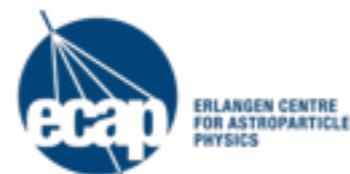


IceCube – Exploring the Universe with Neutrinos at the South Pole

ERLANGEN CENTRE
FOR ASTROPARTICLE
PHYSICS

Alexander Kappes
Inauguration of Research Training Group GRK 2149
Telgte, 24–26 November 2015



IceCube – Exploring the Universe with Neutrinos at the South Pole

Inauguration of Research Training Group GRK 2149
Telgte, 24–26 November 2015

The group



Alexander Kappes



Lew Classen
(Postdoc)



Raffaela Busse
(Master student)

Located at *Institut für Kernphysik*
(currently in setup phase; start in Januar)

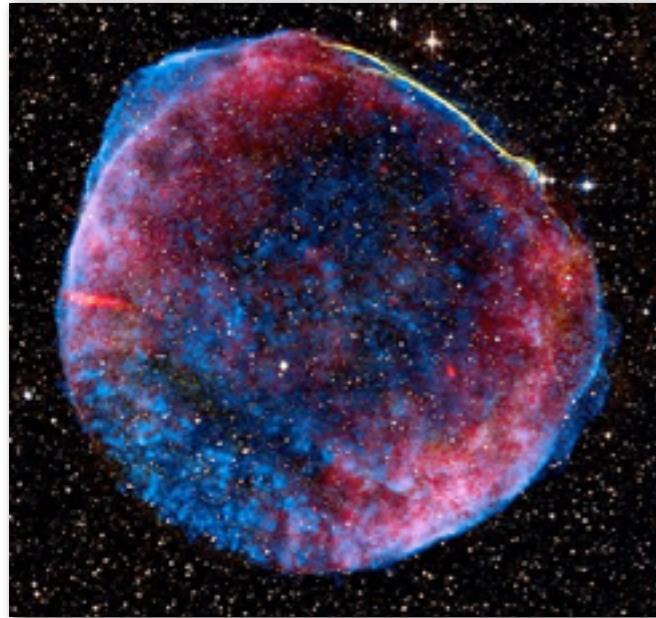
Fields of activity

- Neutrino astronomy
- Neutrino oscillations
- Photon sensor development

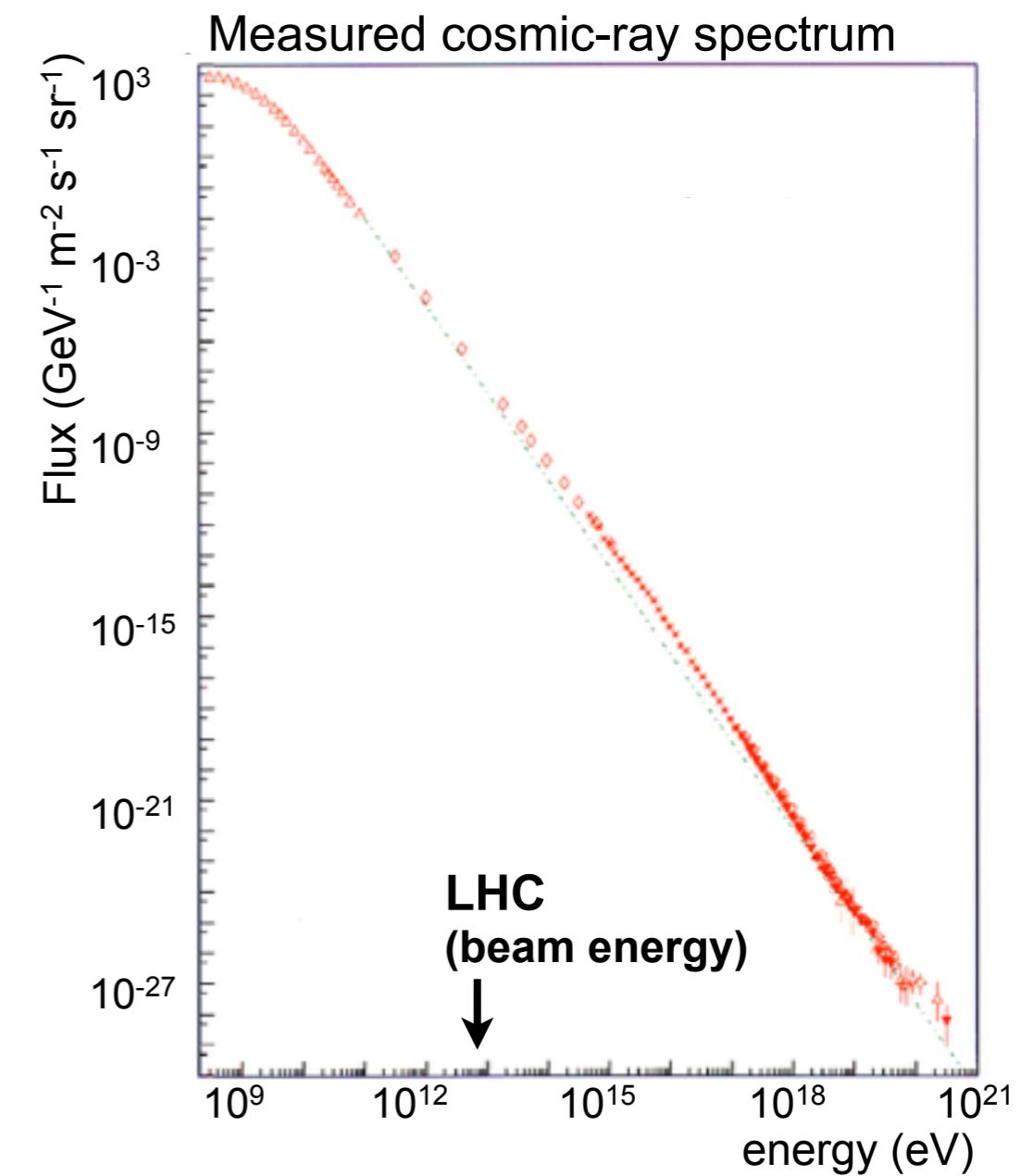
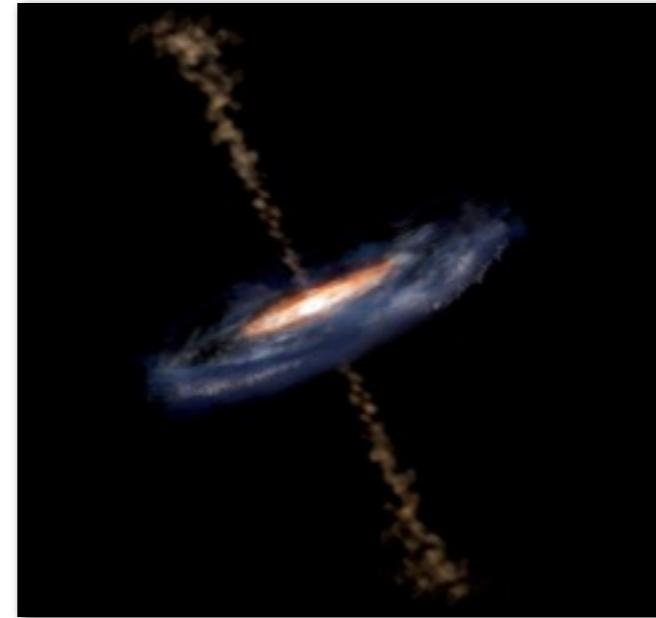
Neutrino astronomy, what's that?

- Explore high-energy universe with neutrinos
- Central question: locate / understand sources of cosmic rays

Supernova remnants
(SN1006, optical, radio, X-rays)



Aktive Galactic nuclei
(artist's view)

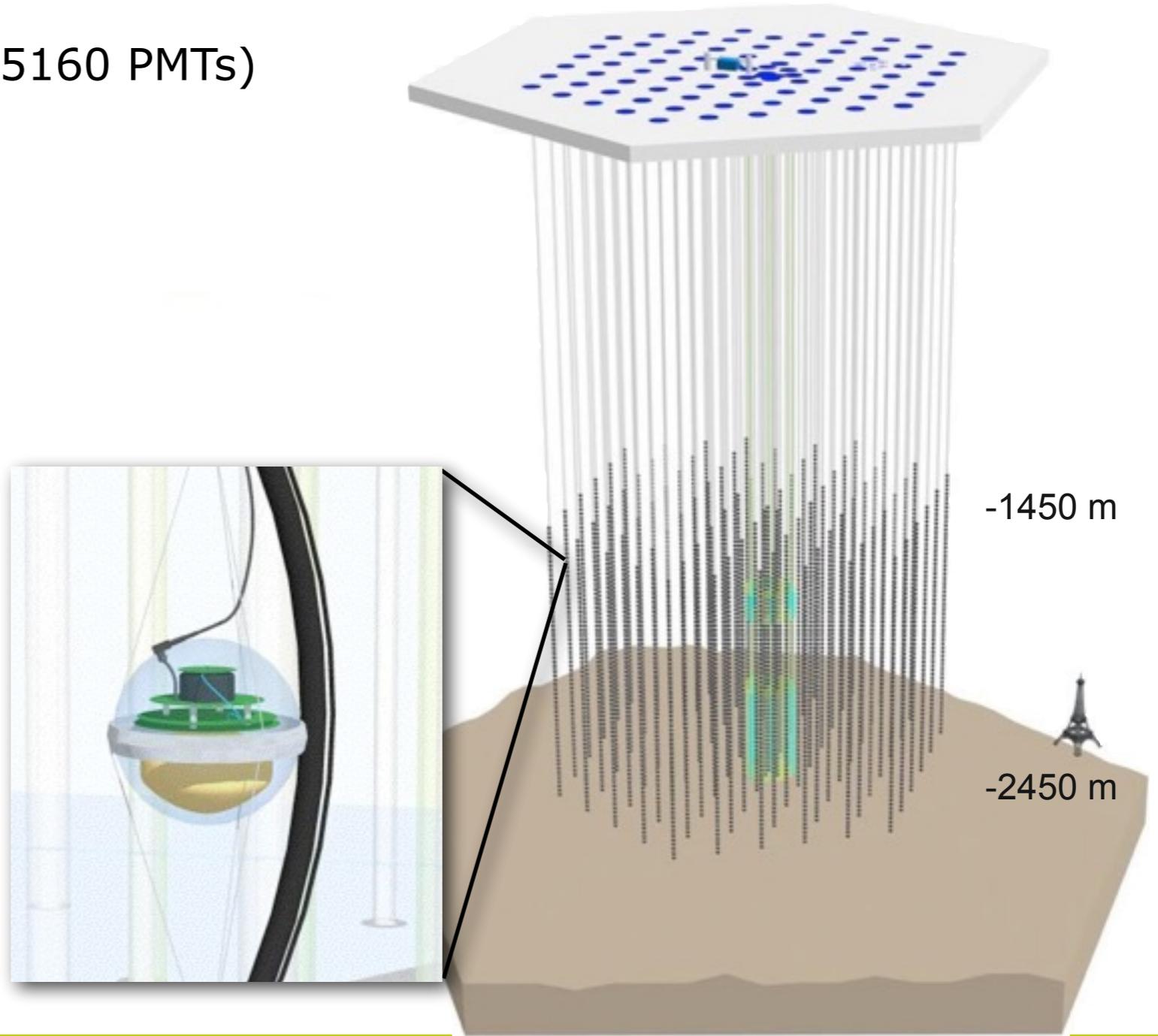






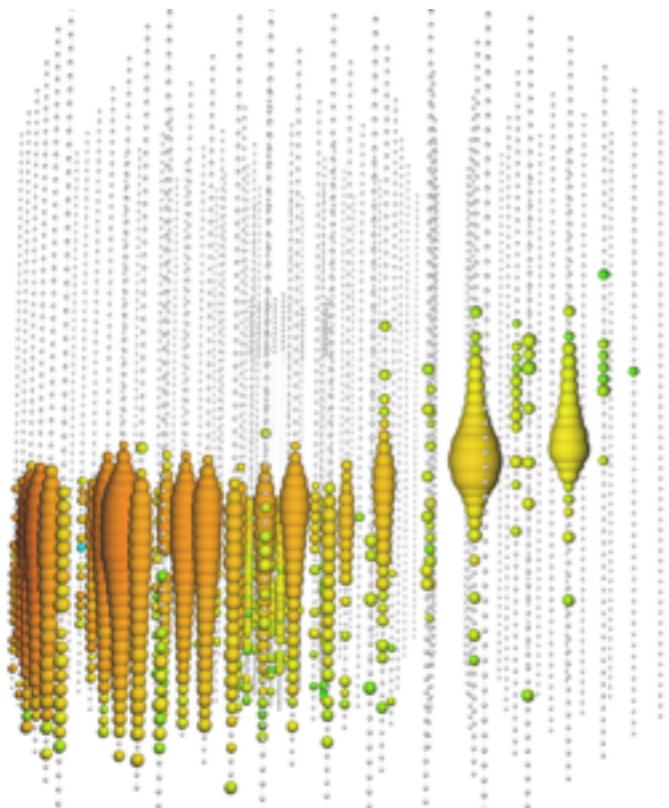
The IceCube Observatory

- Neutrino telescope: 86 strings (5160 PMTs)
instrumented volume: 1 km^3
- Completed since Dec 2010
(data taking since 2005)

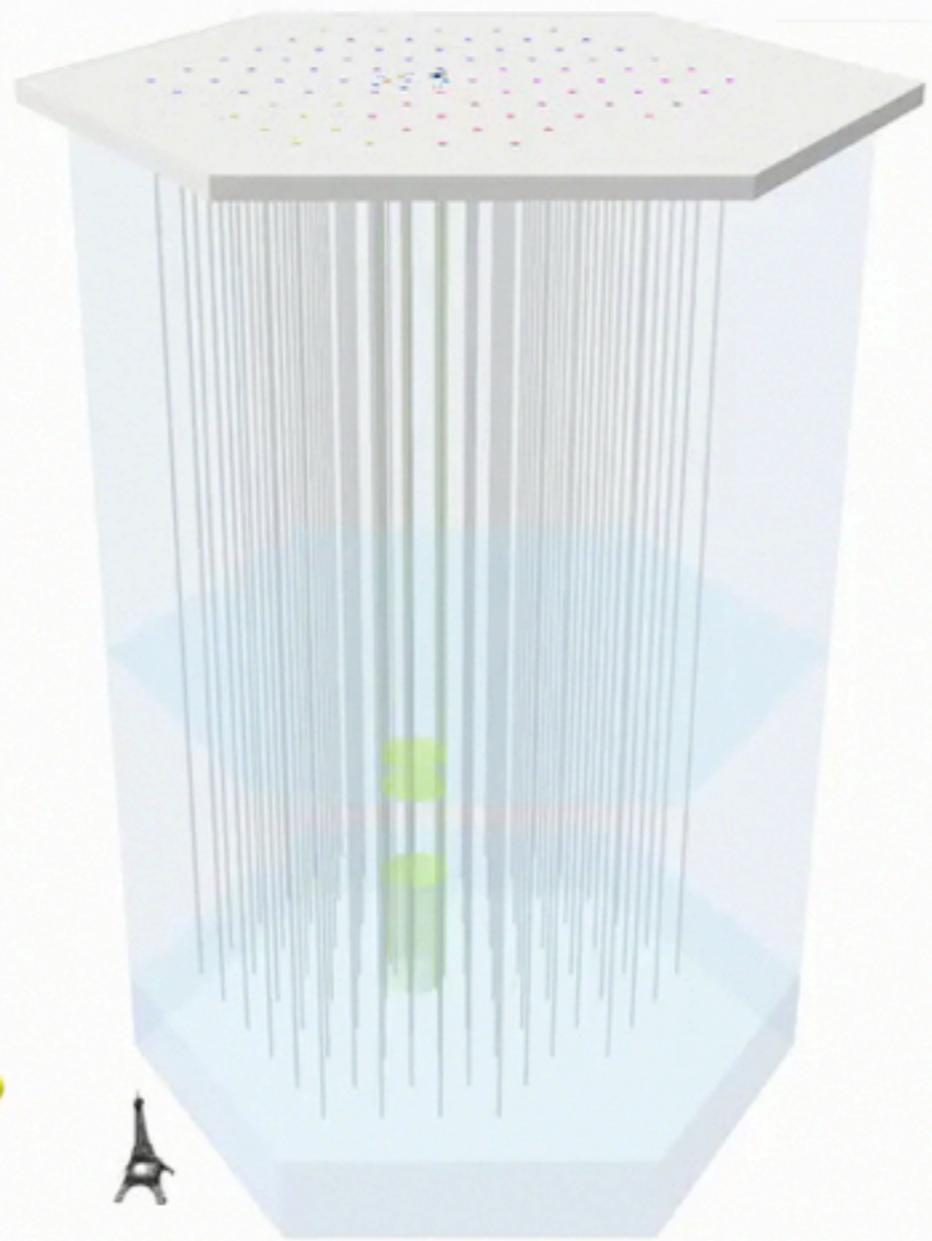


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$E_\nu > 3 \text{ PeV}$



The IceCube Collaboration

USA
Clark Atlanta University
Drexel University
Georgia Institute of Technology
Lawrence Berkeley National Laboratory
Massachusetts Institute of Technology
Michigan State University
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

Sweden
Stockholms universitet
Uppsala universitet

Germany
Deutsches Elektronen-Synchrotron
Friedrich-Alexander-Universität Erlangen-Nürnberg
Humboldt-Universität zu Berlin
Ruhr-Universität Bochum
RWTH Aachen
Technische Universität München
Technische Universität Dortmund
Universität Mainz
Universität Wuppertal

Denmark
Niels Bohr Institutet

Japan
Chiba University

Korea
Sungkyunkwan University

UK
University of Oxford

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

Switzerland
Université de Genève

Australia
University of Adelaide

New Zealand
University of Canterbury

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)

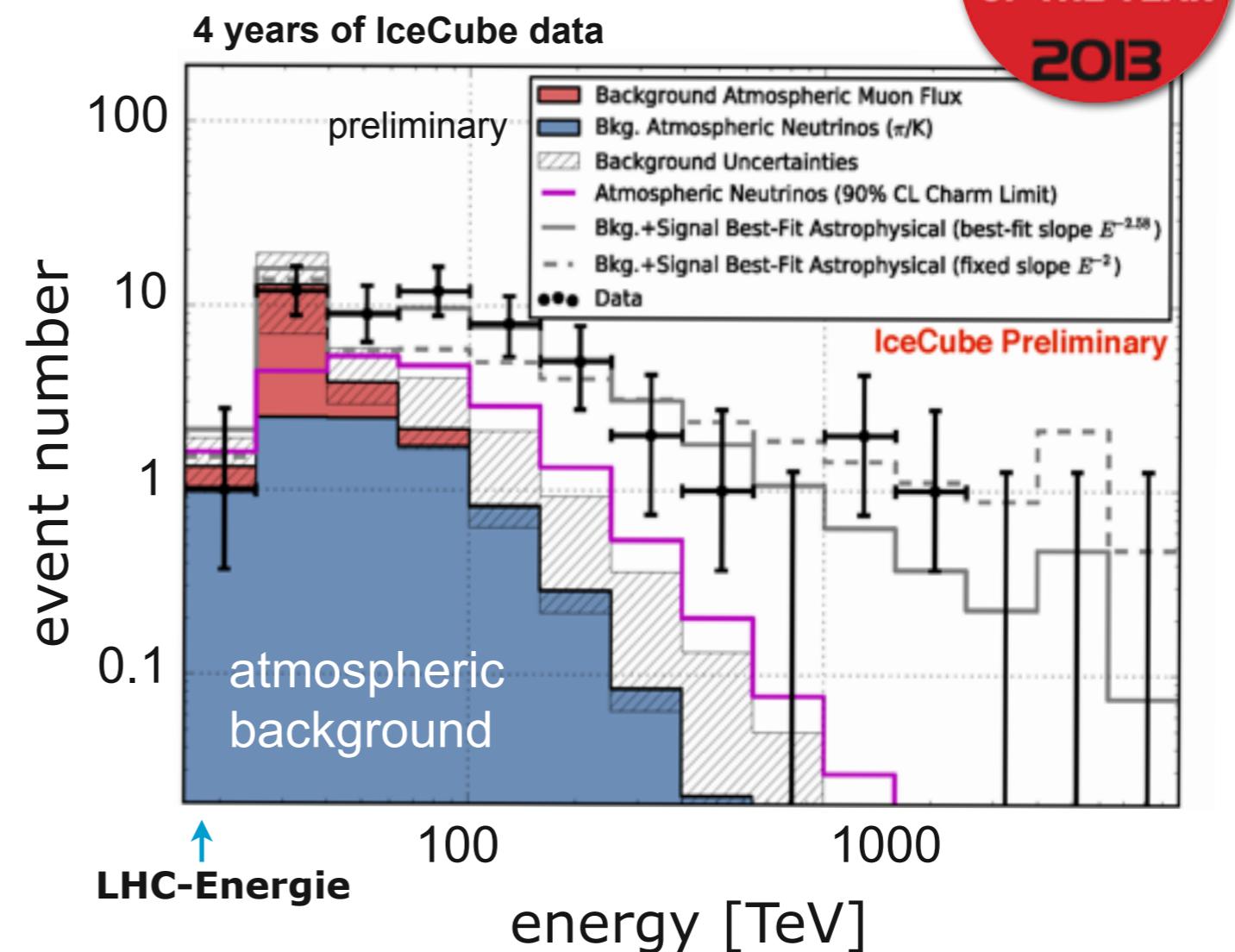
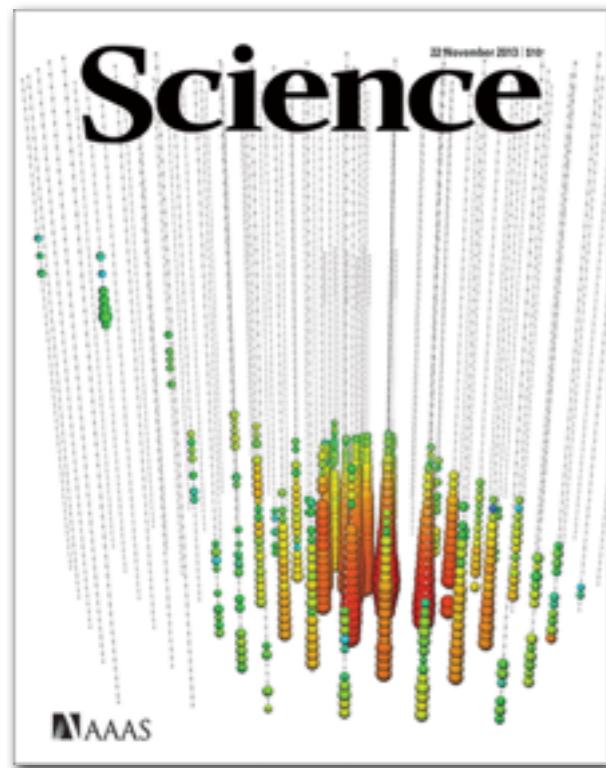
Deutsches Elektronen-Synchrotron (DESY)
Japan Society for the Promotion of Science (JSPS)
Knut and Alice Wallenberg Foundation
Swedish Polar Research Secretariat
The Swedish Research Council (VR)

University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)

300 members from 45 institutes in 12 countries

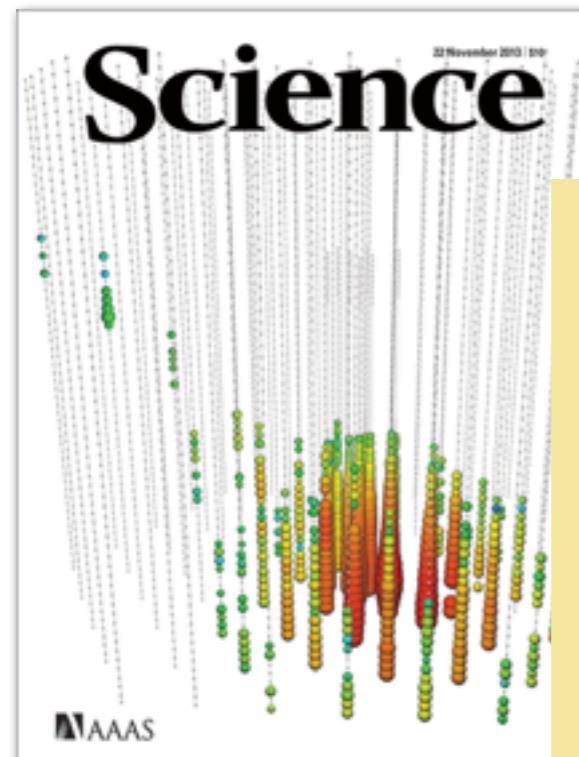
The very first (high-energy) cosmic neutrinos

- Observation of excess at high energies
- By now 4 neutrinos with $\gtrsim 500 \times$ LHC energy



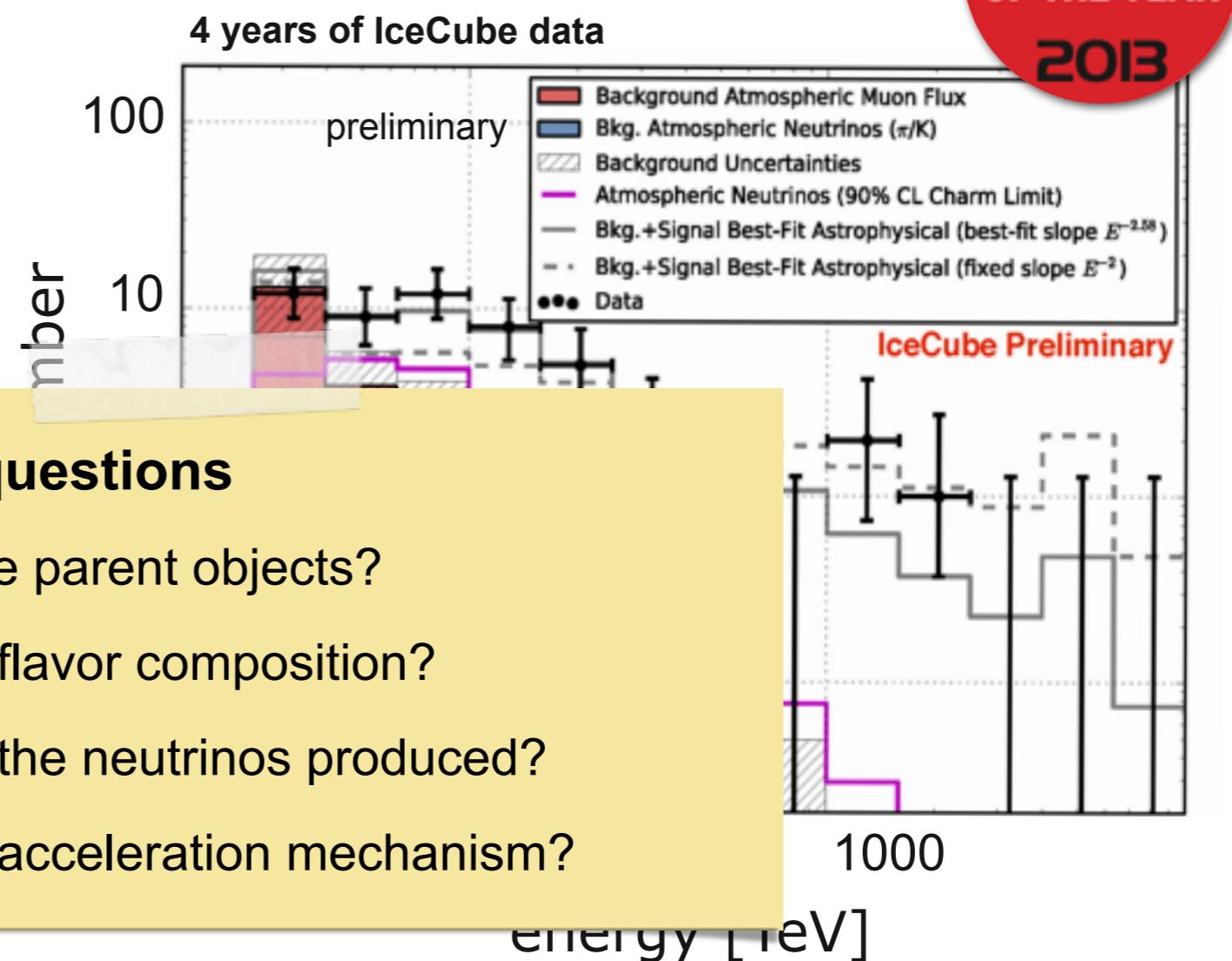
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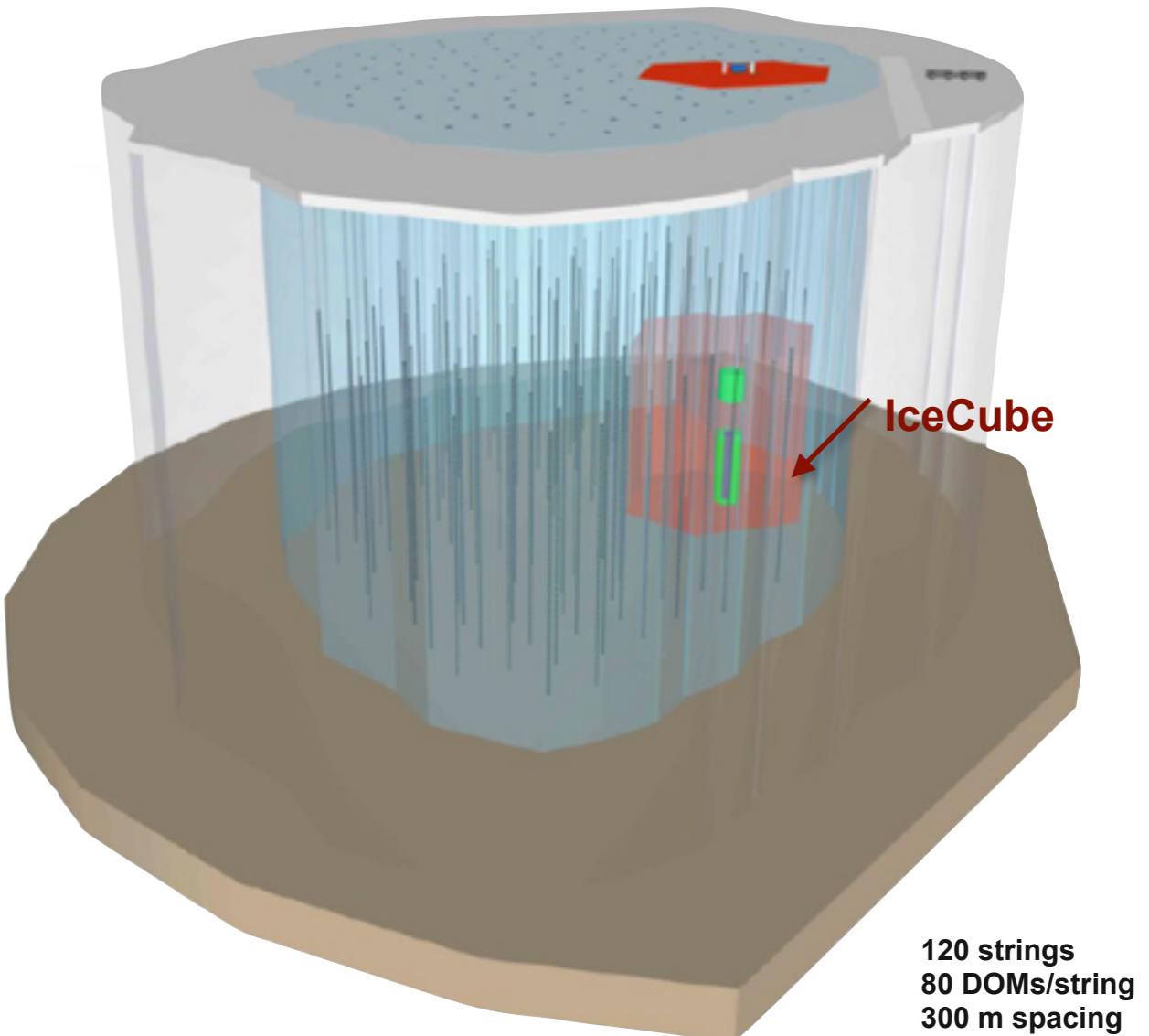
Many open questions

- What are the parent objects?
- What is the flavor composition?
- How where the neutrinos produced?
- What is the acceleration mechanism?



The next generation – IceCube-Gen2

- High-energy array: neutrino astronomy
 - instrumented ice volume 5–10 km³
 - factor 5–10 gain in sensitivity
- PINGU: neutrino physics
 - ~5 Mton dense array in detector center
 - neutrino oscillations



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2015

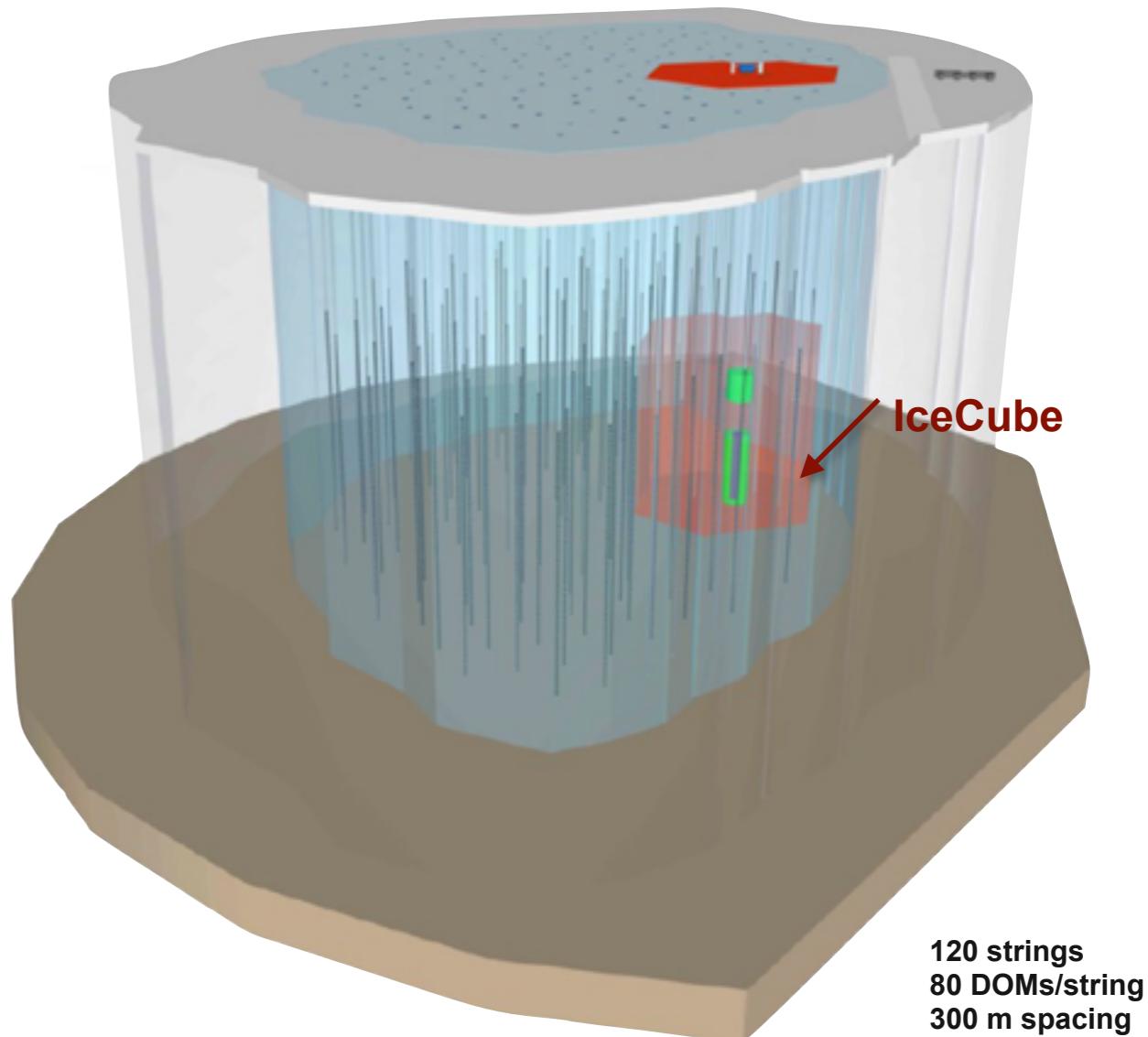


Kajita



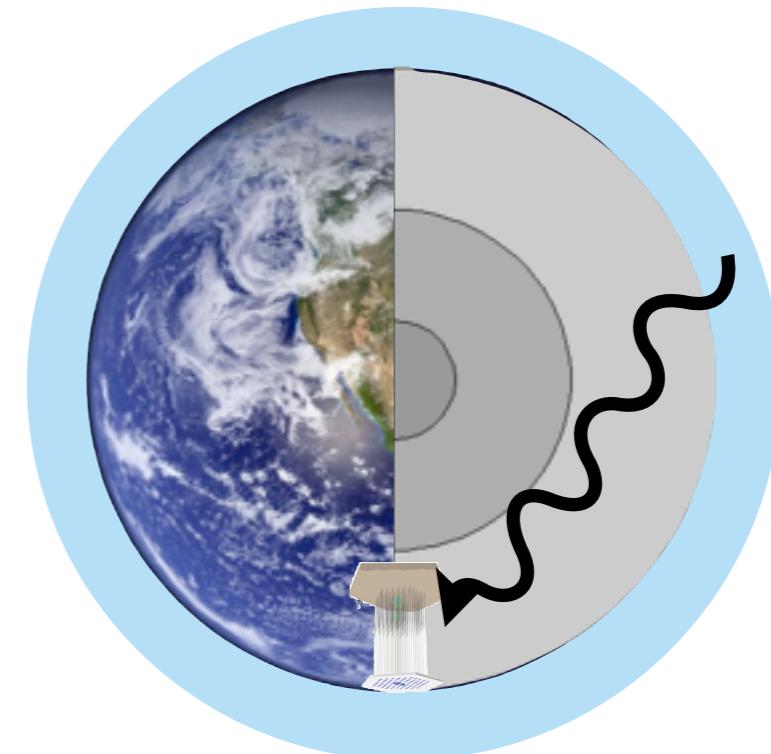
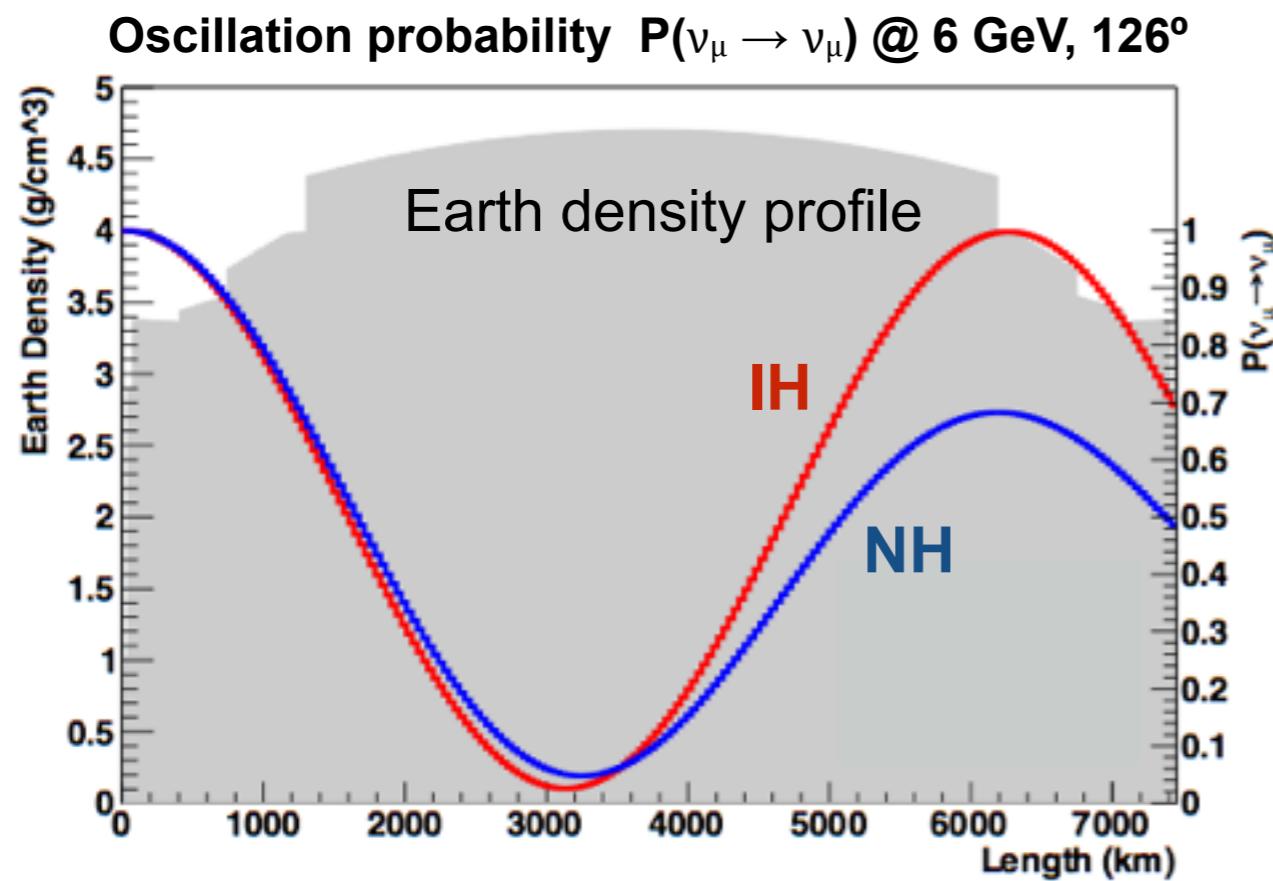
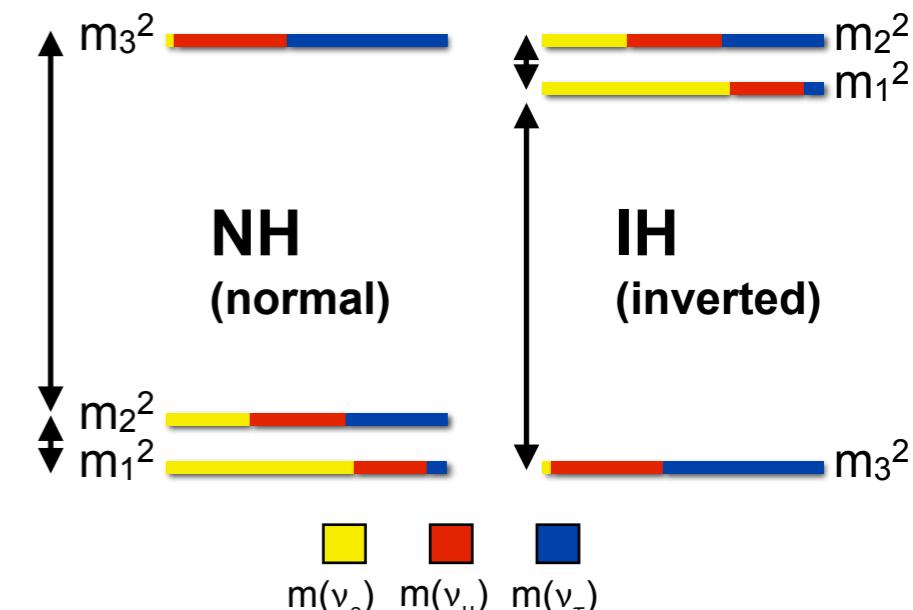
McDonald

"for the discovery of neutrino oscillations, which shows that neutrinos have mass"



Neutrino physics with neutrino telescopes

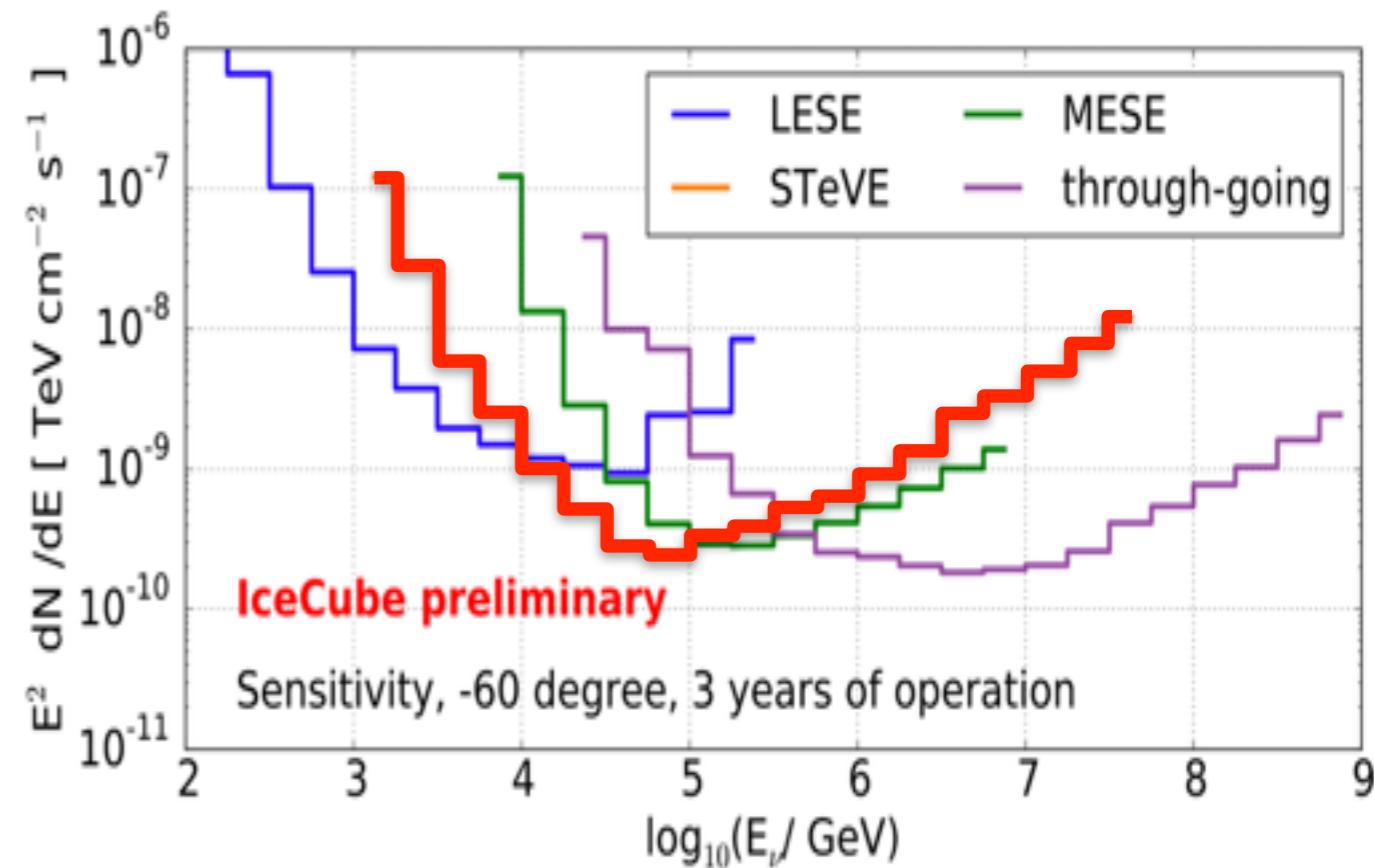
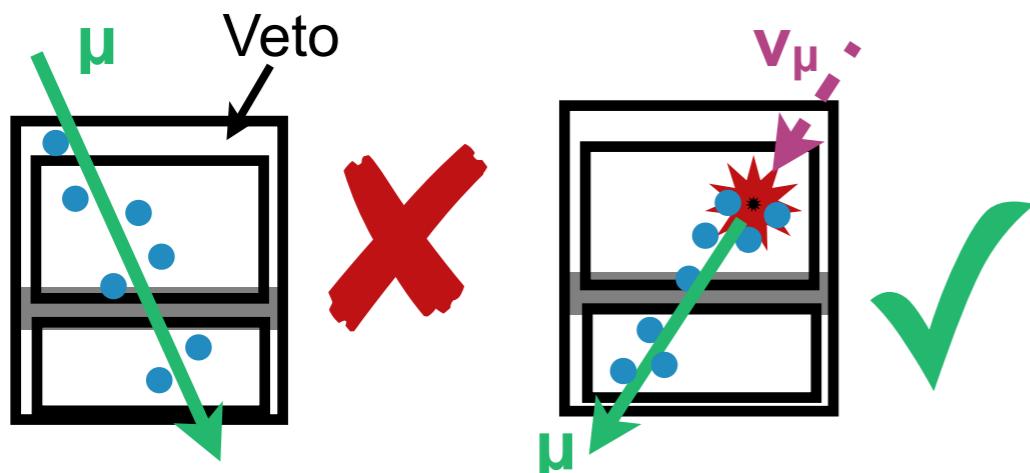
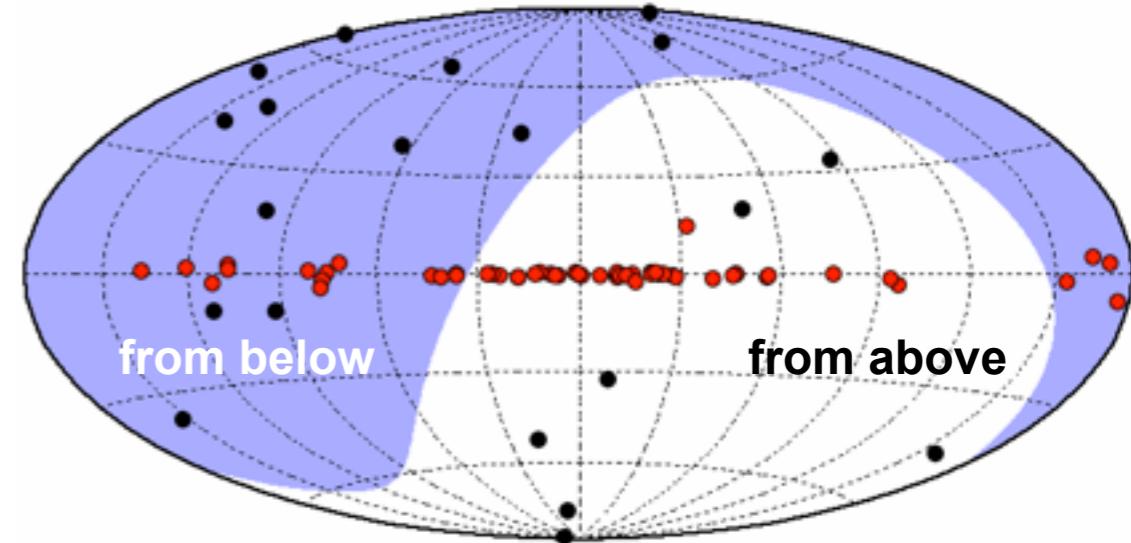
- Oscillation physics with atmospheric neutrinos
- Holy grail: neutrino mass ordering
→ in reach with PINGU



Current activities

Analysis of IceCube data

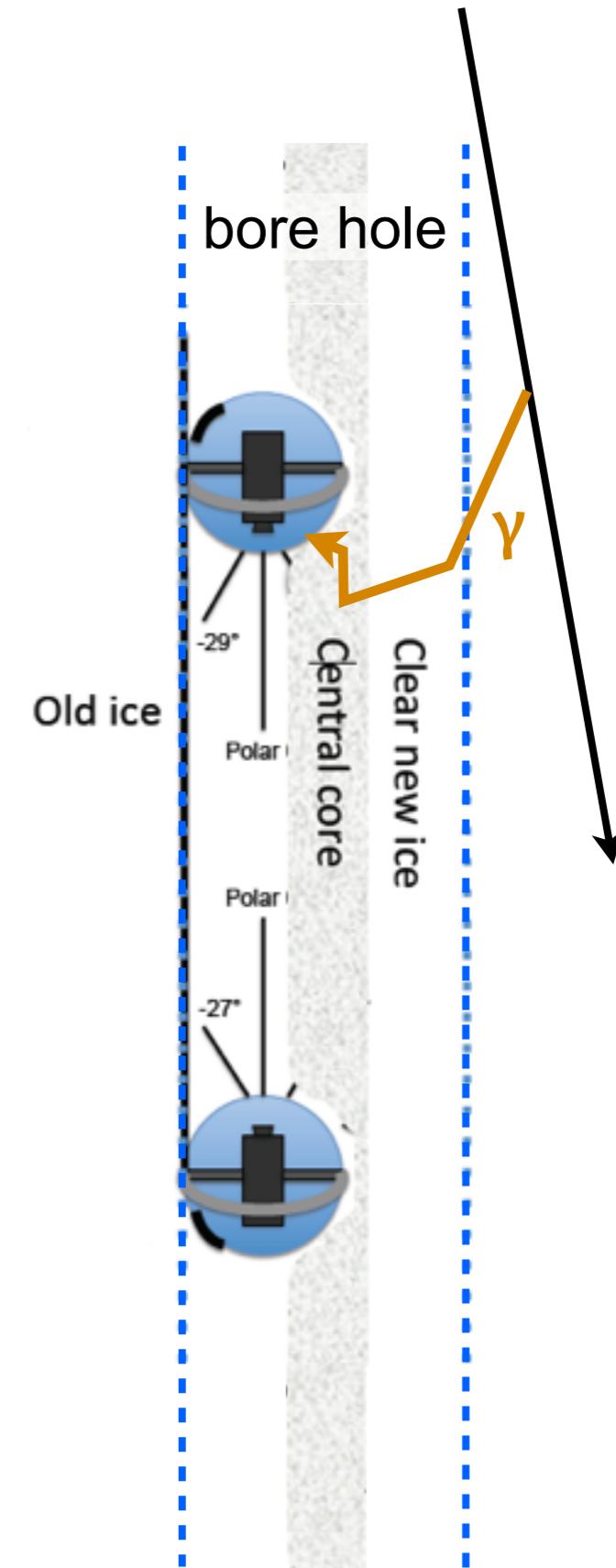
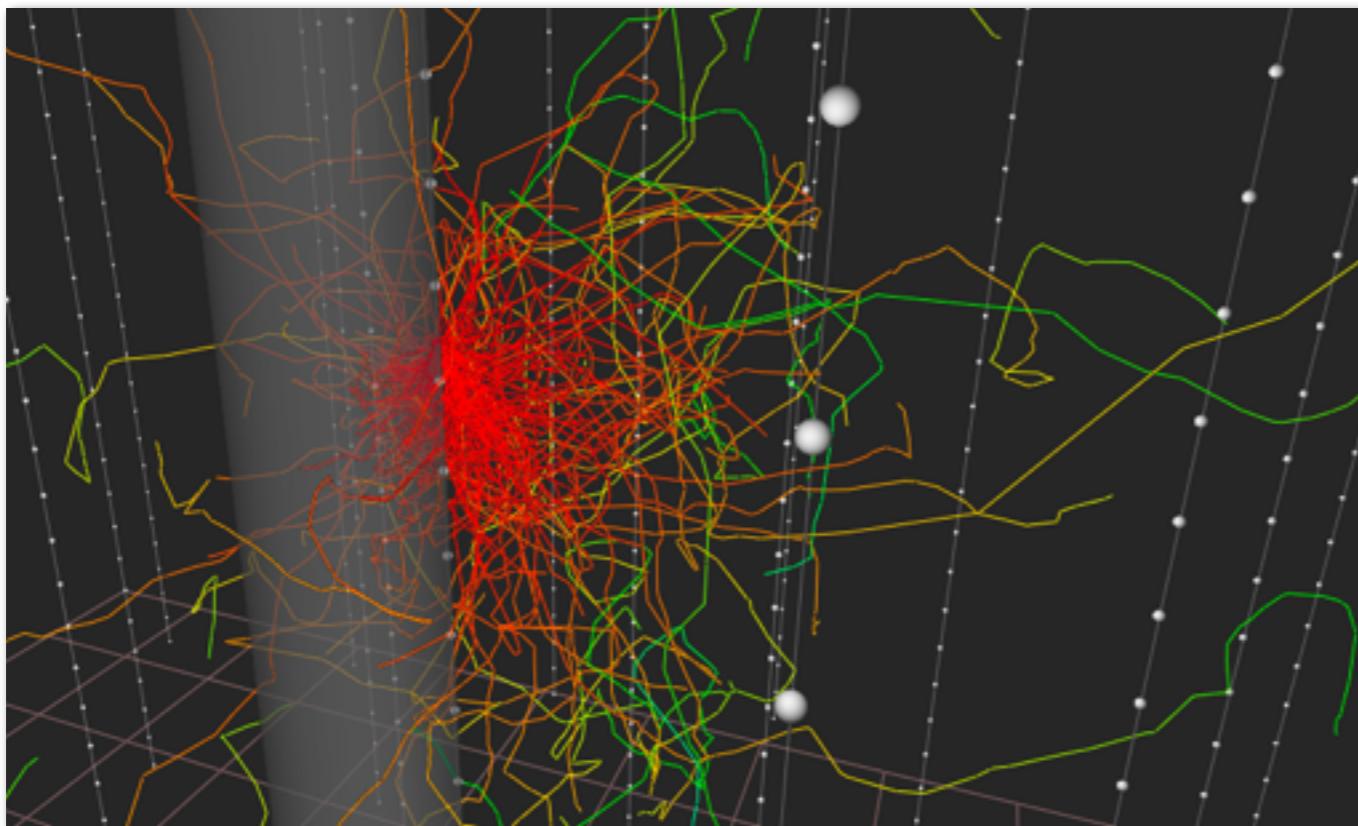
- Point-source search in the southern sky
 - Many interesting galactic TeV γ -ray sources
 - Problem: large atmospheric background



Current activities cont'd

Simulation

- Improvement of photon propagation
 - direct propagation of Cherenkov photons (parallel processing on GPUs)
 - implementation of accurate hole ice simulation



Current activities cont'd

Development of new optical sensor for IceCube-Gen2
(cooperation with DESY/Zeuthen and Alberta/Canada)

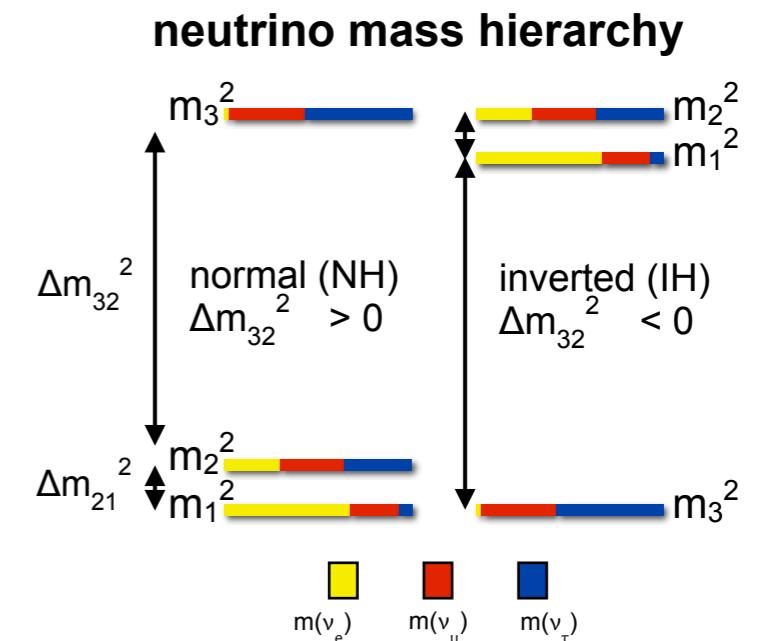
- PMT characterization
- Mechanical setup
- Readout
- Prototype building
- Performance simulations



Prospective activities:

- Multi-Messenger astronomy
- Neutrino oscillations
- Indirect WIMP dark matter
- Sterile neutrinos

GRK 2149: Strong and **Weak**
Interactions – from
Hadrons to **Dark Matter**



The neutrino sky

