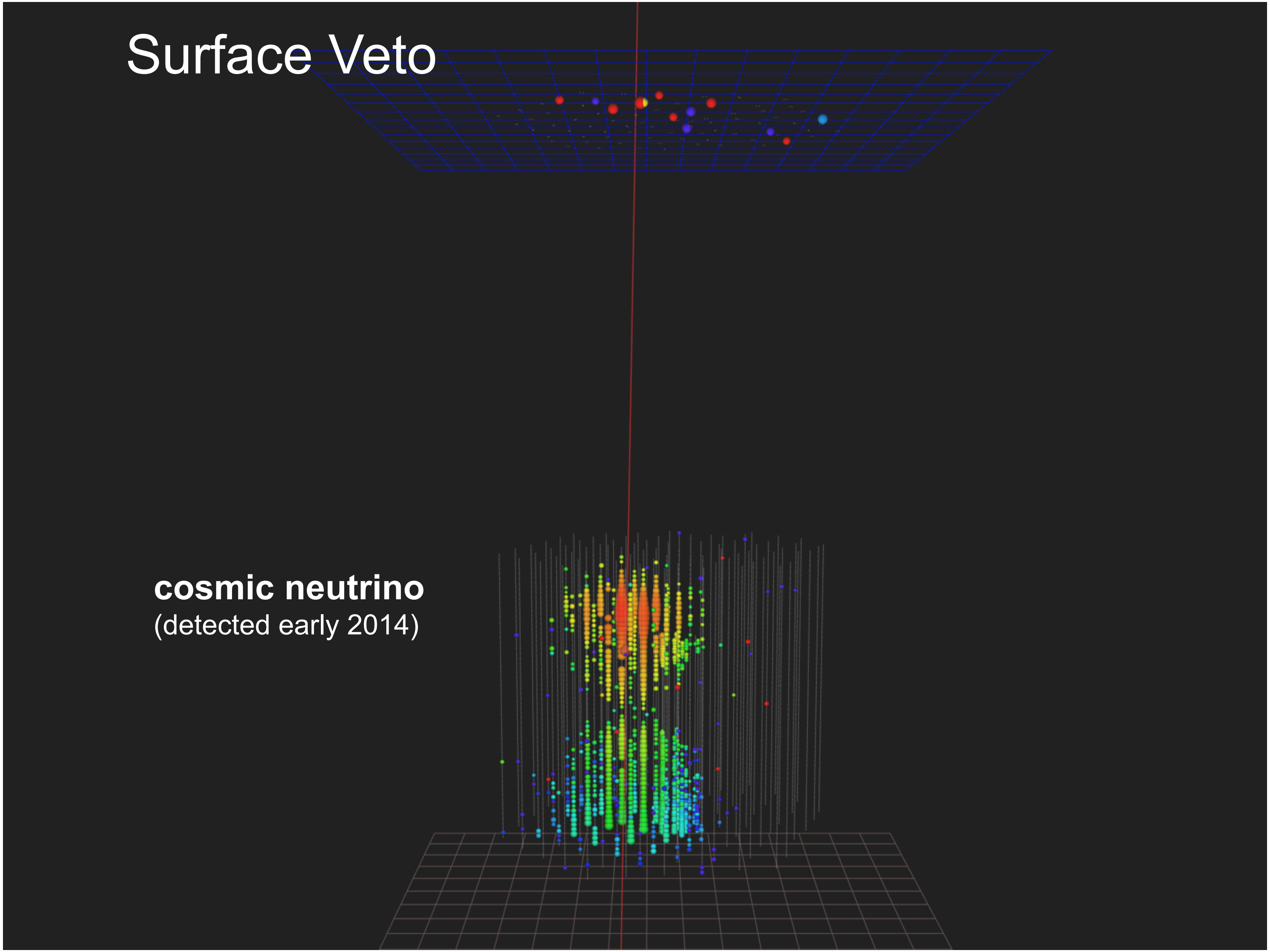
- **Surface area: ~5 km²**
- Volume: ~6.5 km³
- Angular resolution: 0.2-0.6°

Configuration studies



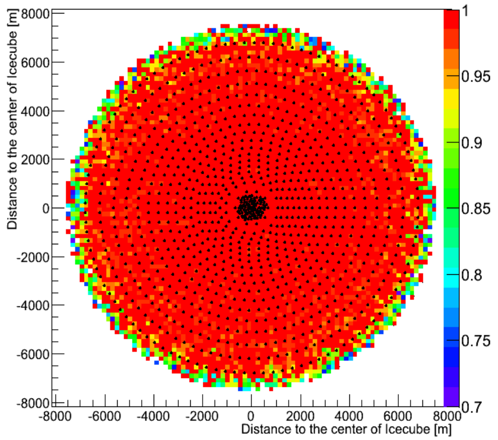


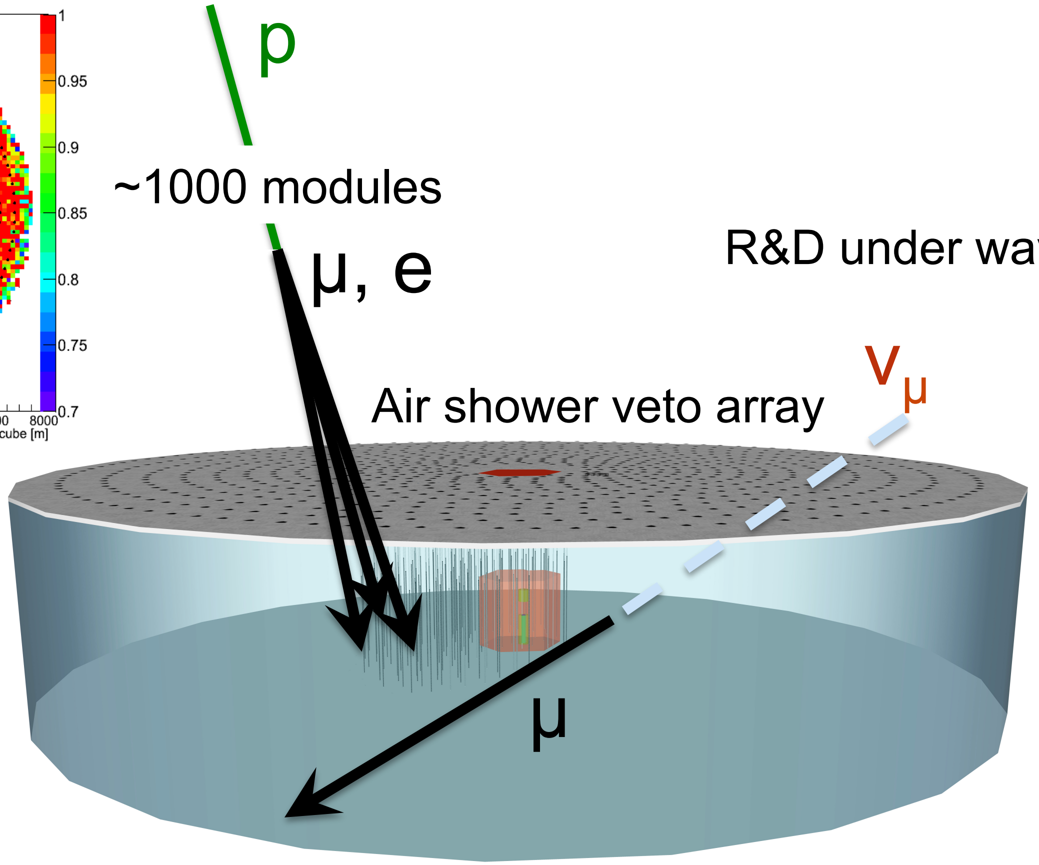
- Surface area: ~5 km^2
- Volume: ~6.5 km^3
- **Angular resolution: 0.2-0.6°**


Surface Veto
cosmic neutrino
(detected early 2014)

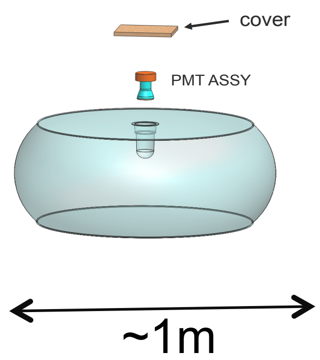
Surface Veto

- Surface detector for ~1 PeV cosmic primary to reject most atmospheric muon AND neutrino background above 100 TeV.
- 100 km^2 surface veto ⇒ ~ 5 bg. free cosmic neutrinos / yr





R&D under way



J. Aufenberg
RWTH Aachen

IceCube → DeepCore

IceCube

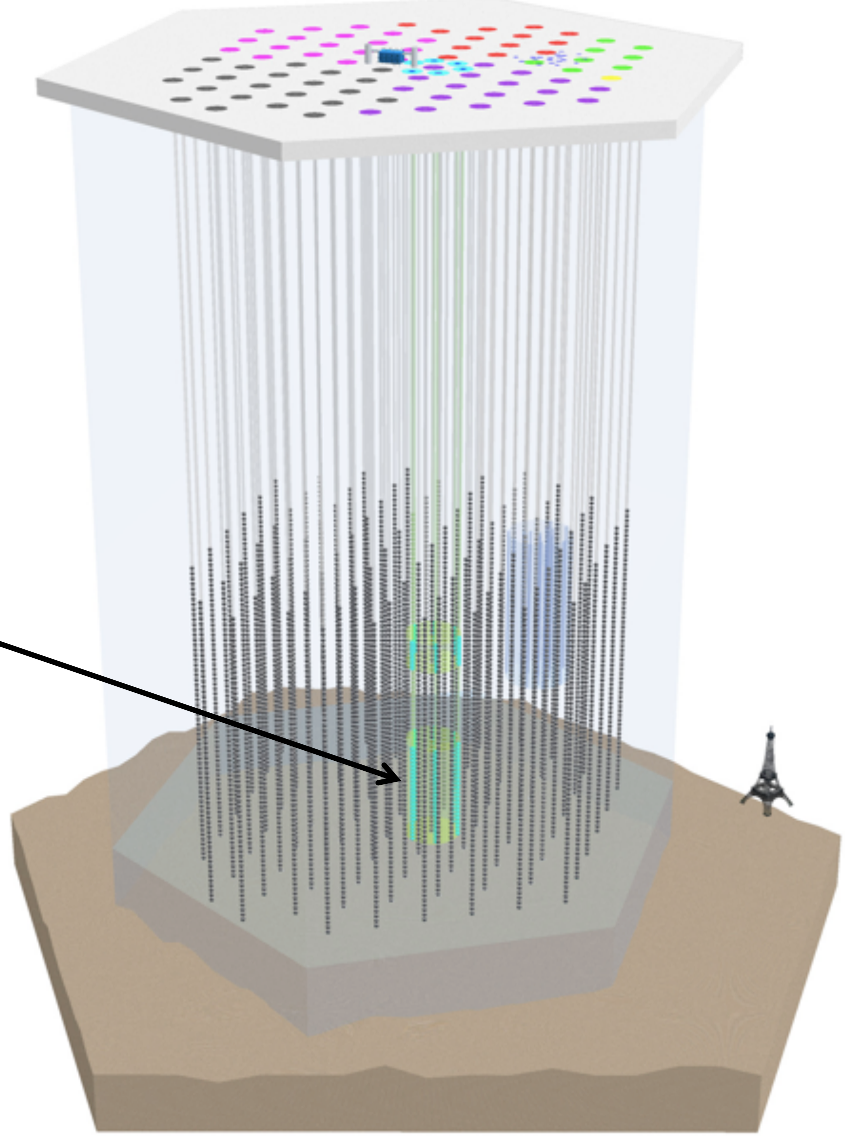
- 86 Strings
- E_{thresh} ~ 100 GeV

➔ astrophysical neutrinos

DeepCore

- 8 denser strings
- E_{thresh} ~ 10 GeV

➔ neutrino oscillations



Initial demonstrator analysis:
Gross et al. (TUM), PRL (2013)

IceCube → DeepCore

IceCube

- 86 Strings
- E_{thresh} ~ 100 GeV

➔ astrophysical neutrinos

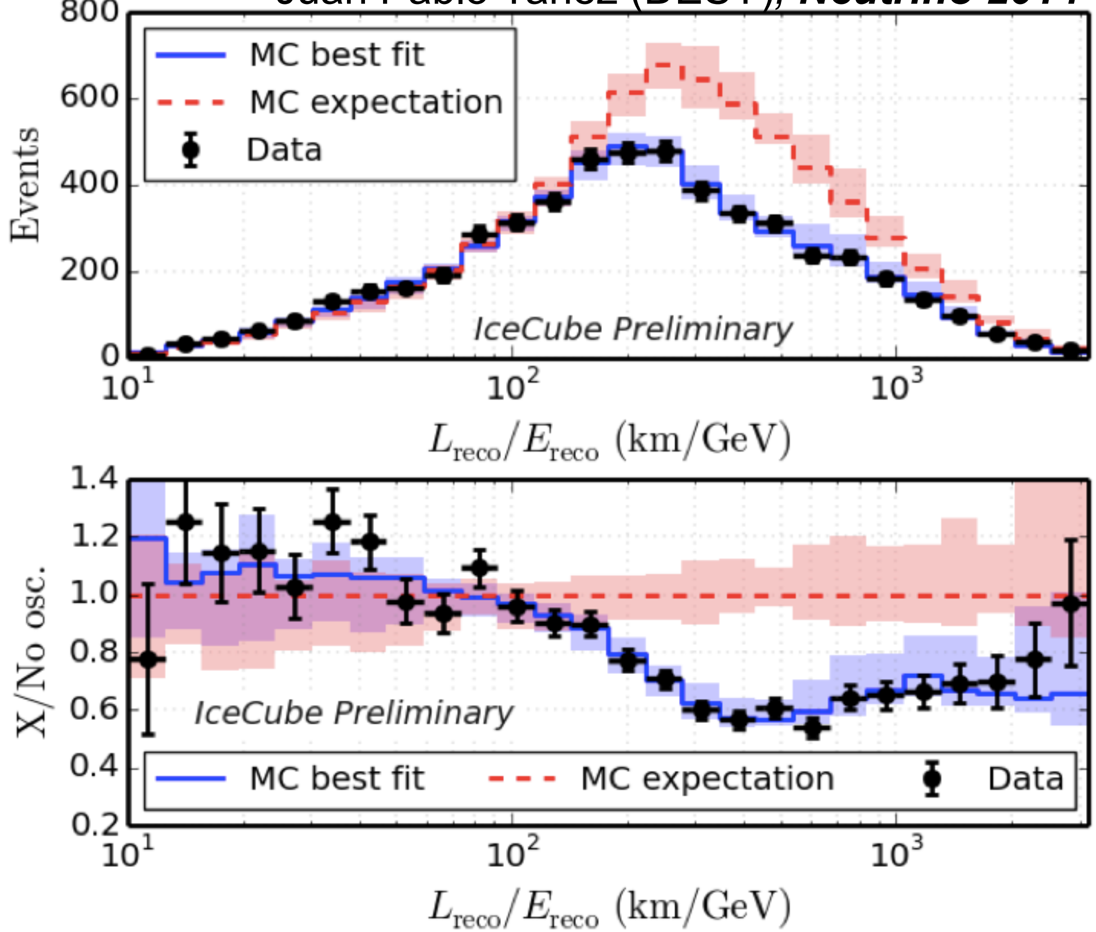
DeepCore

- 8 denser strings
- E_{thresh} ~ 10 GeV

➔ neutrino oscillations

Initial demonstrator analysis:
Gross et al. (TUM), PRL (2013)

Juan Pablo Yanez (DESY), ***Neutrino 2014***



IceCube → DeepCore

IceCube

- 86 Strings
- E_{thresh} ~ 100 GeV

➔ astrophysical neutrinos

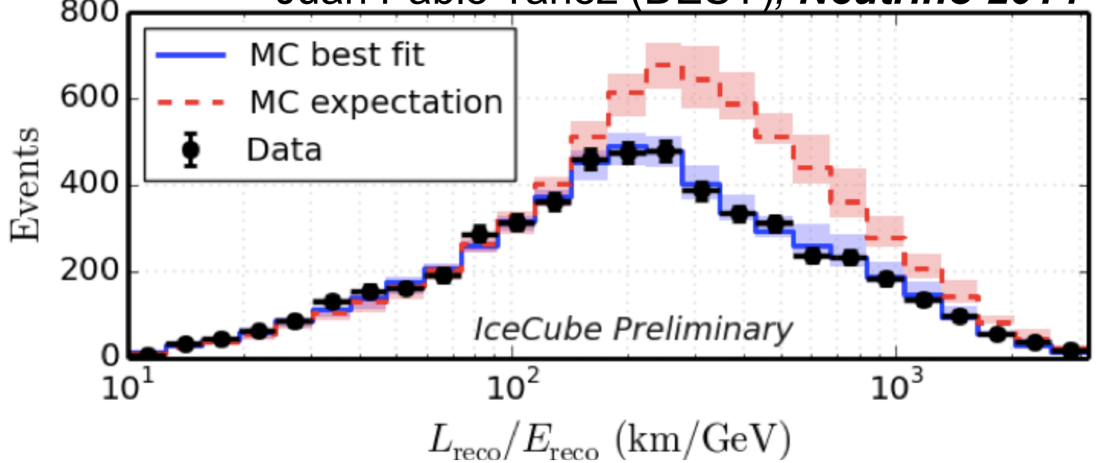
DeepCore

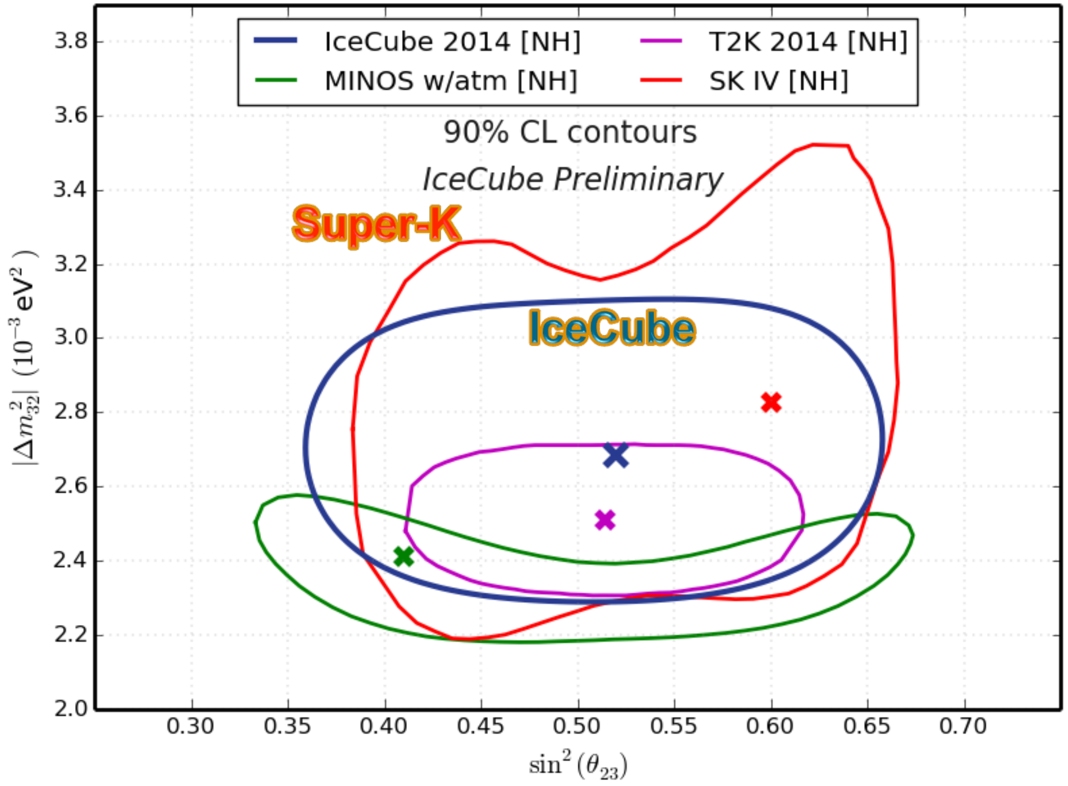
- 8 denser strings
- E_{thresh} ~ 10 GeV

➔ neutrino oscillations

Initial demonstrator analysis:
Gross et al. (TUM), PRL (2013)

Juan Pablo Yanez (DESY), ***Neutrino 2014***





IceCube → DeepCore → PINGU

IceCube

- 86 Strings
- E_{thresh} ~ 100 GeV

➔ astrophysical neutrinos

DeepCore

- 8 denser strings
- E_{thresh} ~ 10 GeV

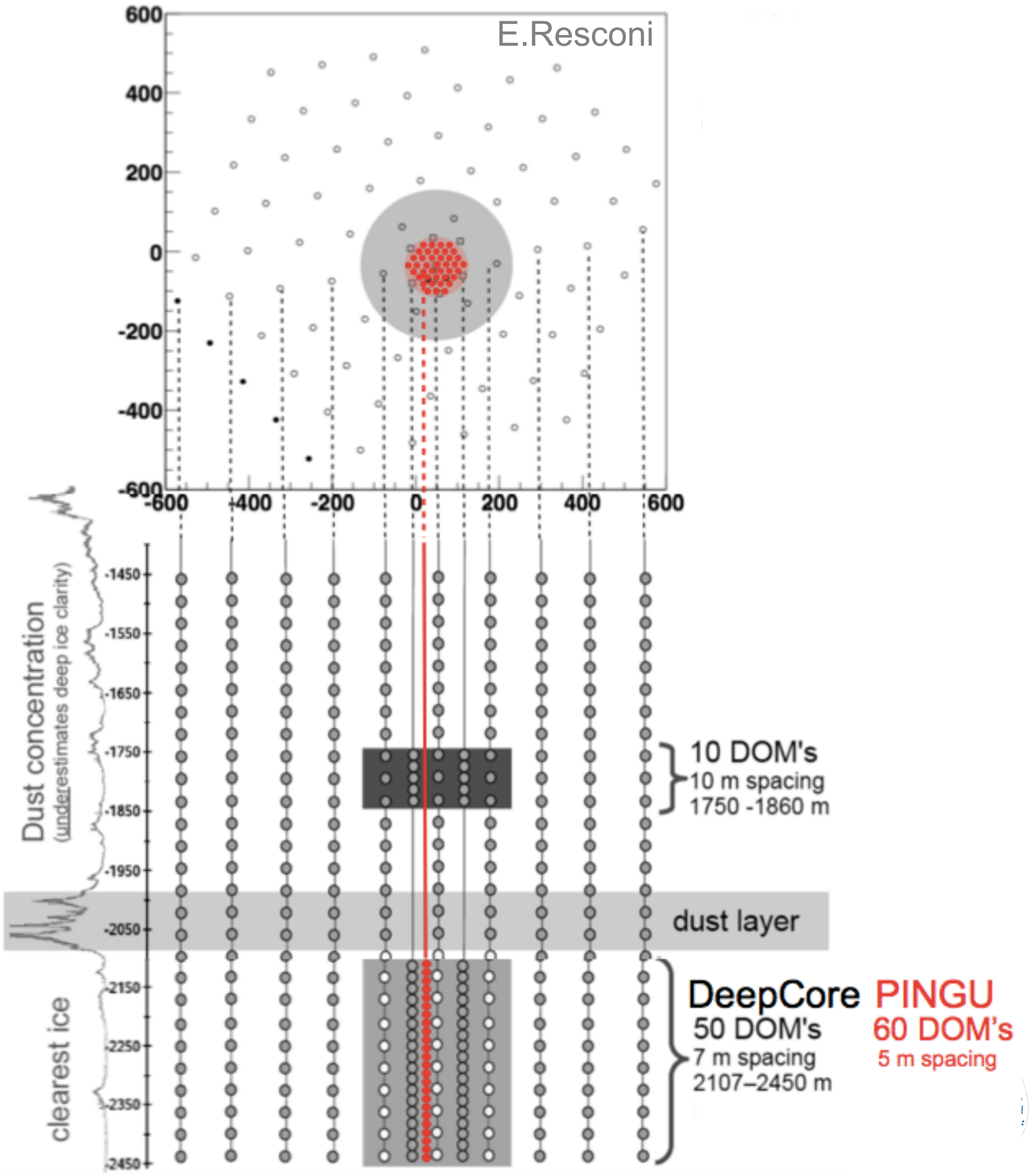
➔ neutrino oscillations

PINGU (planed)

- 40 strings
- E_{thresh} ~ 1 GeV

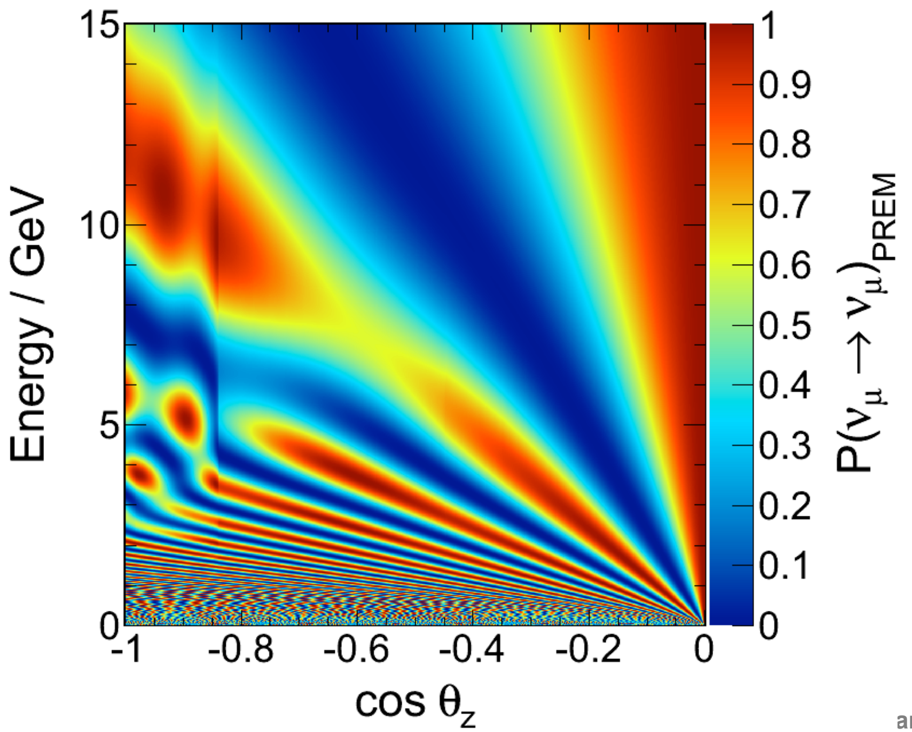
➔ neutrino mass hierarchy

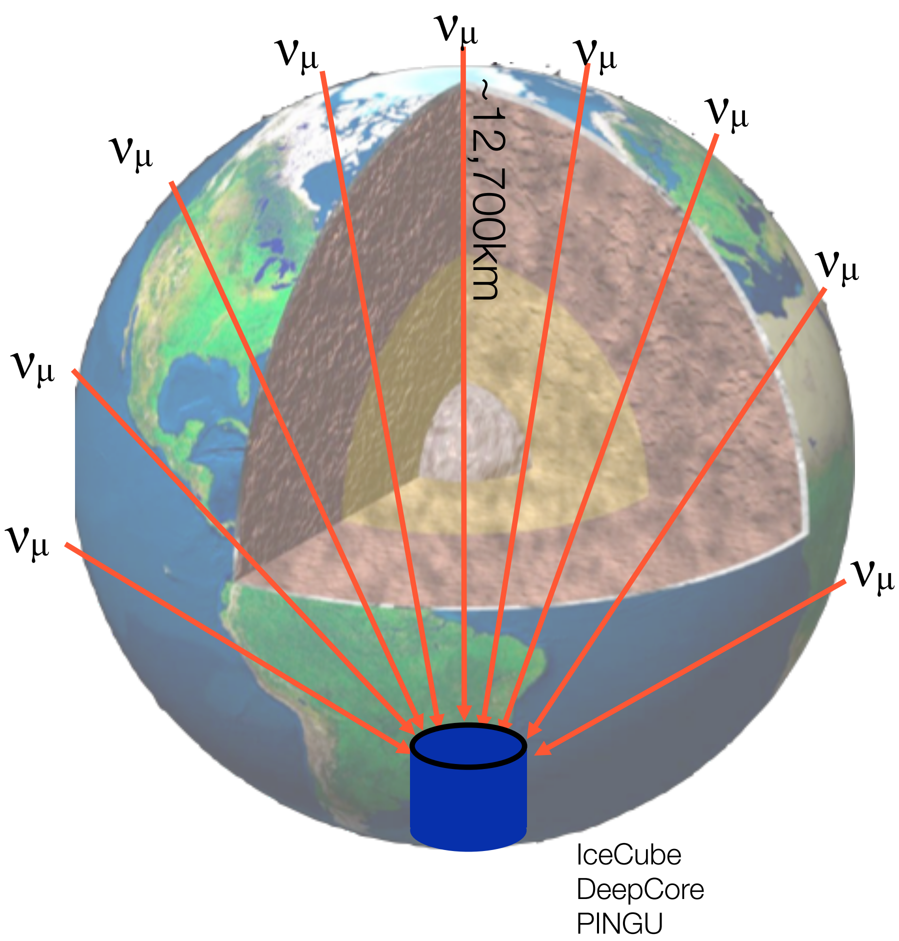
Letter of Intent, *arXiv:1401.2046*



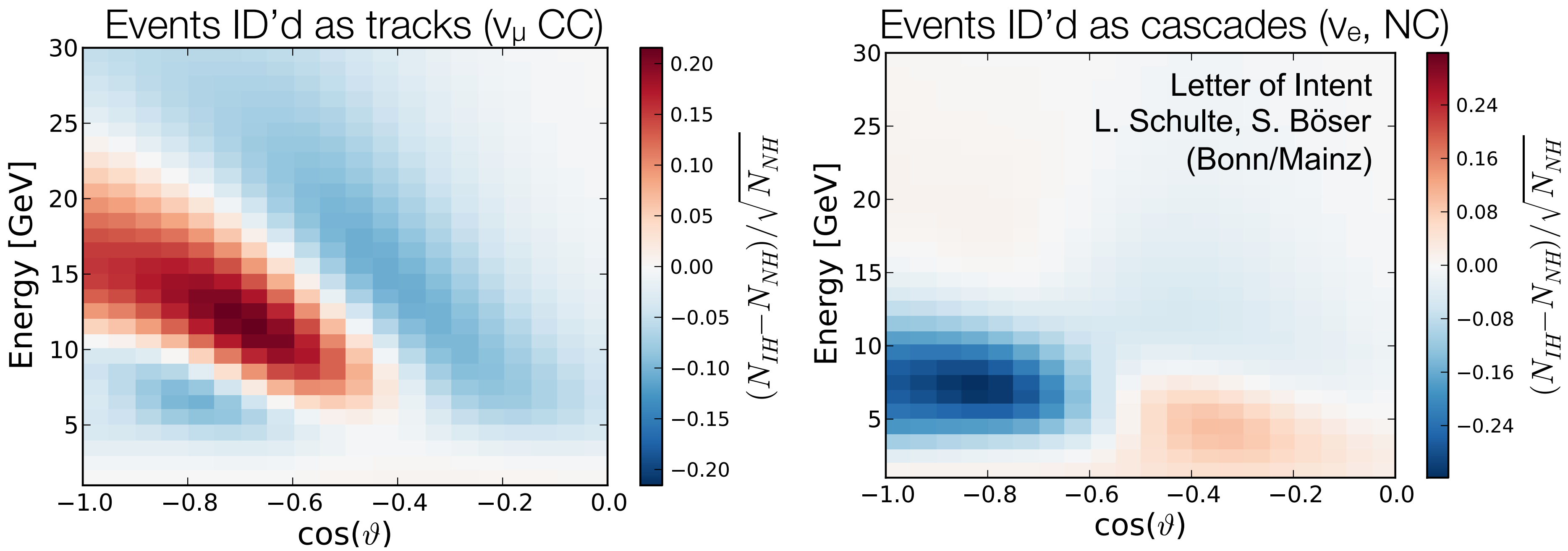
Neutrino Oscillations with atmospheric Neutrinos

- First oscillation minimum at 24 GeV, i.e. DeepCore energies
- Hierarchy-dependent matter effects below 12 GeV
  (e.g. Akhmedov et al. JHEP2013)





PINGU and the Neutrino Mass Hierarchy



- Cannot distinguish ν from $\bar{\nu}$ directly – rely instead on differences in fluxes and cross sections
- Distinctive NMH-dependent signatures for tracks and cascades
- Full simulation for detector efficiency, reconstruction, and particle ID

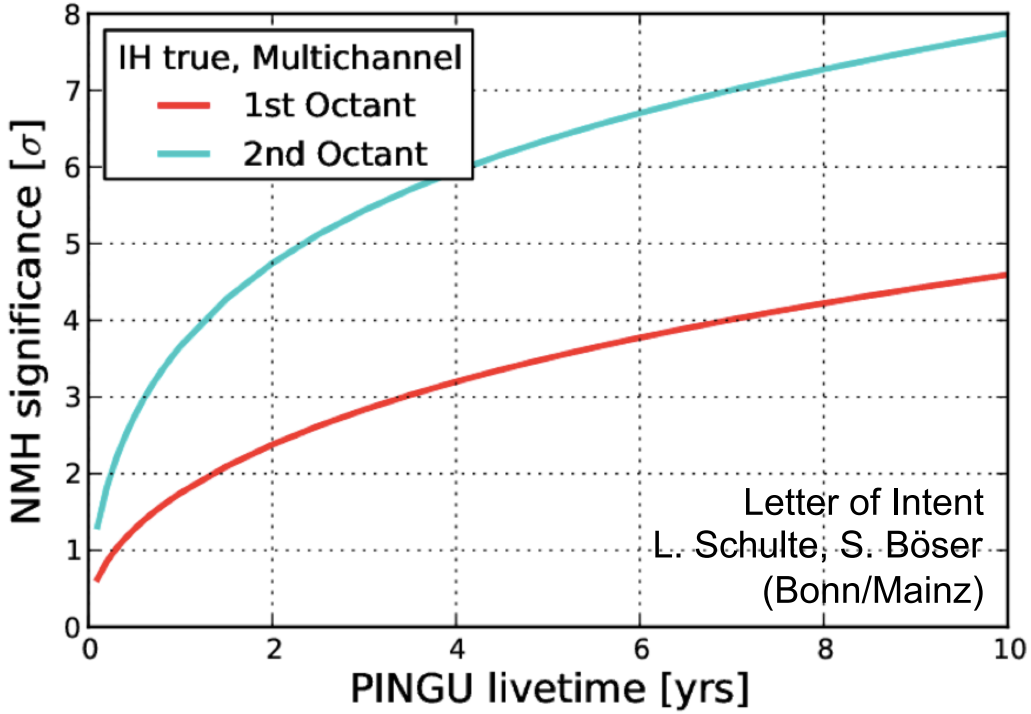
PINGU and the Neutrino Mass Hierarchy

With baseline geometry, for PINGU a determination of the mass hierarchy with 3σ significance appears possible with 3.5 years of data

- Optimization of analysis techniques and more detailed treatment of systematics underway

- Synergy with JUNO:
  Nearly a factor two better constraints from combination
  (e.g. Blennow, Schwetz, arXiv: 1306.3988)

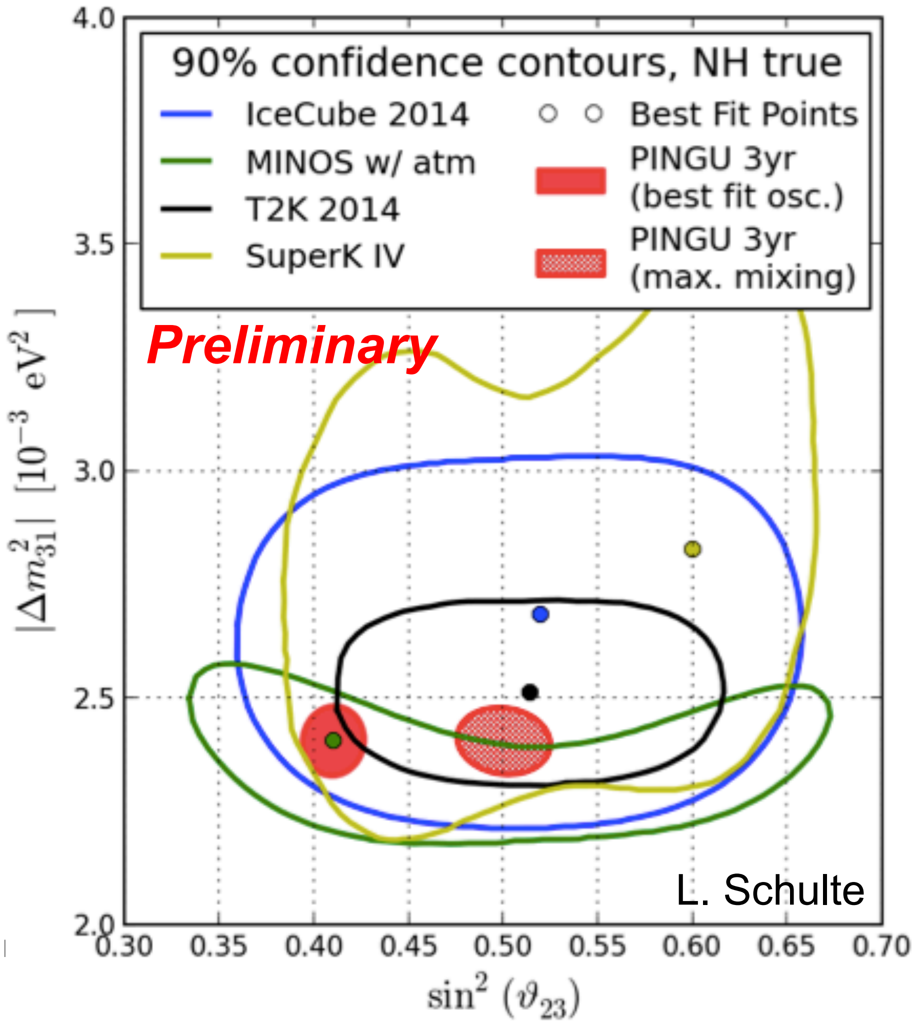
- And there is more: Neutrino oscillartions, dark matter,...



PINGU and the Neutrino Mass Hierarchy

With baseline geometry, for PINGU a determination of the mass hierarchy with 3σ significance appears possible with 3.5 years of data

- Optimization of analysis techniques and more detailed treatment of systematics underway.
- Synergy with JUNO:
  Nearly a factor two better constraints from combination (e.g. Blennow, Schwetz, arXiv: 1306.3988)
- **And there is more: Neutrino oscillartions, dark matter,...**



The IceCube–PINGU Collaboration

USA
Clark Atlanta University
Georgia Institute of Technology
Lawrence Berkeley National Laboratory
Ohio State University
Pennsylvania State University
South Dakota School of Mines & Technology
Southern University and A&M College
Stony Brook University
University of Alabama
University of Alaska Anchorage
University of California, Berkeley
University of California, Irvine
University of Delaware
University of Kansas
University of Maryland
University of Wisconsin–Madison
University of Wisconsin–River Falls
Yale University

Canada
University of Alberta–Edmonton
University of Toronto

Japan
Chiba University
University of Tokyo

Sungkyunkwan University, **Korea**

UK
University of Oxford
University of Manchester

Belgium
Université Libre de Bruxelles
Université de Mons
Universiteit Gent
Vrije Universiteit Brussel

Niels Bohr Institutet, **Denmark**

Sweden
Stockholms universitet
Uppsala universitet

Germany
Deutsches Elektronen–Synchrotron
Friedrich–Alexander–Universität Erlangen–Nürnberg
Humboldt–Universität zu Berlin
Max–Planck–Institut für Physik
Ruhr–Universität Bochum
RWTH Aachen
Technische Universität München
Universität Bonn
Technische Universität Dortmund
Universität Mainz
Universität Wuppertal

Université de Genève, **Switzerland**

University of Adelaide, **Australia**

University of Canterbury, **New Zealand**

International Funding Agencies

Fonds de la Recherche Scientifique (FRS–FNRS)
Fonds Wetenschappelijk Onderzoek–Vlaanderen (FWO–Vlaanderen)
Federal Ministry of Education & Research (BMBF)
German Research Foundation (DFG)
Deutsches Elektronen–Synchrotron (DESY)
Inoue Foundation for Science, Japan
Knut and Alice Wallenberg Foundation
NSF–Office of Polar Programs
NSF–Physics Division
Swedish Polar Research Secretariat
The Swedish Research Council (VR)
University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)

Summary & Outlook

- Building on IceCube's success, expand to lower/higher energies
- Enormous science potential from neutrino astronomy to particle physics
- Next Generation IceCube planed with 120 strings and ~8000 DOMs
- NSF-MREFC proposal in 2015 for funding in 2017, significant international contributions expected
- Construction to start in 2019 – PINGU first
- **German community already strongly involved**

Excellent time to join the effort