The next generation neutrino telescope at the South Pole: IceCube-Gen2

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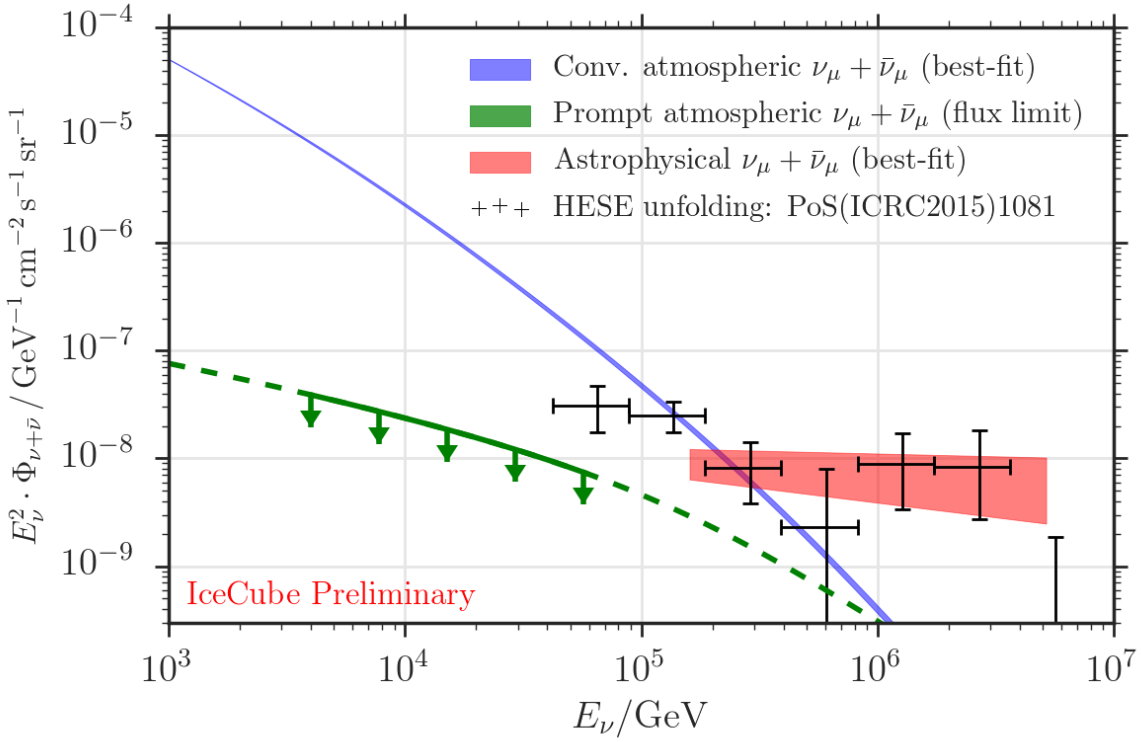
Summary of findings by IceCube

- Discovered TeV-PeV cosmic neutrino flux
  - Best fit power-law index in the energy region above 190TeV (7-year up μ) is−2.16±0.11
  - Becomes −2.58±0.25 (2015) when reducing energy threshold to 60TeV
- Many upperlimits on the various production models



The next targets of the neutrino astrophysics

- Identification of neutrino emitting objects ⇒ **origin and mechanism**
  - If neutrino source is transient, It is most relevant to study IceCube events followed up the other telescope in a timely manner. The HE alert system is in operation only since the last/this year. The next few years of observation is of particular interest
  - If steady sources, the limit obtained already by IceCube is already quite tight. A large improvements in the next few year is not expected
- Discovery of τ neutrinos ⇒ **the neutrino oscillation in a cosmological distance**
- Cosmic neutrino flavor ratio ⇒ **mechanism**
- Discovery of UHE neutrinos (above 10PeV) ⇒ **the origin of the highest energy cosmic-rays** upto 10^{20}eV
- More precise measurements of the astrophysical neutrino fluxes ⇒ **origin and mechanism**
  - Is there spectra hardening around the 100TeV region? Is it an indication of different components?
  - Spectra hardening or cut-off around 5-10PeV？
  - Is the flux truly isotropic? sub-dominant galactic component?
  - Any other features are important clue to their origins

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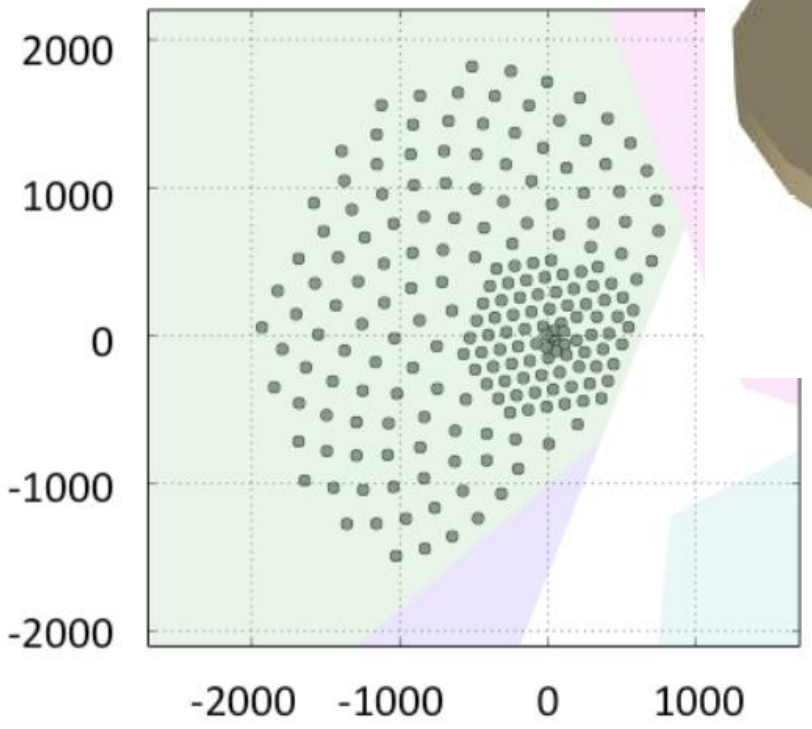
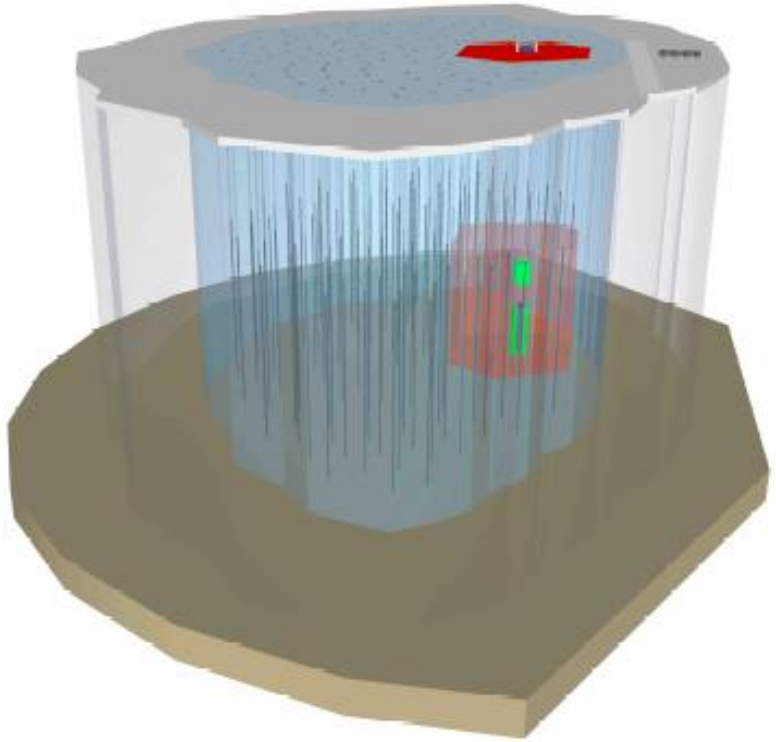


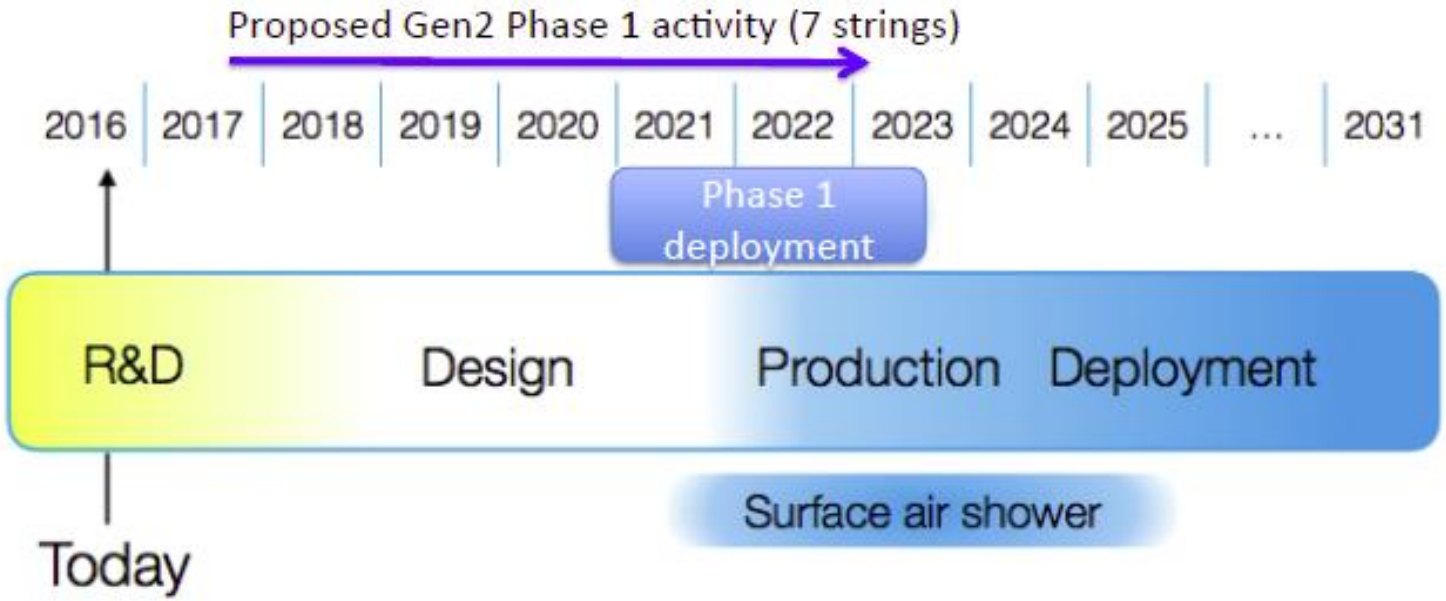


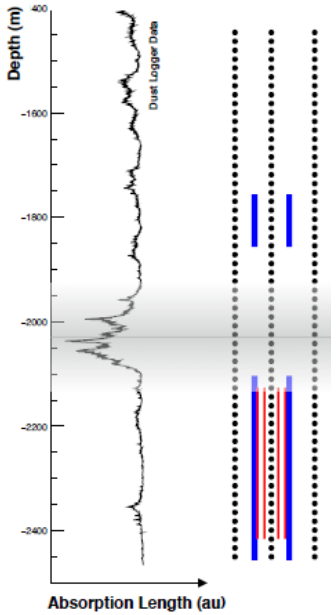
- Main array
  - 100 strings
  - 100 sensors/string
  - 240m distance
- Dense array
  - 26 strings
  - 125-192 sensors/string
- Surface array
  - muon veto

Target:
O(5-10) times IceCube data rates

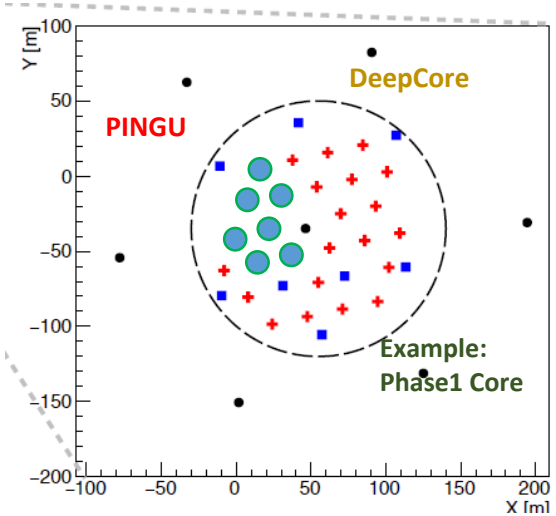
Gen2-Phase1

- An effective use of O($10M) for Mid-scale funding (MSF) opportunity (NSF)
- Use the MSF to accelerate our next generation projects (There may be some hard to estimate amount of time to get O($300M) budget with unforeseen circumstance)
- Strategy: $5M for "***Drill Refurbishment***", once drill is ready things easier to move forward
- The rest for new ice calibration devices (prototypes are already available) and 7 core(dense) strings
- Fixed design and tests by the end of 2018, 2019- production, deployment 2021/2022 and 2022/2023 seasons
- ***Enhanced Hot water Drill, design updates on-going,*** as soon as NSF approval





- 7 strings
- 125 optical sensors



Phase-1 Astrophysics

- Discovery of τ neutrinos ⇒ **the neutrino oscillation in a cosmological distance**
  - a device to mimic high energy tau neutrino event signatures *in situ*
- Cosmic neutrino flavor ratio ⇒ **mechanism**
- Improvements in the angular resolutions for particle shower events
  - currently 10-15deg angular resolution, dominated by ice systematics
  - 5-10deg achievable

  ⇒ **Improved diffuse flux measurements**

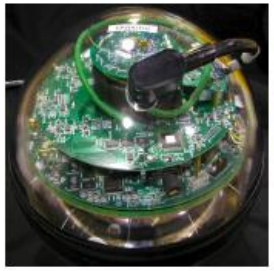
  ⇒ **Improved point source capability (linear dependence)**

Modules for Gen2

	Instr. diameter	Instr. diameter	Hole diam.	Rel. Drill time/ IceCube	$30/gallon at Pole Fuel
	in	[cm]		%	Million gal
M-DOM	14	35.6	62.2	7	0.91
P-DOM	13	33.0	60.0	0	0.85
D-EGG	12	30.5	57.8	-7	0.79
WOM-3		25.0	53.2	-21	0.67
WOM-1		12.0		-35-40	0.52
L-OM		16.5		-35-40	0.52

- WOM/LOM are not ready by Phase-1 at least
- PDOM, MDOM, DEgg have better sensitivity than the current DOM
- While still missing detailed simulation including each module to extract physical sensitivity, their difference seems to be at most a few tens of percent. All physics dependent. An apple-to-apple comparisons for the given cost is not easy
- The best is taking advantages of features of each module

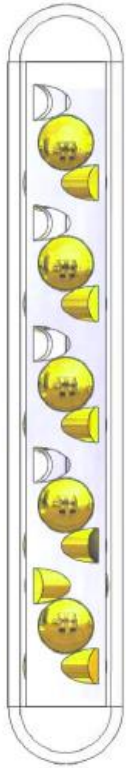
PDOM 1x10''



MDOM 24x3''

DEgg 2x8''

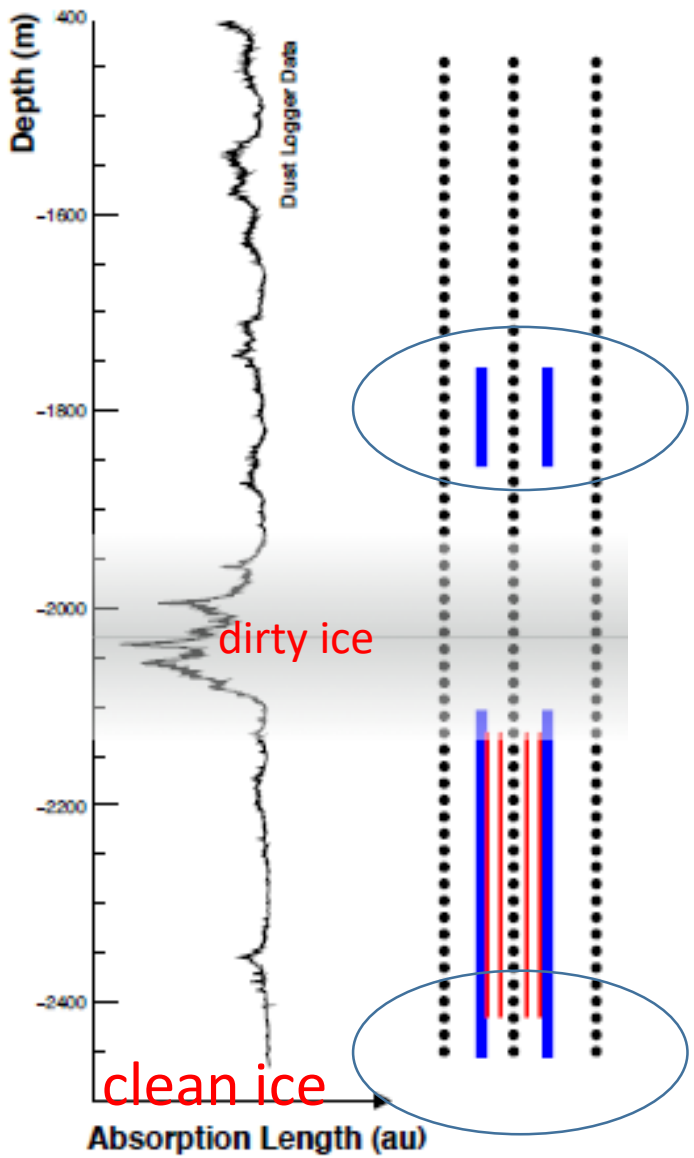
LOM
many x1''



WOM
wavelength
shifter, 2x3''

Japanese contribution in 2018-2023 time scale

- Responsible for veto sensors with D-Egg
- 15 modules x 7strings = 105 modules (e.g. 10 top, 5 bottom) for veto (upper) and HE event reconstruction (bottom)
- Housing for calibration devices
- <u>Improved muon track/cascade reconstruction</u> by D-Egg is a key
- Will be a start of the full Gen2 array!
- Schedule
  - Base design fixed by the end of 2017
  - Testing during 2018
  - Production in 2019-2020 for phase-1
  - 2021- Production for the full Gen2
  - 2023/2024 - Depolyment



IceCube Gen2 Phase 1 Neutrino Observatory

- Project Office
  - Project Management
  - Systems Engineering
  - Project Controls (EVMS)
  - Environmental, Health, and Safety
  - Quality Systems
  - Human Resources
  - Finance
  - Education and Outreach
  - Communications
  - Polar Operations
- Gen2 Enhanced Hot Water Drill
  - Drill Management
  - Power Plant
  - Tower Operations Site
  - Computing and Control System Infrastructure
  - Electrical Distribution System
  - Water Handling Systems
  - Drill Traverse Equipment and Operations
  - Drill Field Seasons
- Deep Ice Array
  - Enhanced IceCube DOM (pDOM)
  - Multi-PMT Digital Optical Module
  - D-Egg DOM
  - Downhole Cable Assemblies
  - Deep Ice Field Hub
  - Deep Ice Calibration Systems
- Comms, Power, and Timing (CPT)
  - CPT Field Interface Box
  - Surface Cables
  - CPT Headend Assembly
  - CPT Northern Test System
  - CPT Electronics and FW/SW Systems
- Software
  - Online Software
  - Offline Software
  - Simulation Software
- Computing Infrastructure
  - South Pole Systems
  - Data Transfer
  - Data Storage
  - Distributed Computing
- Antarctic Support Contractor