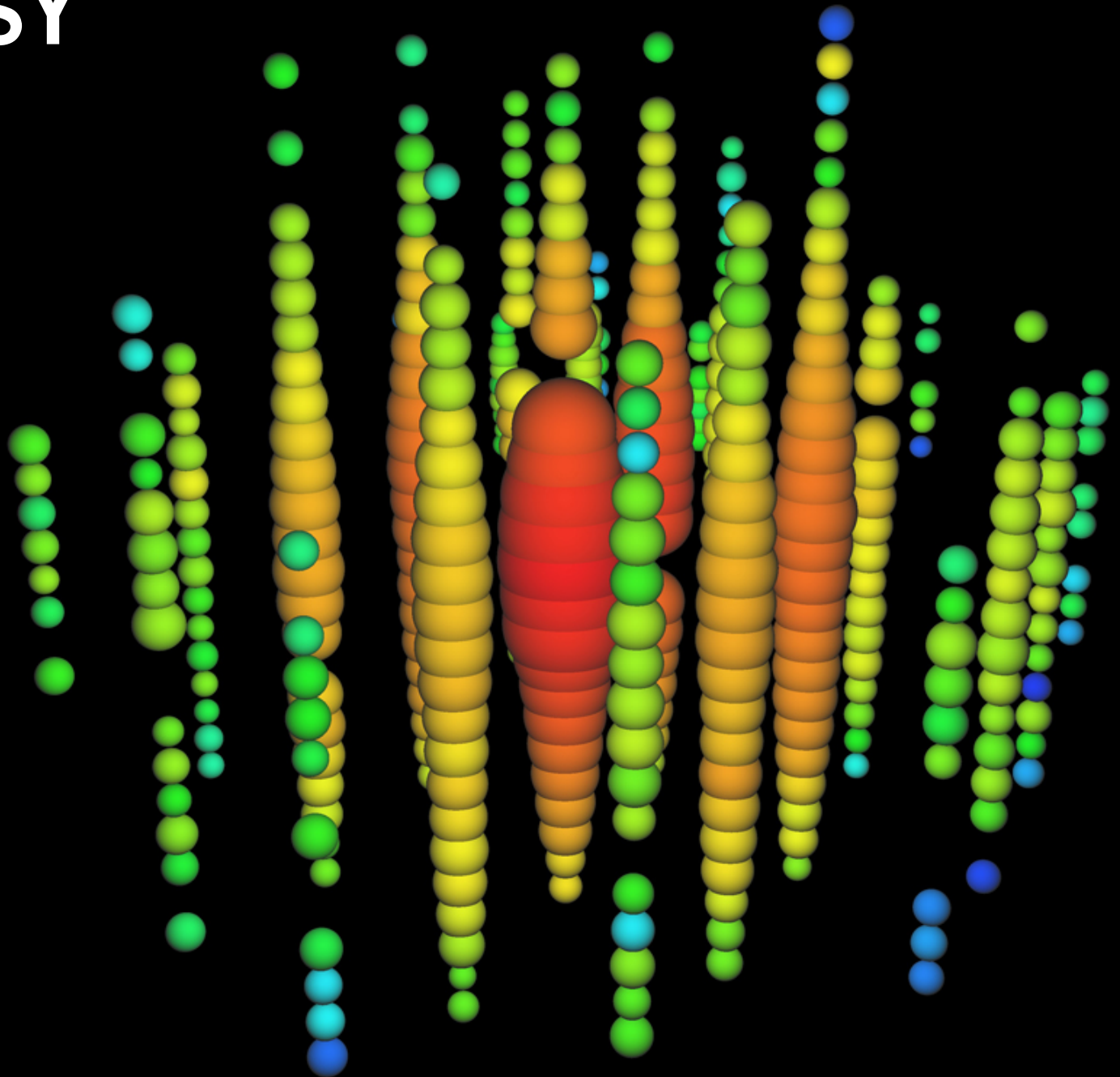


IceCube @ DESY

Marek Kowalski
PRC, 16.10.2014

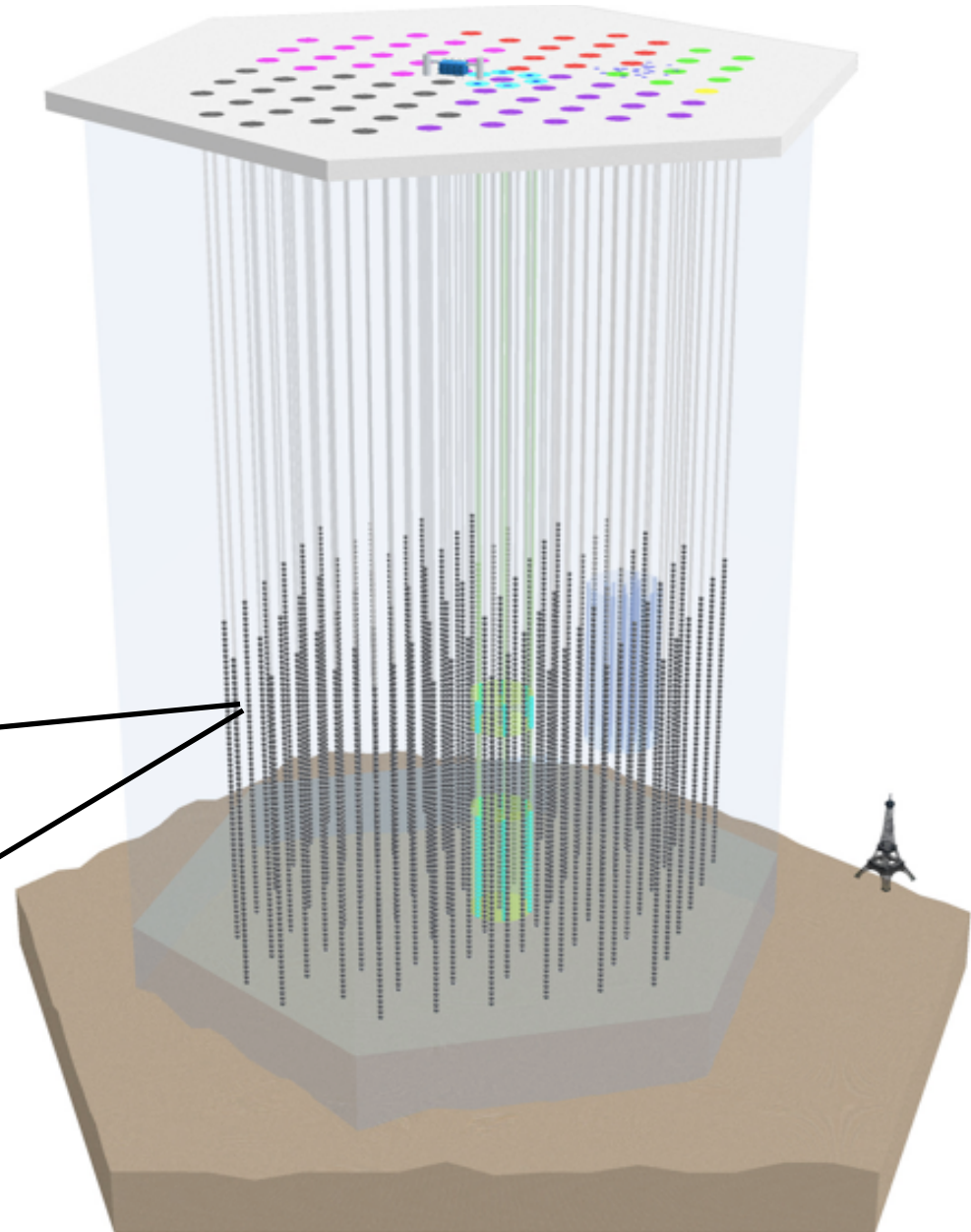
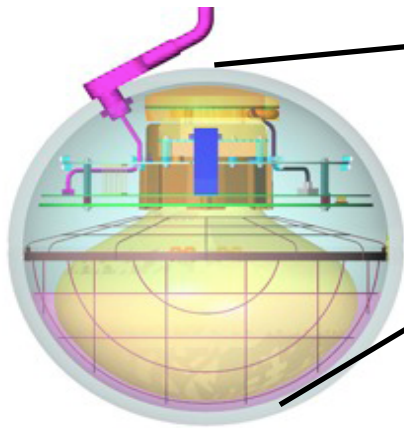


The IceCube Neutrino Observatory

IceCube

- 86 Strings, 5360 DOMs
 - $E_{\text{thresh}} \sim 100 \text{ GeV}$
- astrophysical neutrinos

digital optical module (DOM)
housing 10 inch PMT



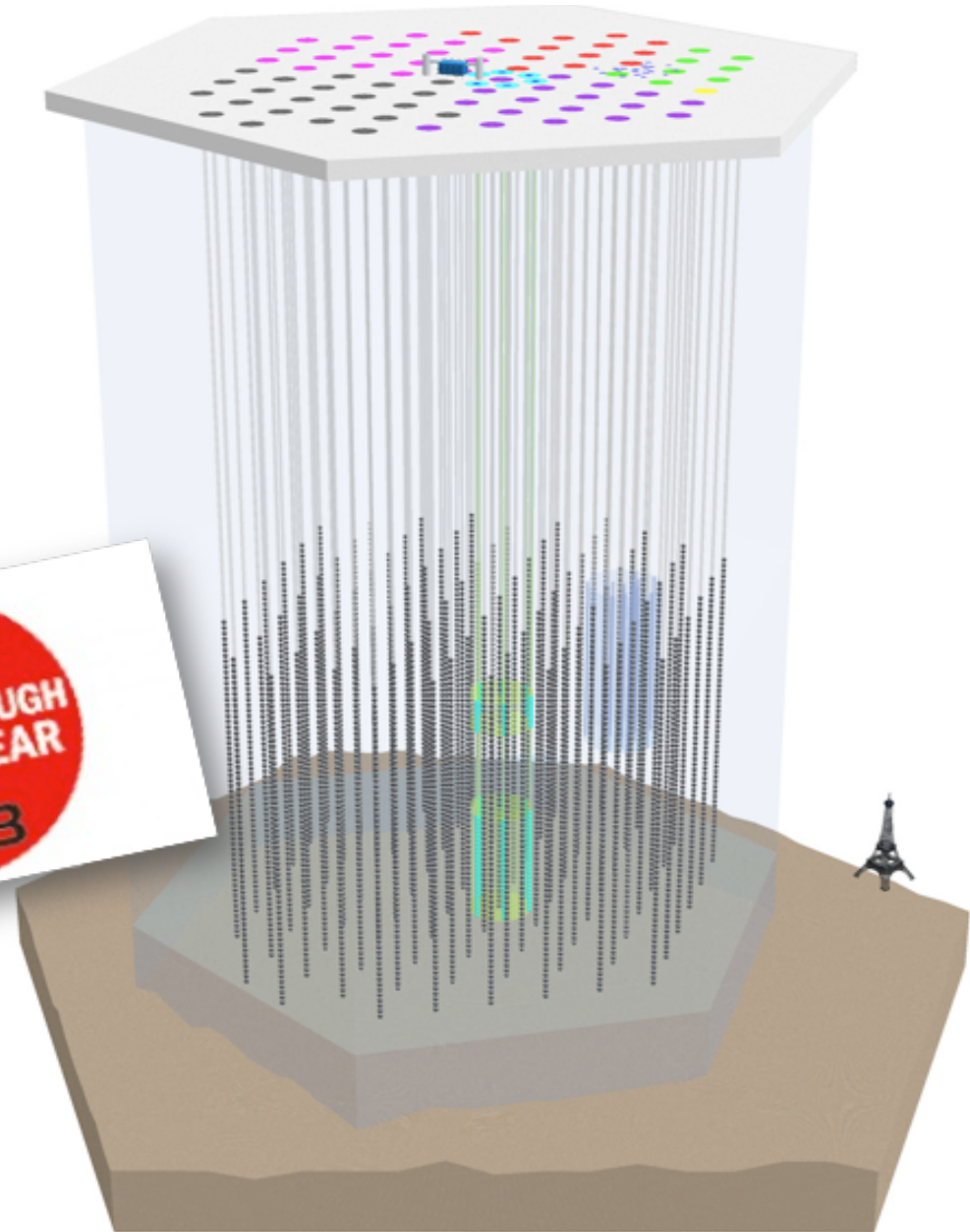
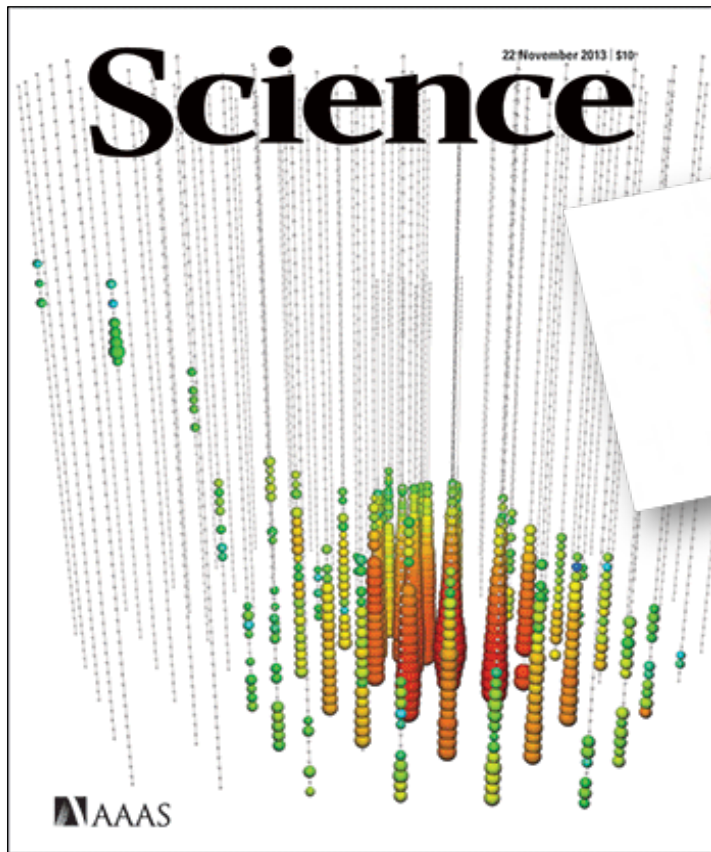
IceCube @ DESY:

5 Staff, 2 Postdocs, 12 PhD

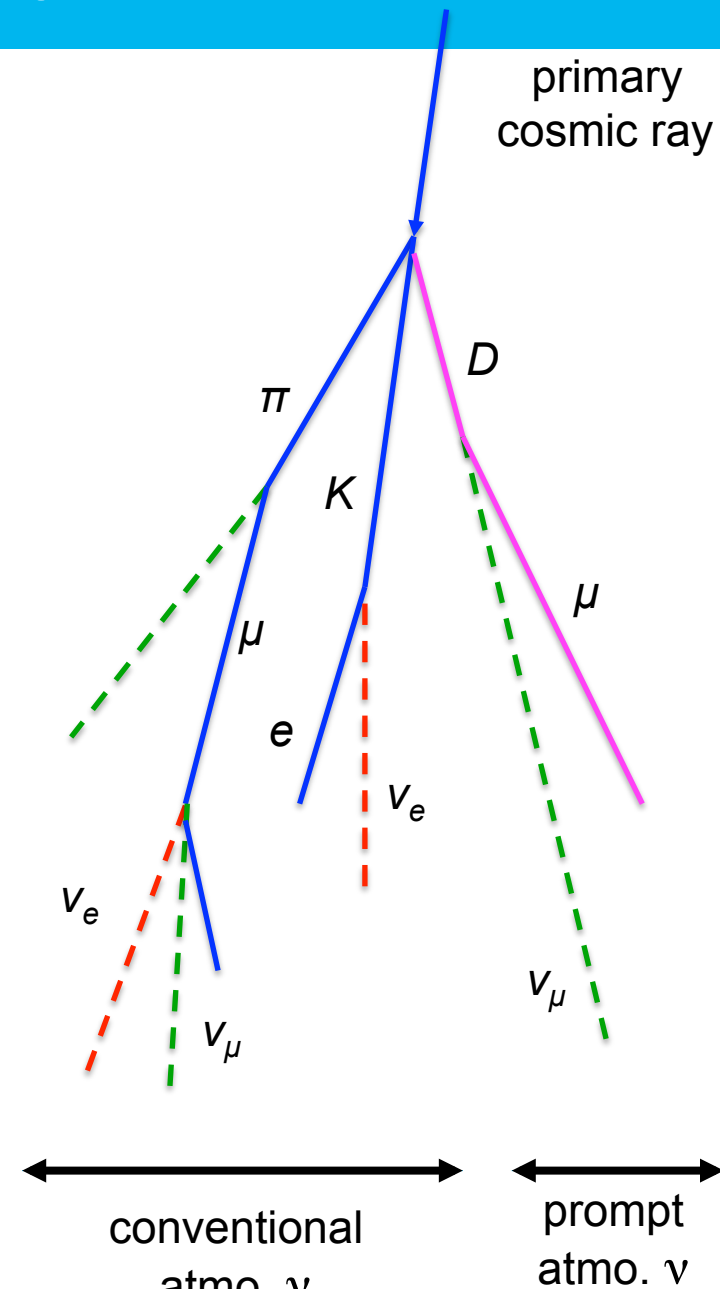
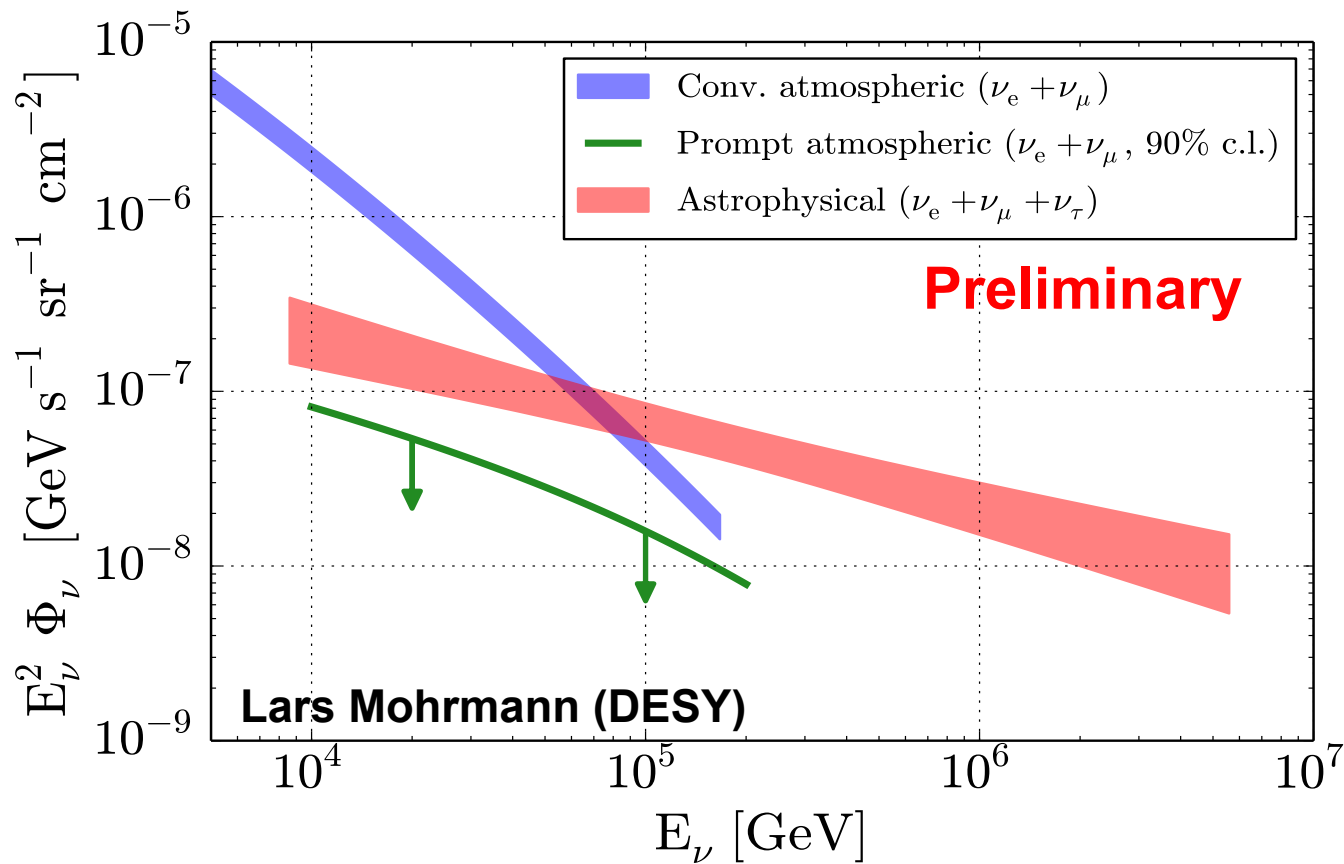
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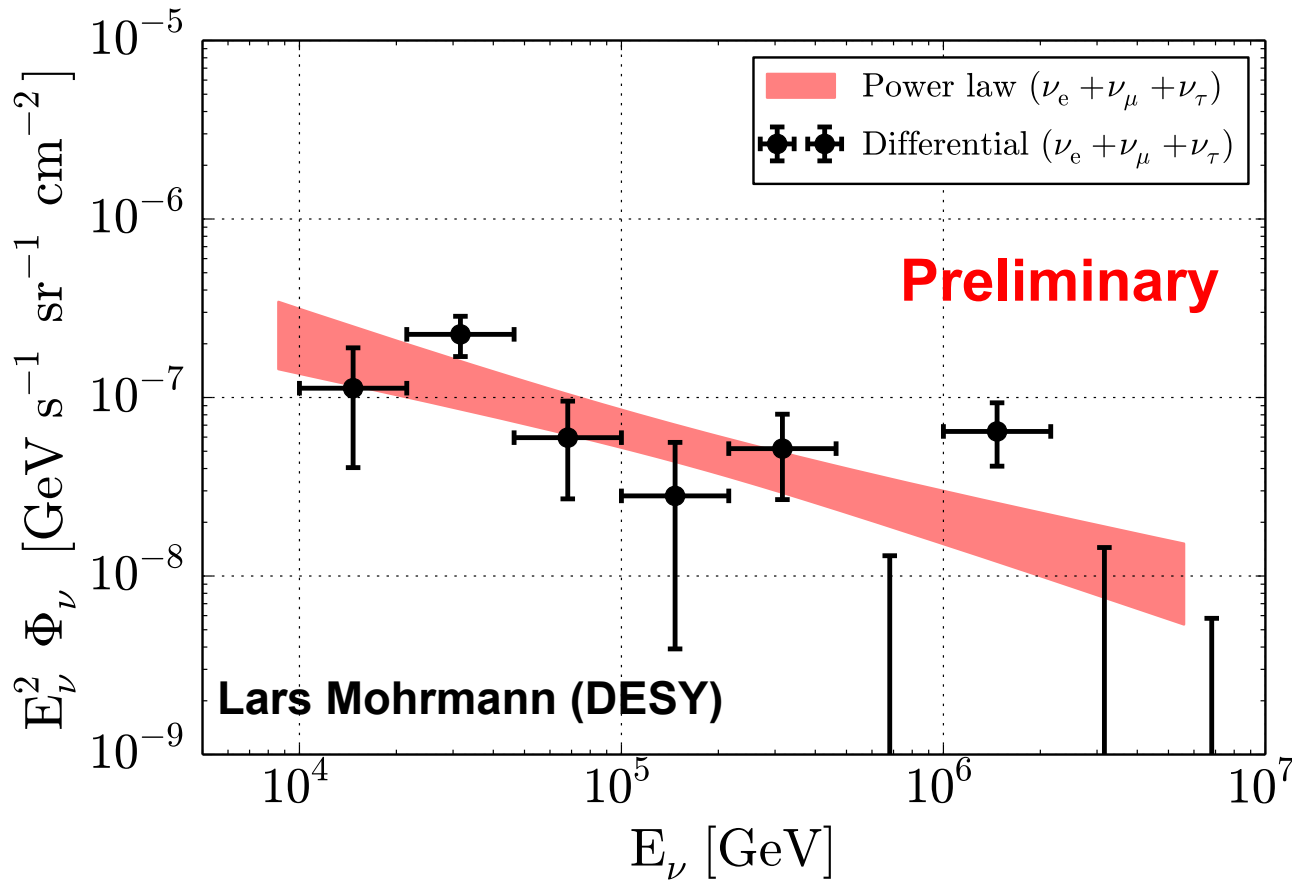
Current constraints on the diffuse flux



Combined analysis of 6 IceCube data sets

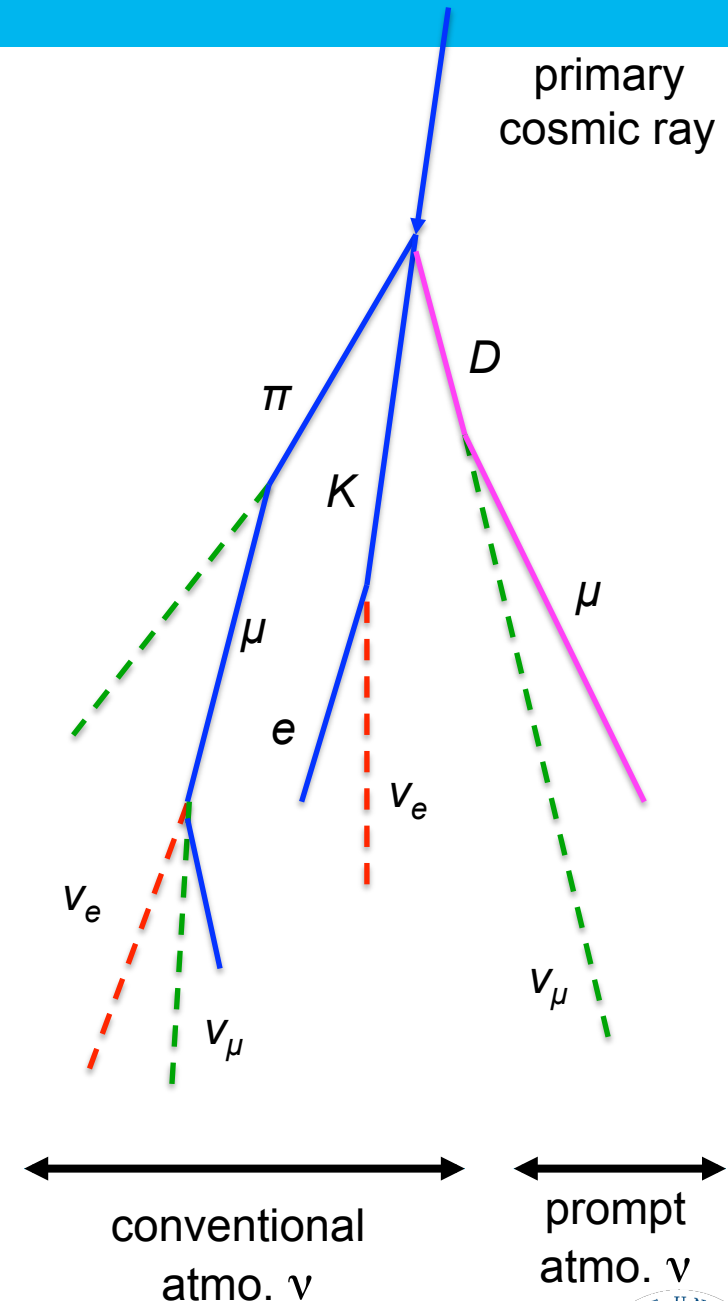
- > $\phi = (2.29 \pm 0.36) \times (E/100 \text{ TeV})^{-\gamma} \times 10^{-18} \text{ GeV}^{-1} \text{ s}^{-1} \text{ sr}^{-1} \text{ cm}^{-2}$ with spectral index $\gamma = 2.50 \pm 0.08$
- > Charmed meson (prompt) component $< 1.5 \times \text{pCCQ}$ model

Current constraints on the diffuse flux



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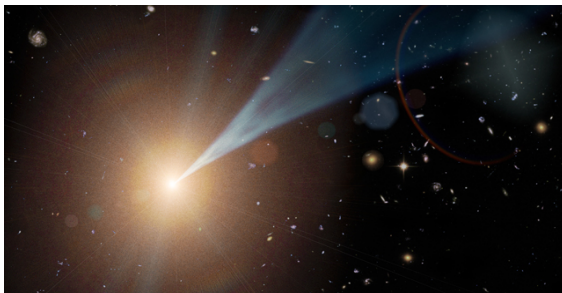
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- Charmed meson (prompt) component $< 1.5 \times$ pCCQ model



Neutrinos from Blazars (Active Galactic Nuclei)

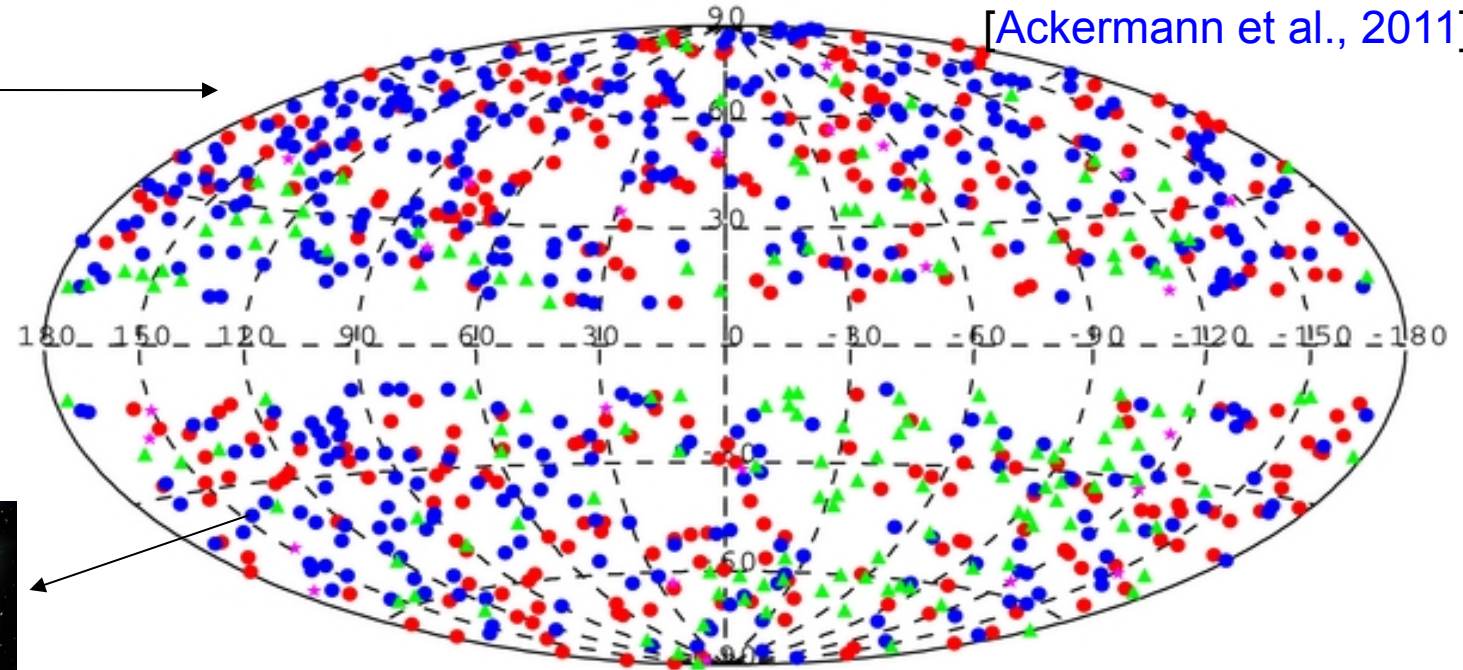


Total sources: ~ 900



FERMI-LAT AGN SKYMAP ($|b| > 10$)

[Ackermann et al., 2011]



● FSRQ

● BL-LAC

◆ Unknown Blazar

- Look for faint **combined** neutrino emission from these sources
- Nothing observed \Rightarrow Neutrinos from FSQR and BL-LAC AGNs less than 10-20% of measured diffuse signal

Thorsten Glusenkamp (DESY)

IceCube neutrino follow-up



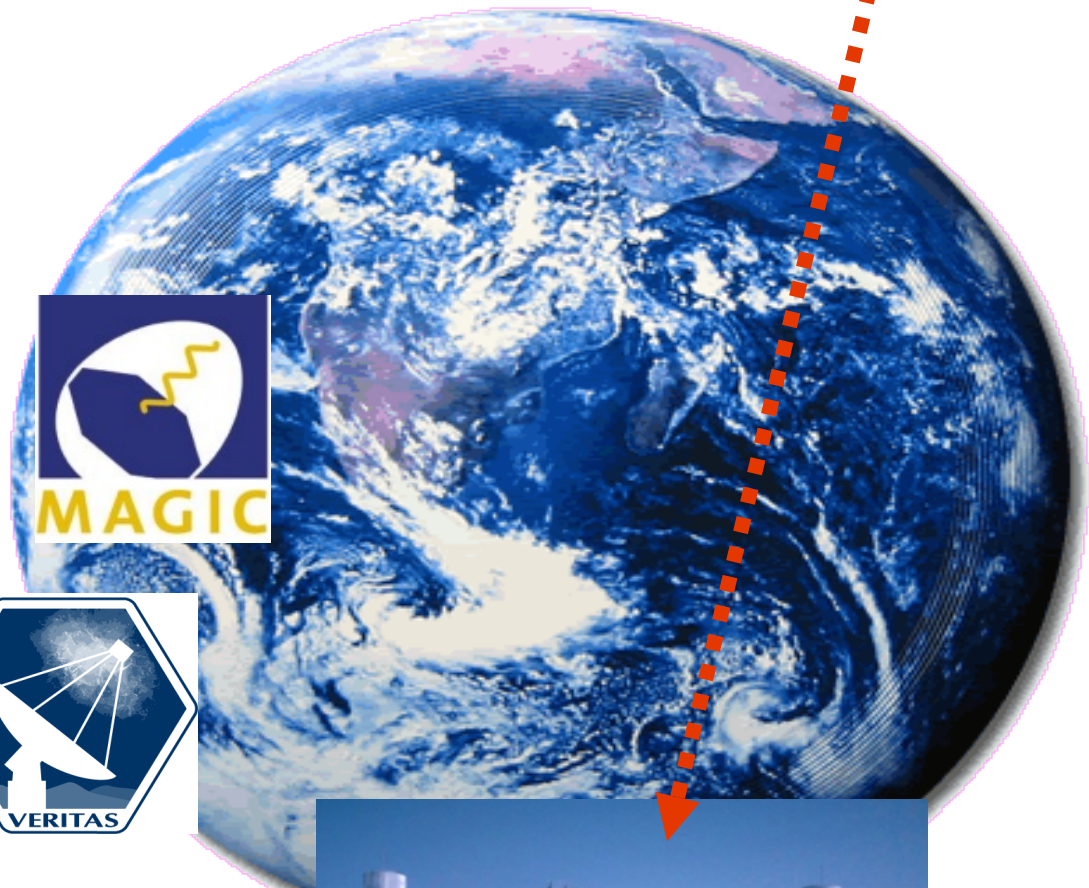
Swift (X-Ray)



PTF (optical)



AGN/SN/GRB



MAGIC

(Gamma-Ray)



VERITAS

(Gamma-Ray)



iridium



ICECUBE
SOUTH POLE NEUTRINO OBSERVATORY



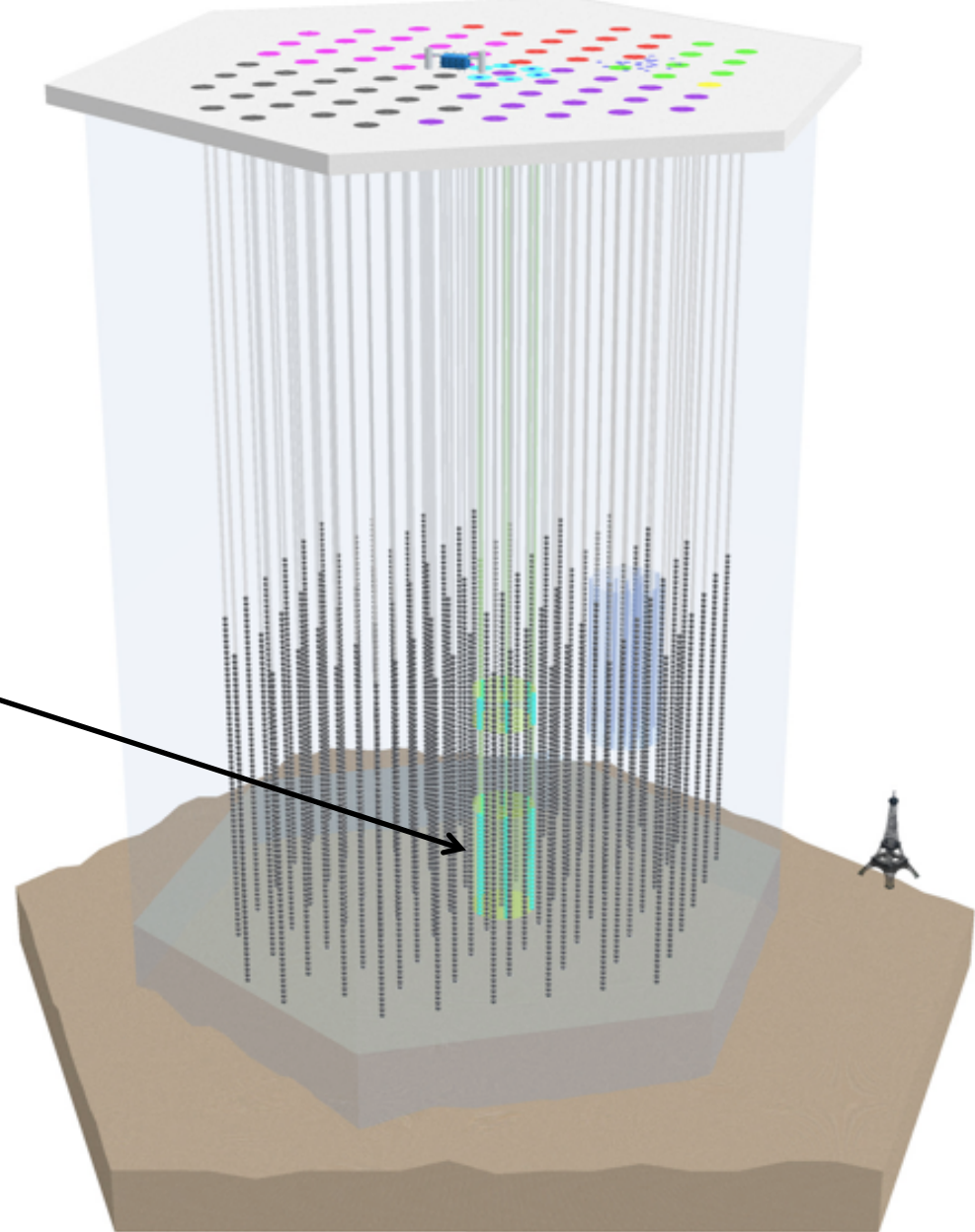
IceCube → DeepCore

IceCube

- 86 Strings
- $E_{\text{thresh}} \sim 100 \text{ GeV}$
- astrophysical neutrinos

DeepCore

- 8 denser strings
- $E_{\text{thresh}} \sim 10 \text{ GeV}$
- neutrino oscillations



IceCube → DeepCore

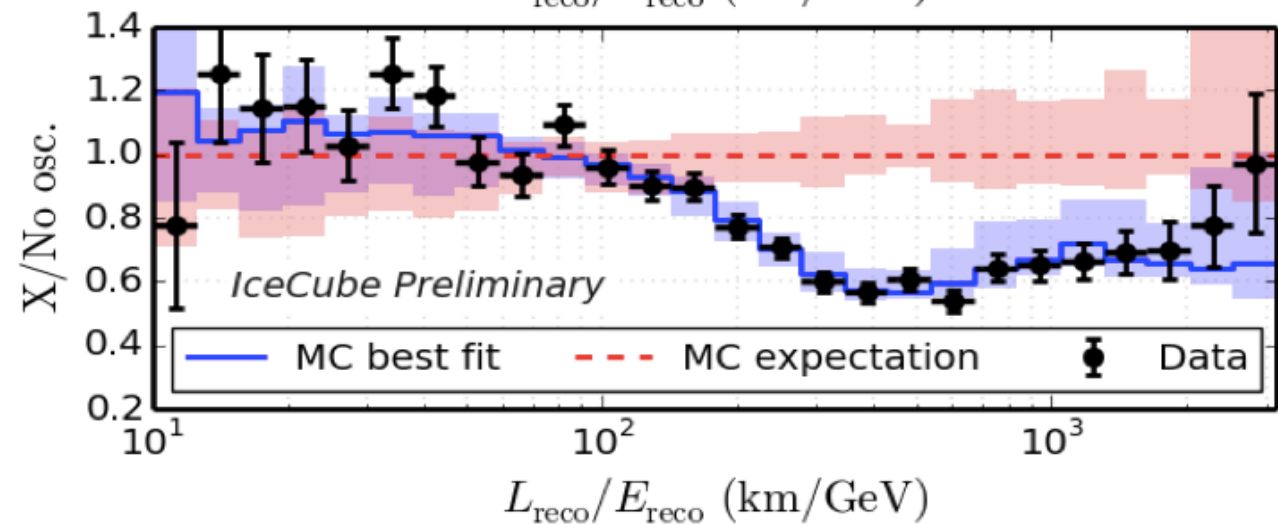
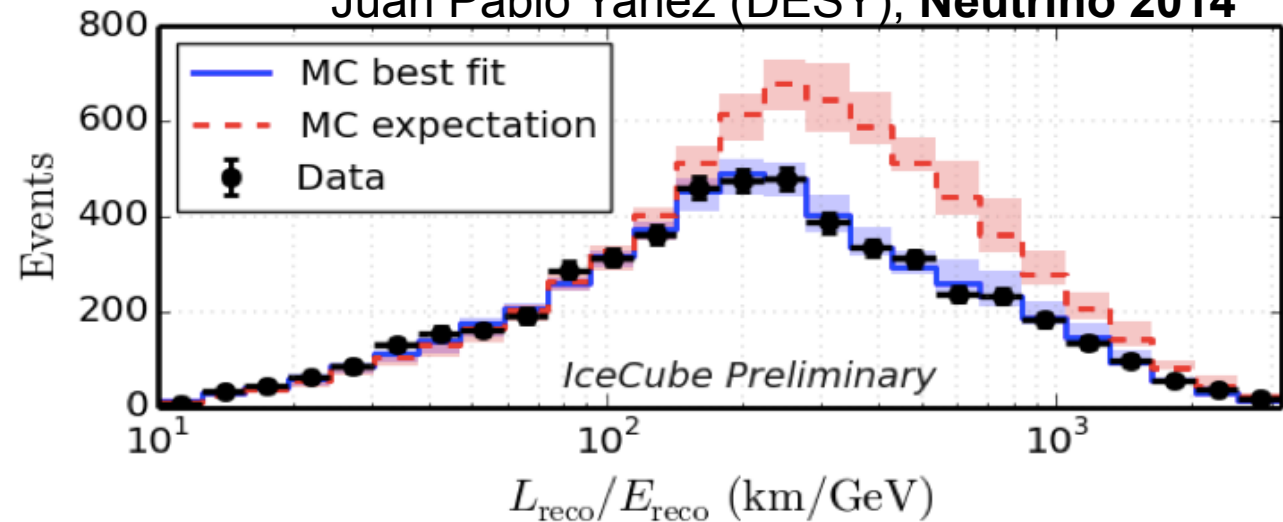
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Juan Pablo Yanez (DESY), Neutrino 2014



IceCube → DeepCore

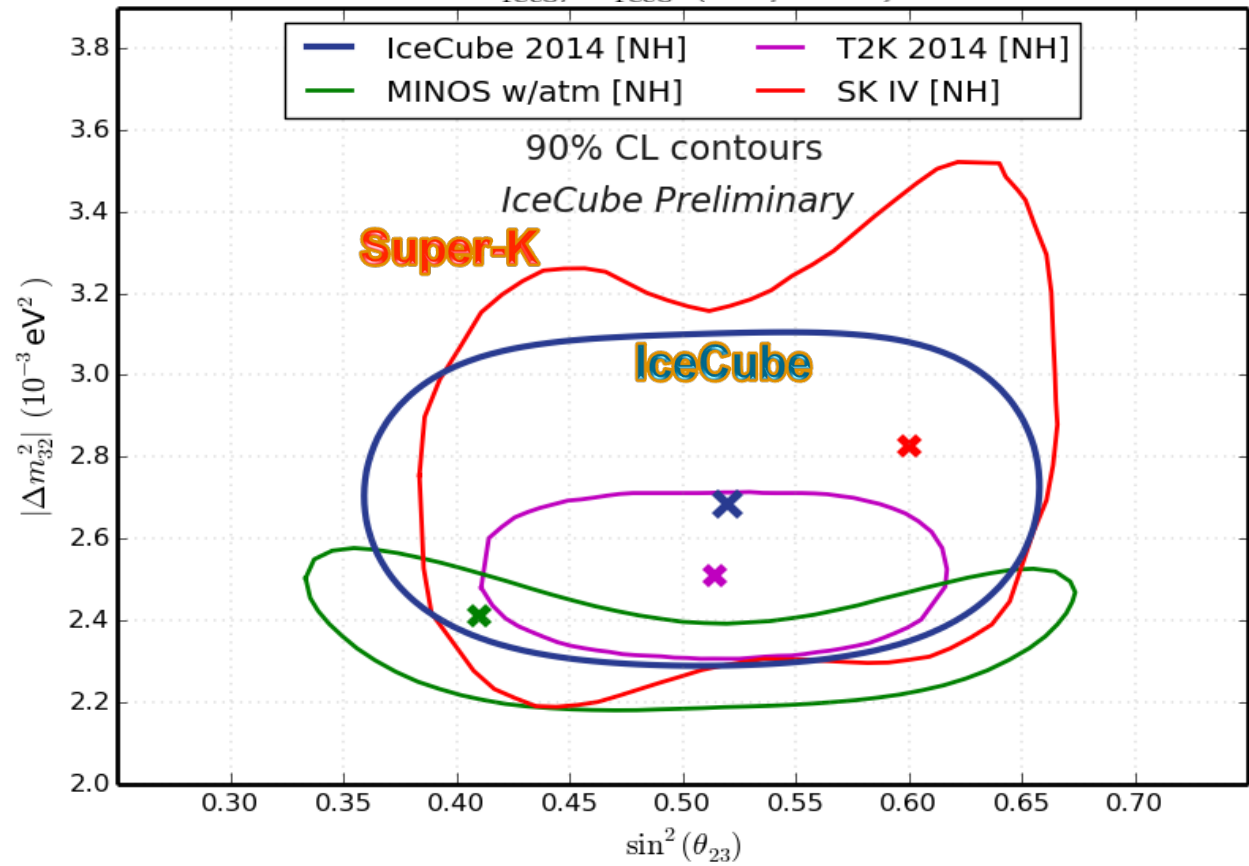
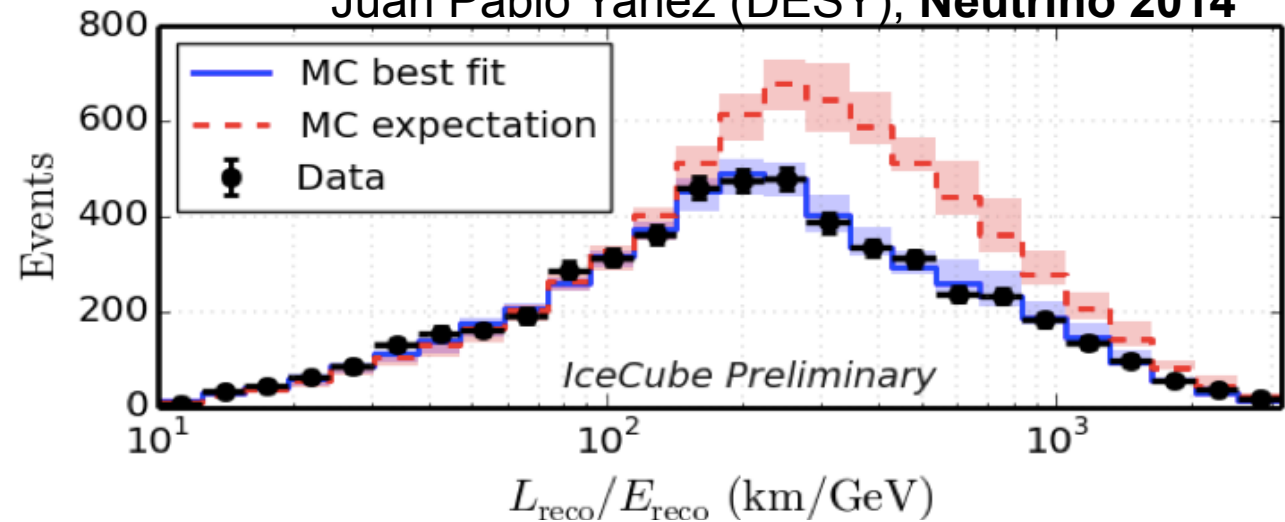
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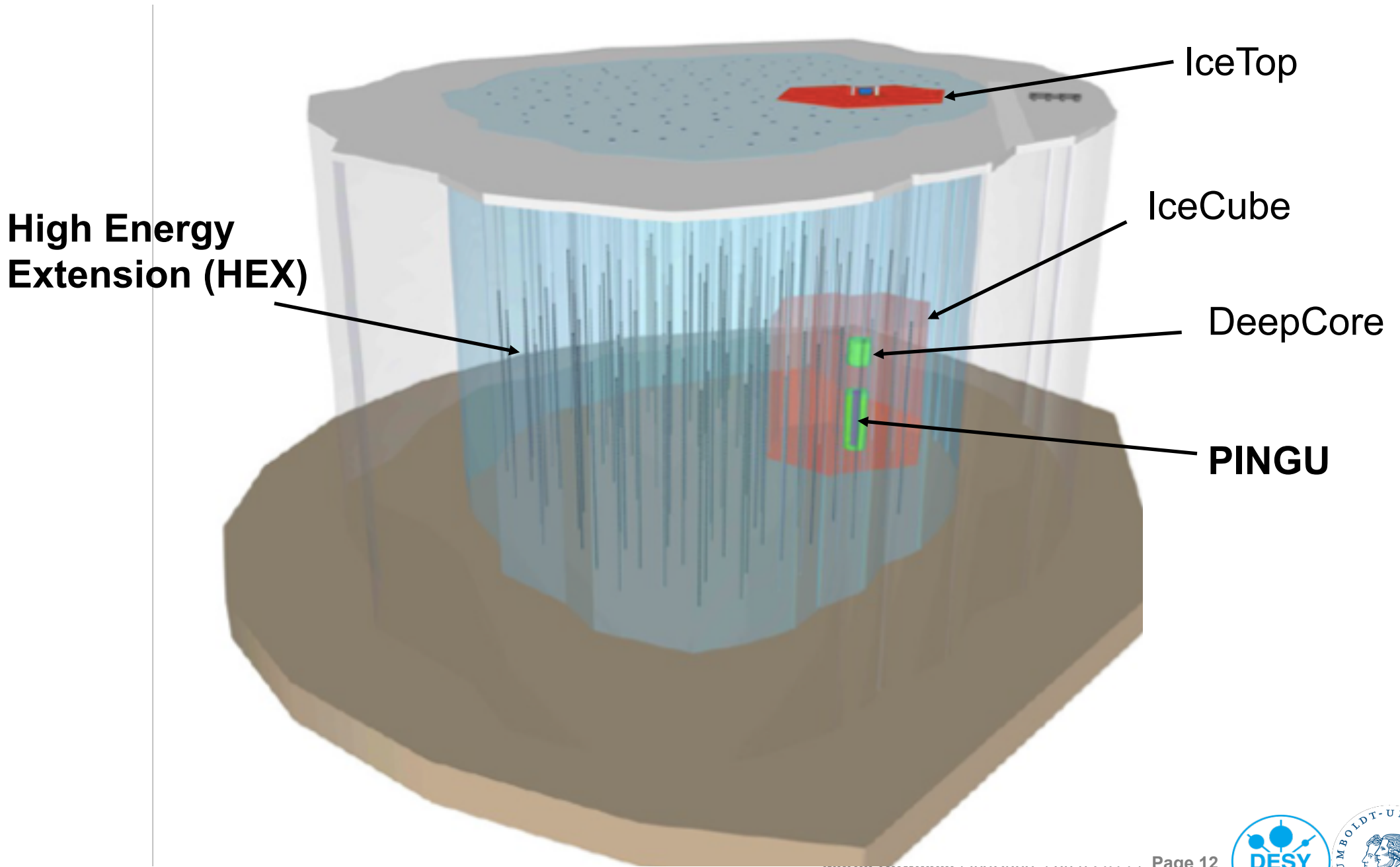
Juan Pablo Yanez (DESY), Neutrino 2014



Next Generation IceCube



Next Generation IceCube (NGIC)

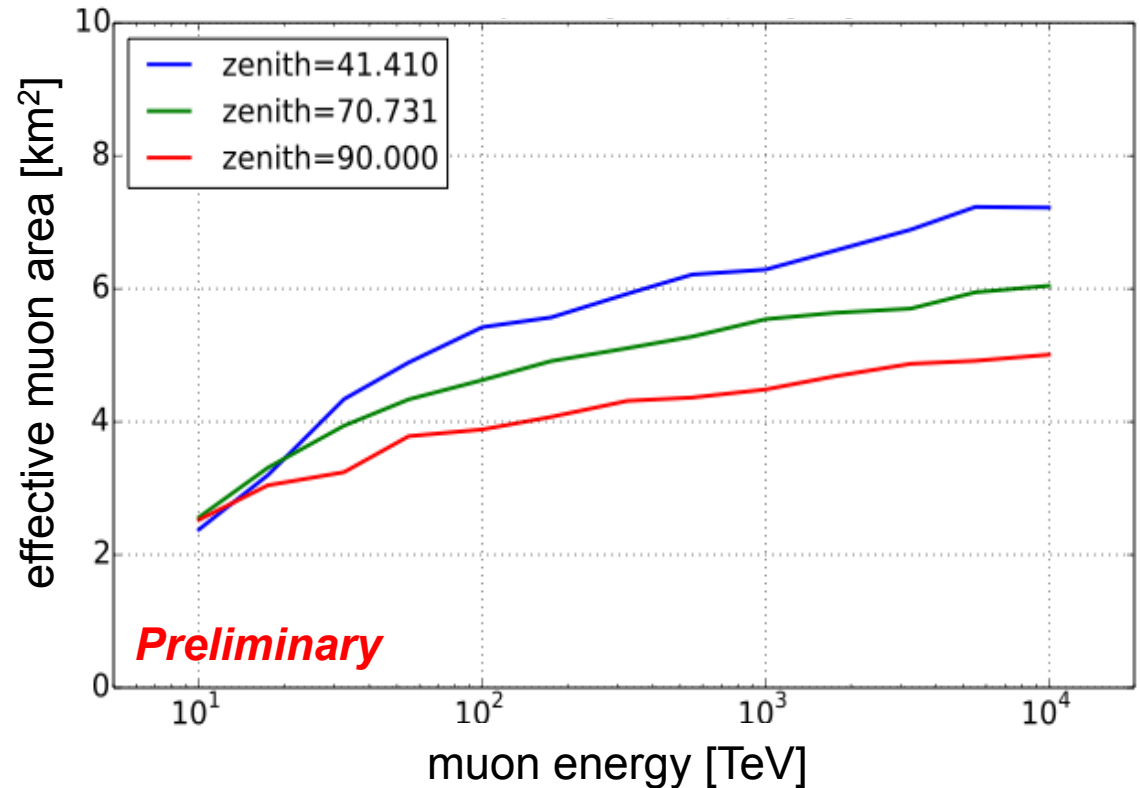
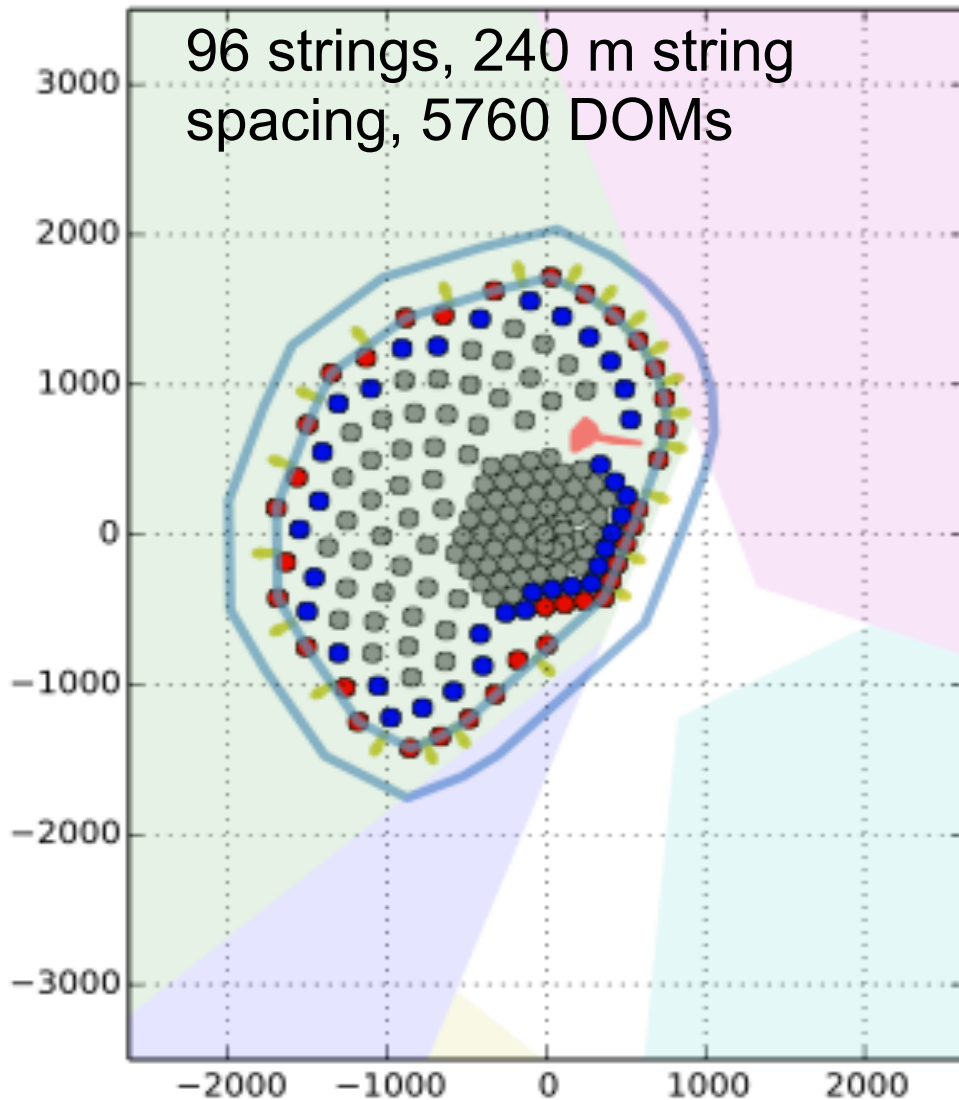


Science drivers for a high energy extension

- ✧ **Resolving neutrino sources**
 - origin of cosmic rays
- ✧ **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

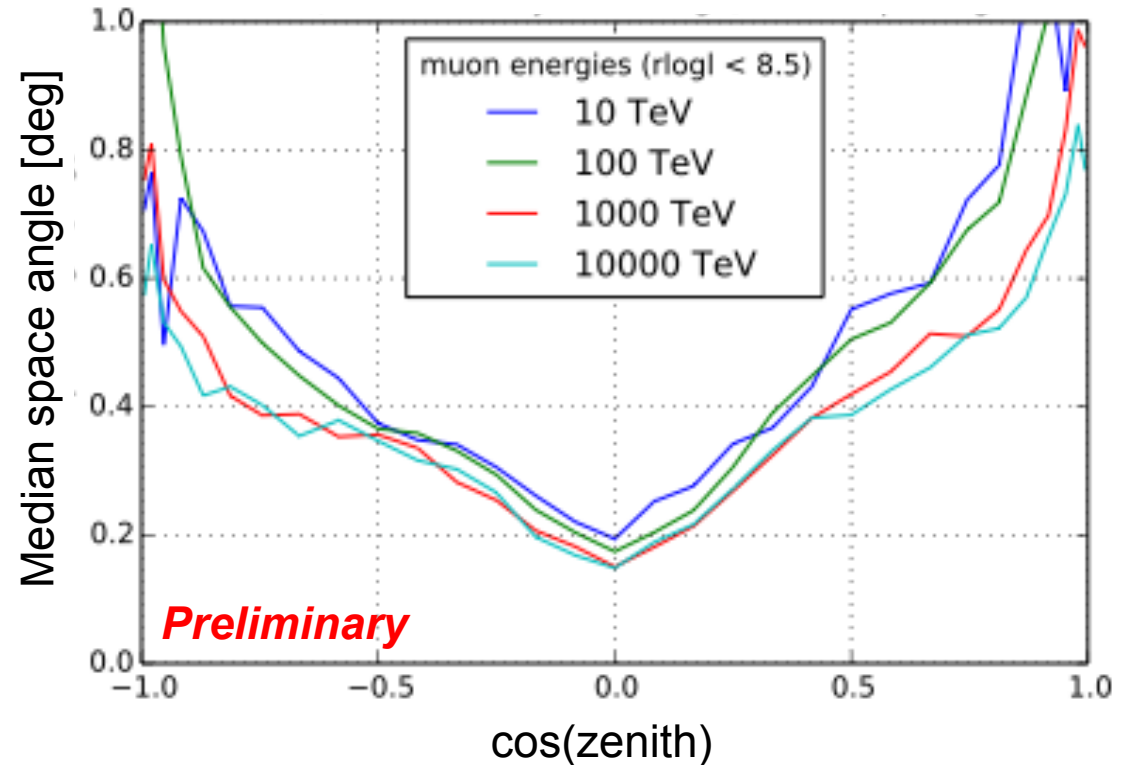
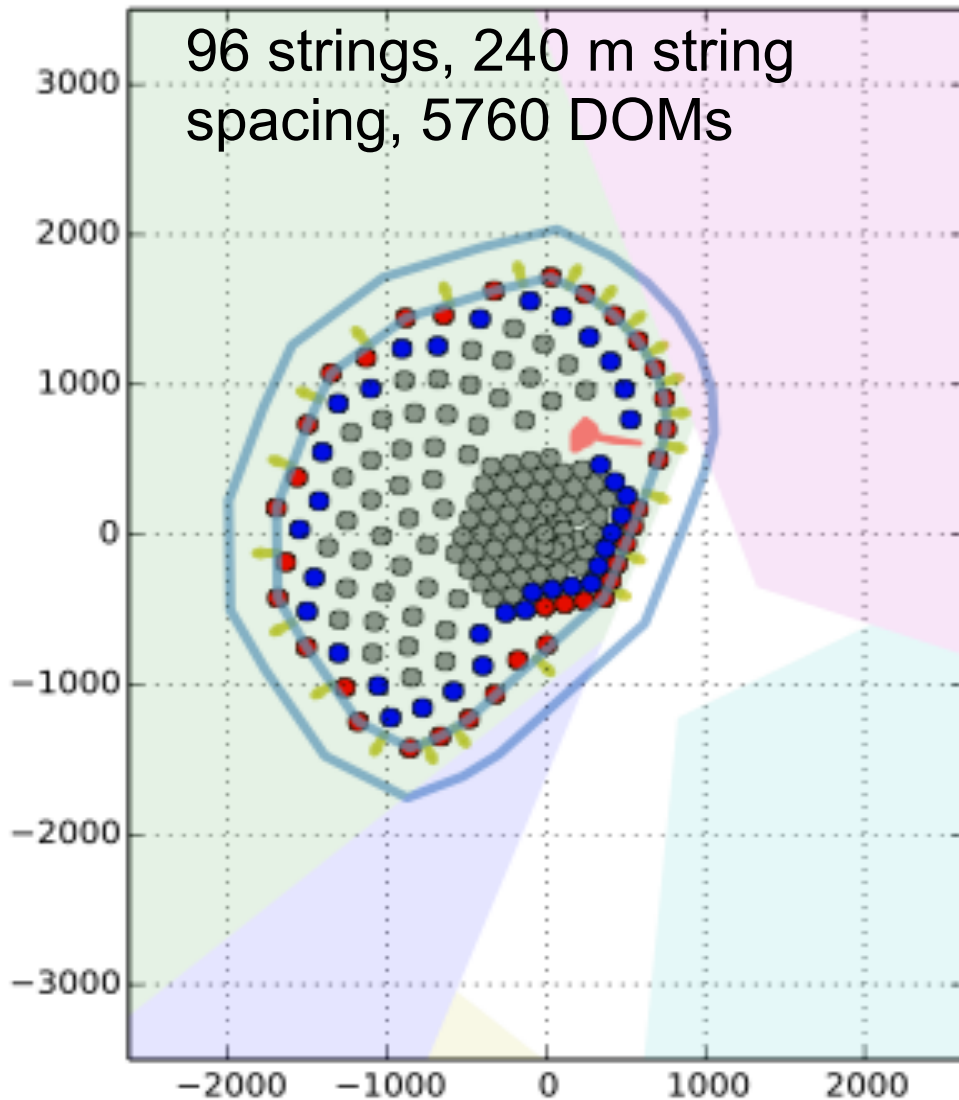
**Order of magnitude increase in
sensitivity required**

Configuration studies



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

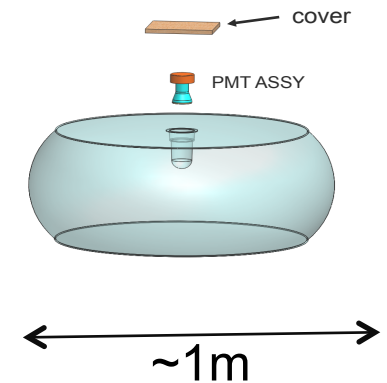
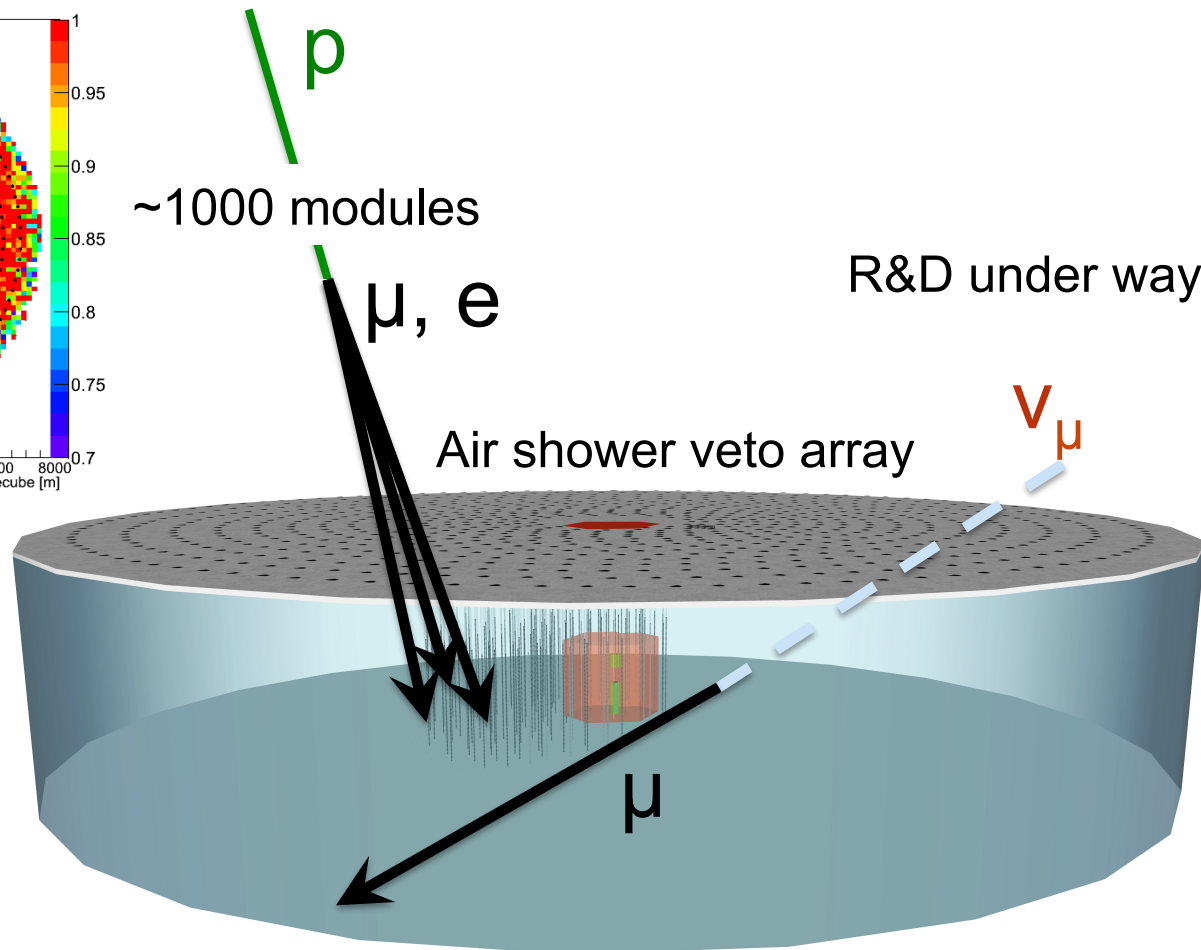
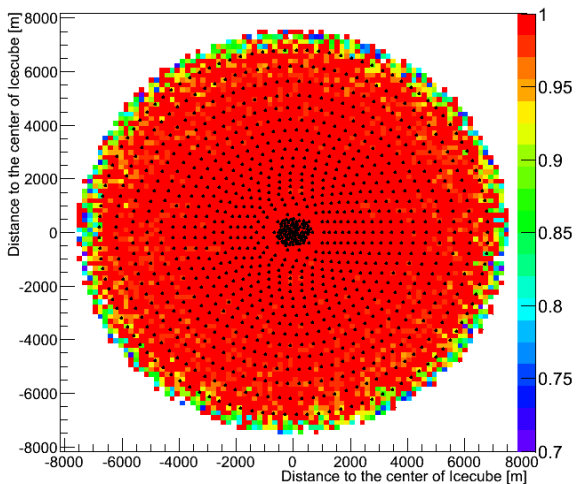
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- Volume: $\sim 6.5 \text{ km}^3$
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Surface Veto

- > Surface detector for ~ 1 PeV cosmic primary to reject most atmospheric muon AND neutrino background above 100 TeV.
- > 100 km² surface veto $\Rightarrow \sim 5$ bg. free cosmic neutrinos / yr



PINGU

IceCube

- 86 Strings
- $E_{\text{thresh}} \sim 100 \text{ GeV}$
- astrophysical neutrinos

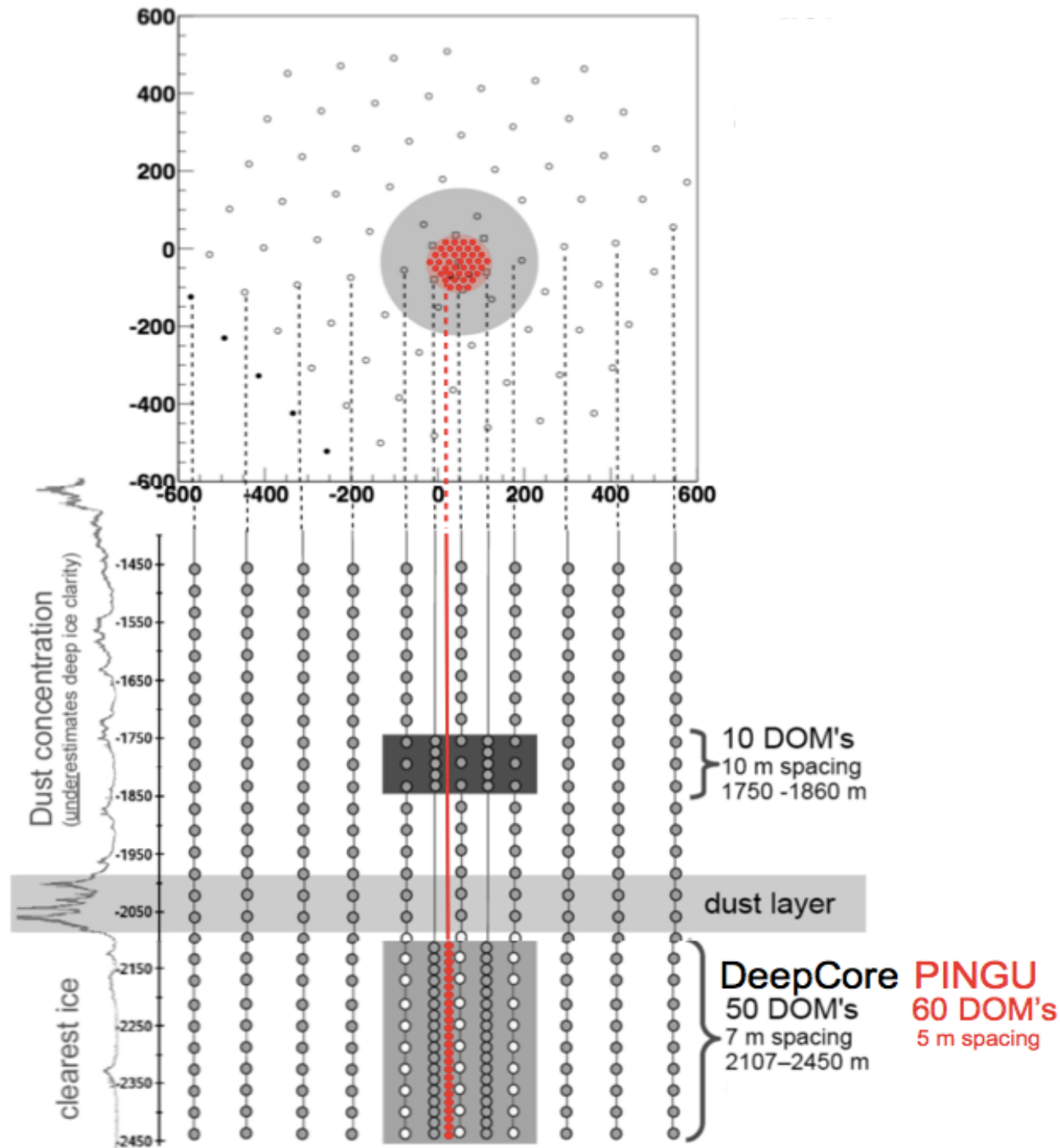
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PINGU (planned)

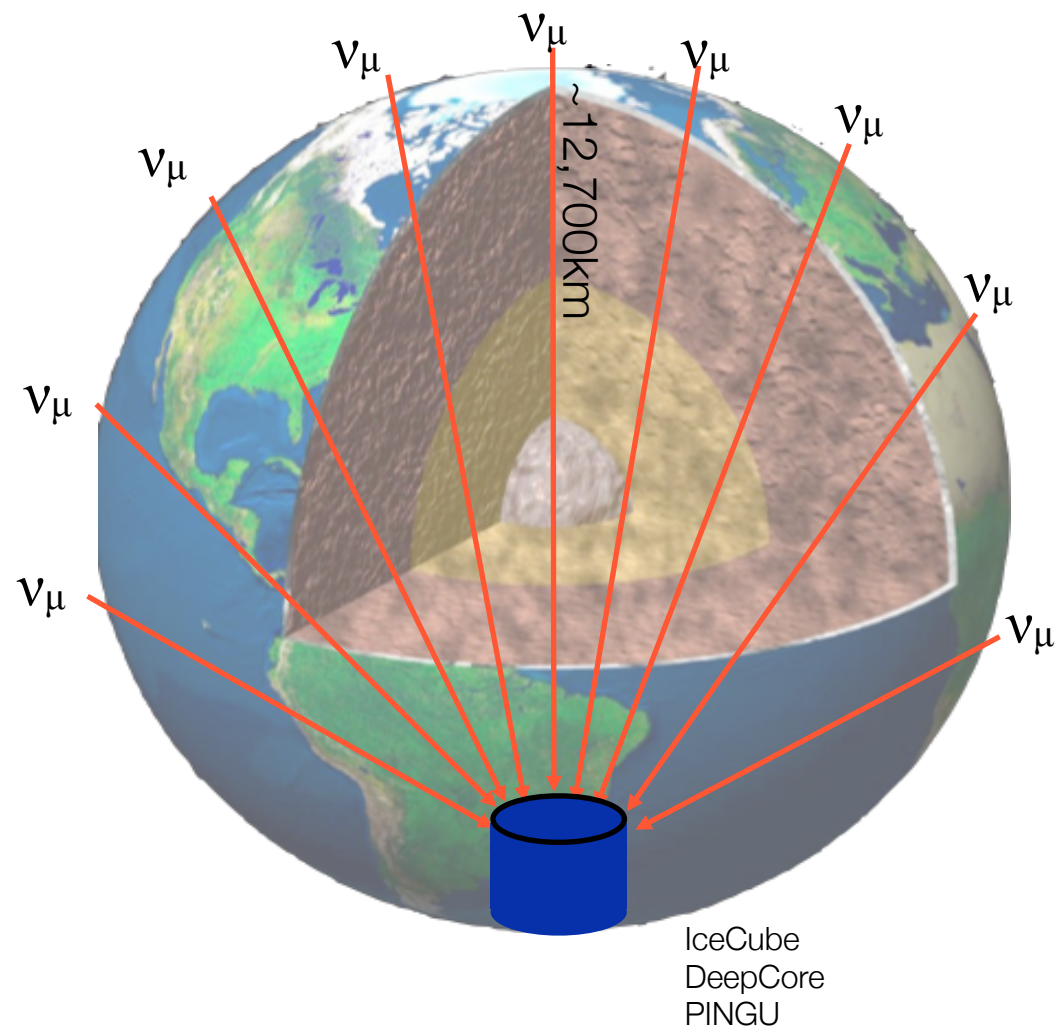
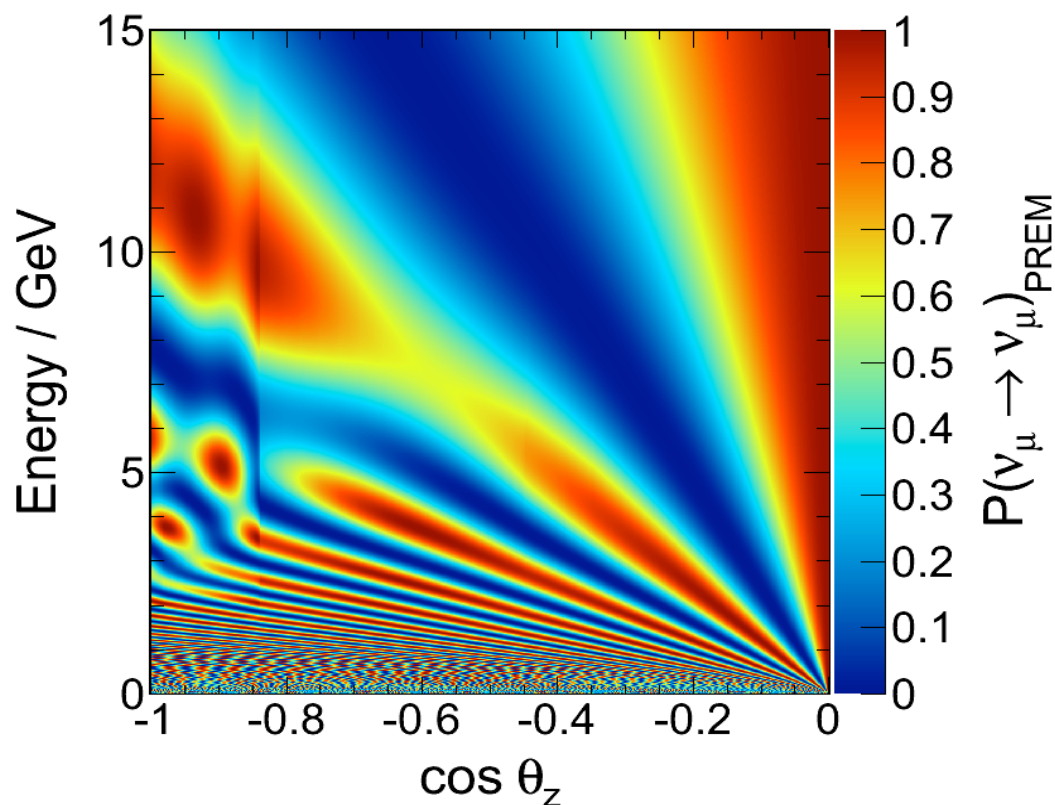
- 40 strings
- $E_{\text{thresh}} \sim 1 \text{ GeV}$
- neutrino mass hierarchy

Letter of Intent, [arXiv:1401.2046](https://arxiv.org/abs/1401.2046)



Neutrino Oscillations with atmospheric Neutrinos

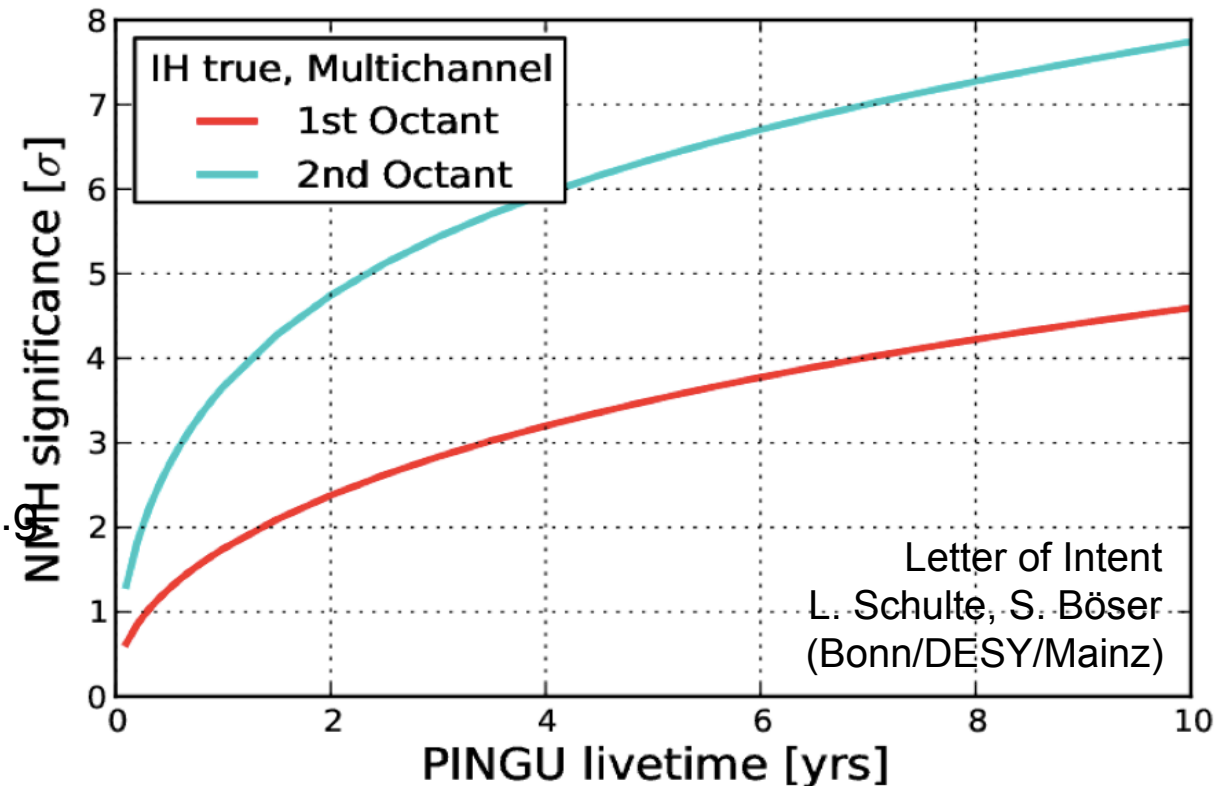
- First oscillation minimum at 24 GeV, i.e. DeepCore energies
- Hierarchy-dependent matter effects below 12 GeV (e.g. Akhmedov et al. JHEP2013)



PINGU and the Neutrino Mass Hierarchy

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

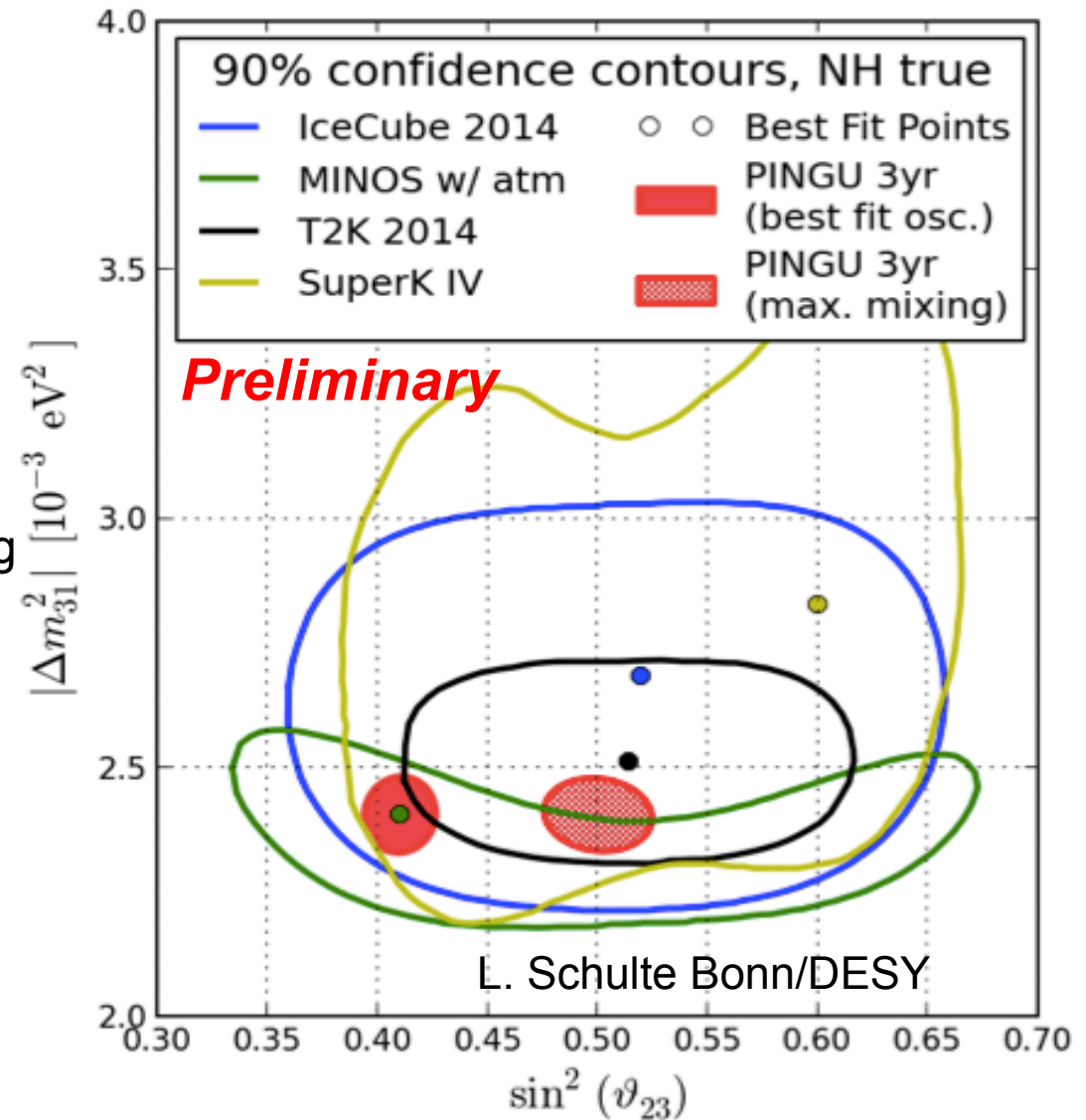
- Optimization of analysis techniques and more detailed treatment of systematics underway
- Synergy with JUNO: Nearly a factor two better constraints from combination (e.g. Blennow, Schwetz, arXiv:1306.3988)
- And there is more: Neutrino oscillations, dark matter,...



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Summary & Outlook

- Improved constraints on diffuse flux, hunt for its sources is starting
- Strong constraints on atmospheric mixing parameters; IceCube surpassed Super-Kamiokande in sensitivity
- Building on IceCube's success, expand to lower/higher energies
- NSF-MREFC proposal in 2015 for funding in 2017, significant international contributions expected
- Construction to start in 2019 – PINGU first
- **DESY strongly involved**



The IceCube-PINGU Collaboration



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)

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 NSF–Physics Division

Swedish Polar Research Secretariat
 The Swedish Research Council (VR)
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