

IceCube - Observing the Universe with Neutrinos

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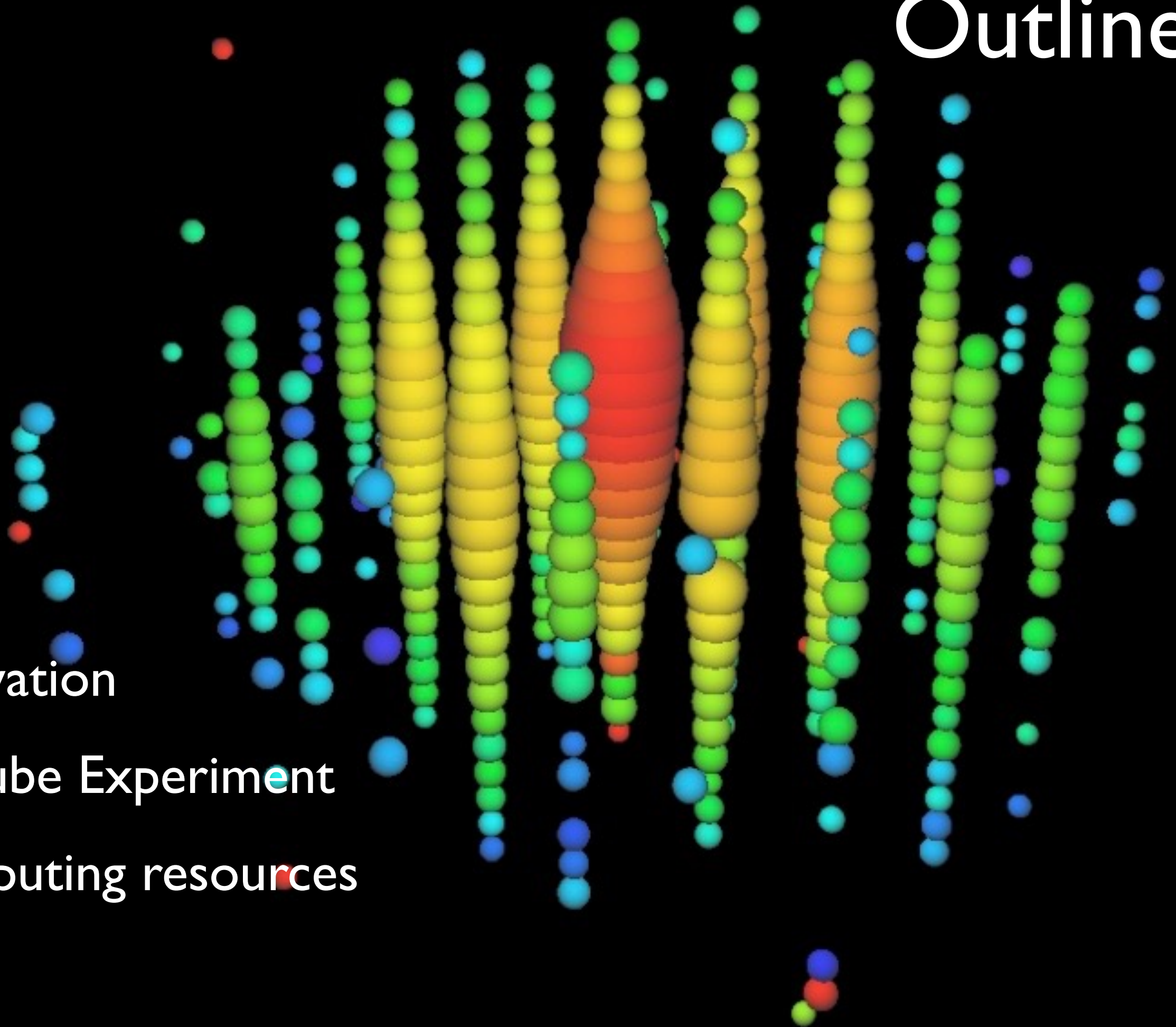
June 13, 2017

KISTI, Daejeon



Outline

- Motivation
- IceCube Experiment
- Computing resources



Birth of Neutrino Astronomy

Supernova SN1987A marks the first and only observation of MeV neutrinos from beyond our solar system

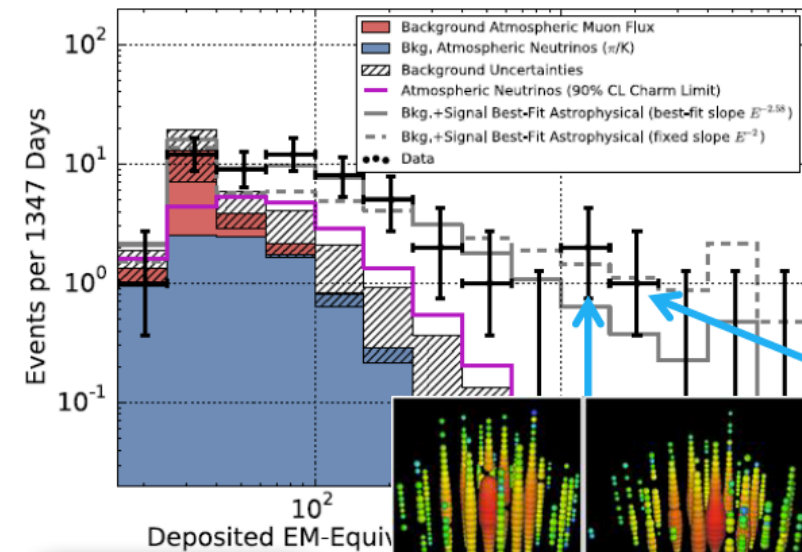
The IceCube Neutrino Telescope detects high-energy (TeV-PeV) astrophysical neutrinos in 2013

30years anniversary symposium of #supernova #1987A #neutrinos at U Tokyo, Dr Carsten Rott (#Sungkyunkwan U) introduce #IceCube @uw_icecube
https://t.co/PqM29ePVD7



Teppeï Katori (@teppeikatori) posted a photo on Twitter
Get the whole picture - and other photos from Teppeï Katori
PIC.TWITTER.COM/PQM29EPVD7

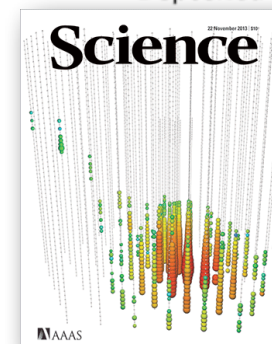
First evidence for an extra-terrestrial h.e. neutrino flux



2 yrs data, 28 evts 4.1σ
Science 342 (2013)

3 yrs data, 37 evts 5.9σ
Phys.Rev.Lett. 113:101101 (2014)

4 yrs data, 54 evts $\sim 7\sigma$



"Bert"
1.04 PeV
Aug. 2011

"Ernie"
1.14 PeV
Jan. 2012

"Big Bird"
2 PeV
Dec. 2012

<이 기사는 2014년 01월 06일자 신문 23면에 게재되었습니다.>

"한국 '세계적 리더' 될 좋은 기회"
기초과학 투자 의지 확발, 한국에 세 연구 티진 등지.. 연구자·학생 영입해 연구



▲이시큐브 암흑물질 탐색팀의 책임자인 성균관대학교 카르스텐 로트 교수가 빙하 속 구형 디텍터를 활용해 중성미자를 검출하는 과정에 대해 설명하고 있다.
"지금은 중성미자 천체입자물리학에 가장 흥미로운 시기다. 한국 과학계가 지금 이 새로운 분야에 적극적으로 참여한다면 리더 그룹으로 자리잡을 수 있다."



Supernova SN 1987A - 23 February 1987



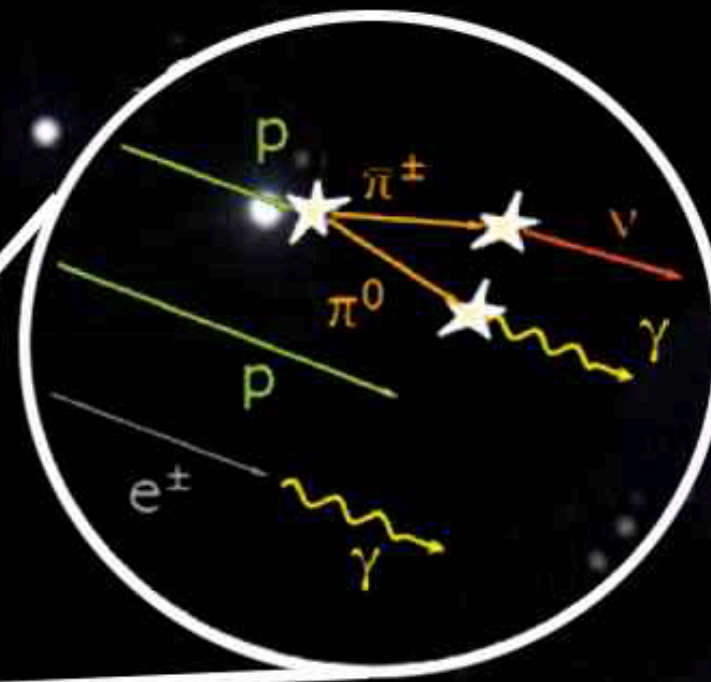
Masatoshi Koshiba Raymond Davis Jr. Riccardo Giacconi

"for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"



2002

cosmic rays
+ neutrinos



Cosmic Ray Sources

- Active Galactic Nuclei (AGN)
- Gamma Ray Bursts (GRB)
- Supernovae (SN)
- Galaxy Clusters
- Unknown



Victor Francis Hess

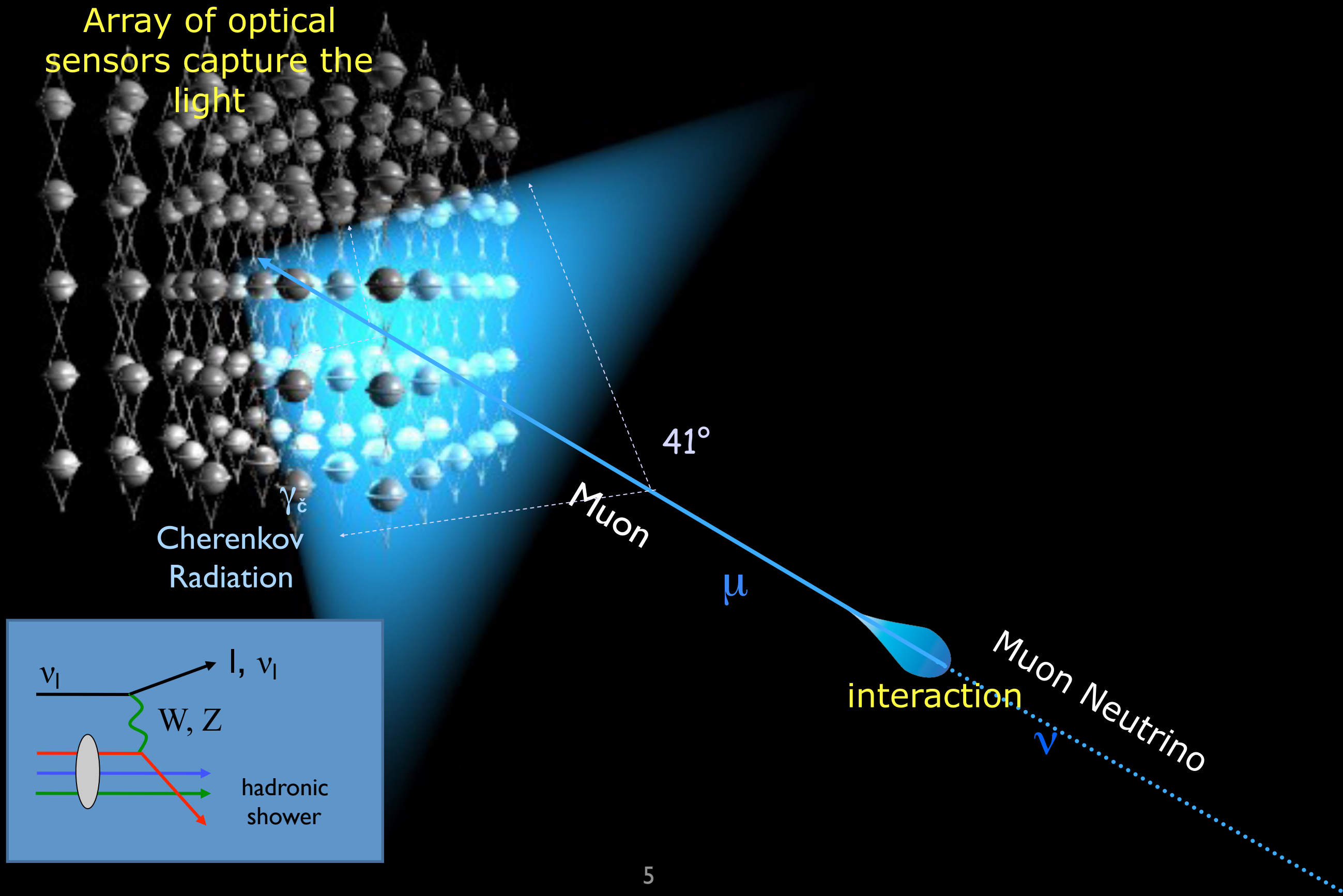
Discovery of
cosmic-rays



1936

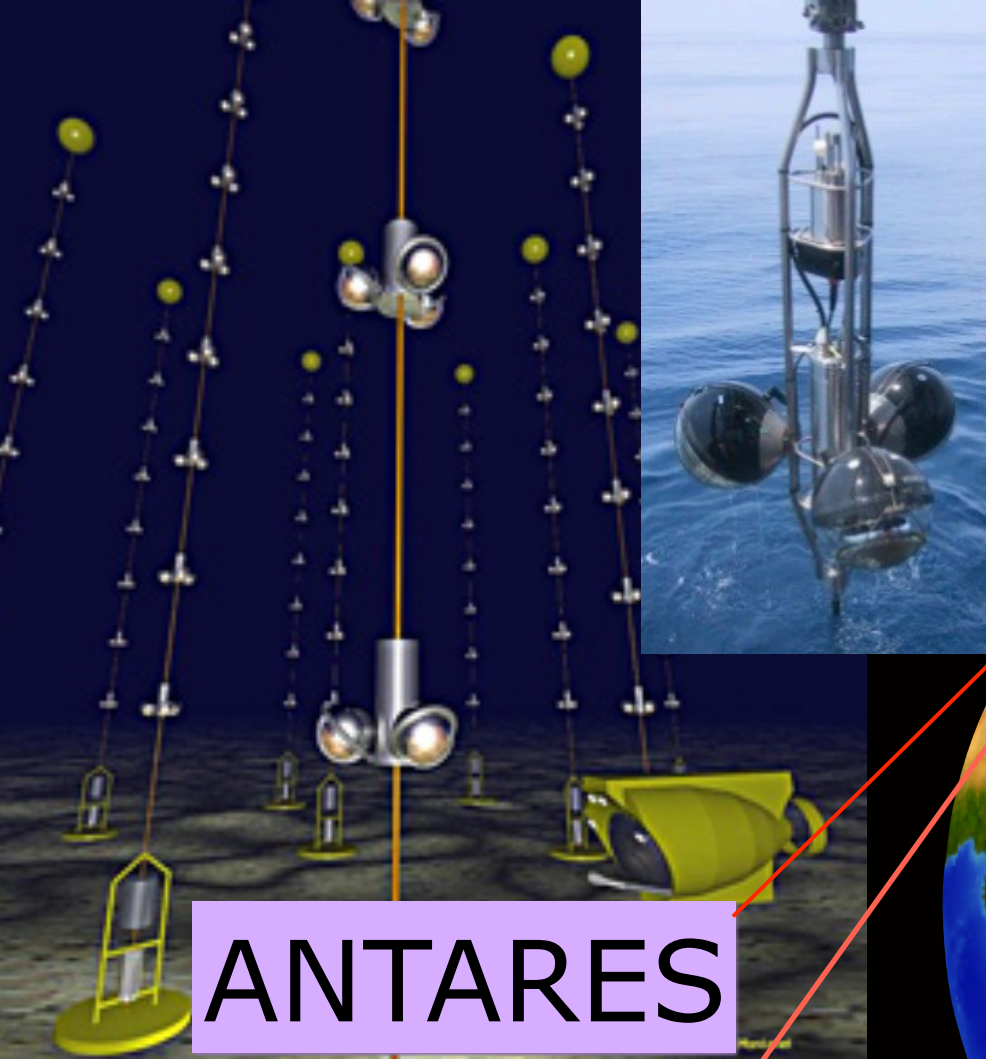
Astrophysical Messengers

Principle of an optical Neutrino Telescope

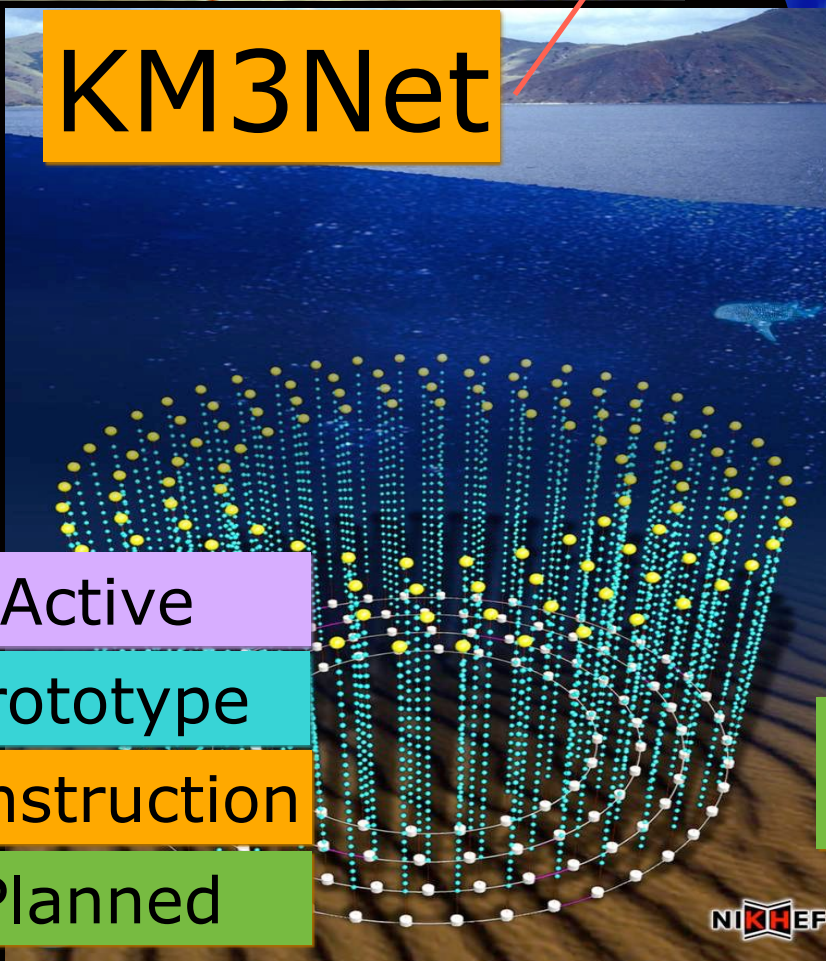


Neutrino Telescopes and IceCube

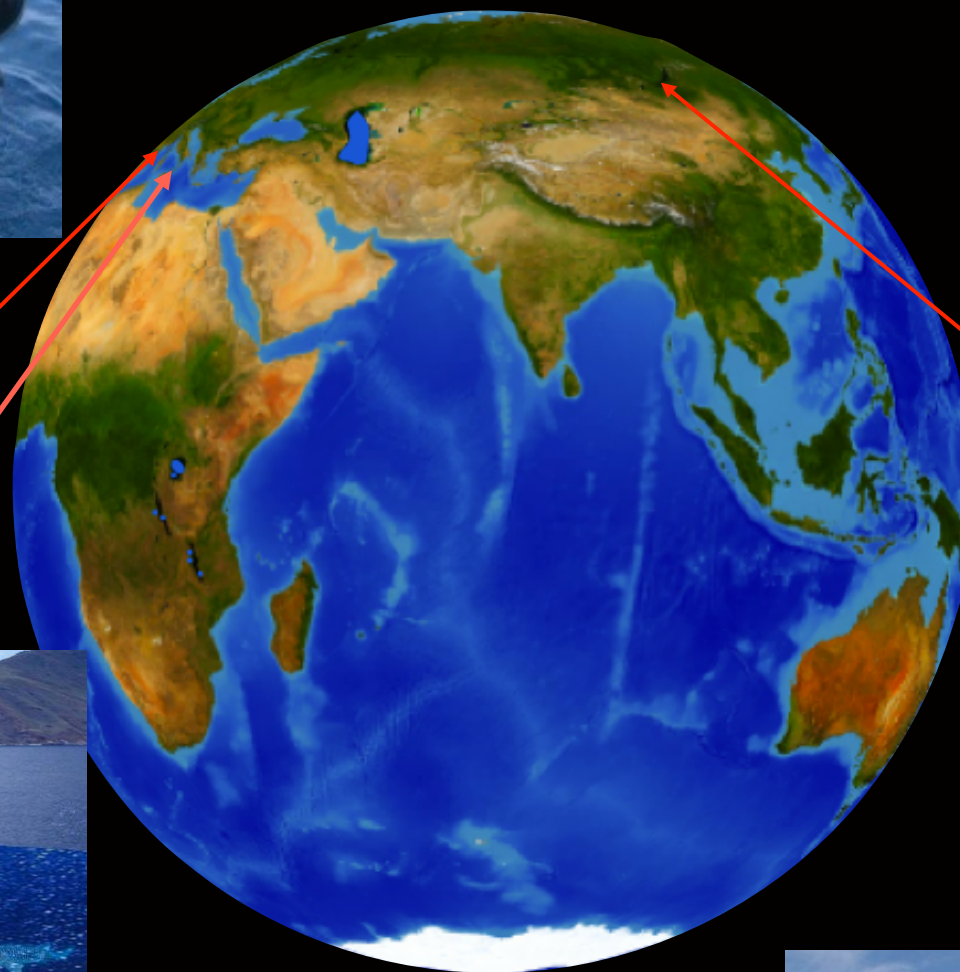
Neutrino Telescopes



ANTARES



KM3Net



Lake Baikal

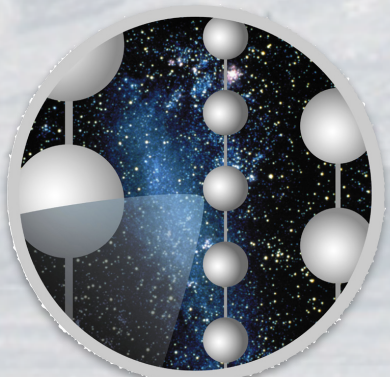
GVD

IceCube

Gen2/PINGU



The IceCube Neutrino Telescope



ICECUBE



The IceCube Collaboration



300 Physicists
47 Institutions
4 Continents

June 13, 2017

My student Seongjin In at the South Pole in 2014/2015





News

more

- Leading 'humanism Renaissance' by 617 years of ...
- The World cup star, Seol Kihyeon is retired, beco...
- Lee Wangeun, Chairman of Shinsung Solar Energ...

Notice

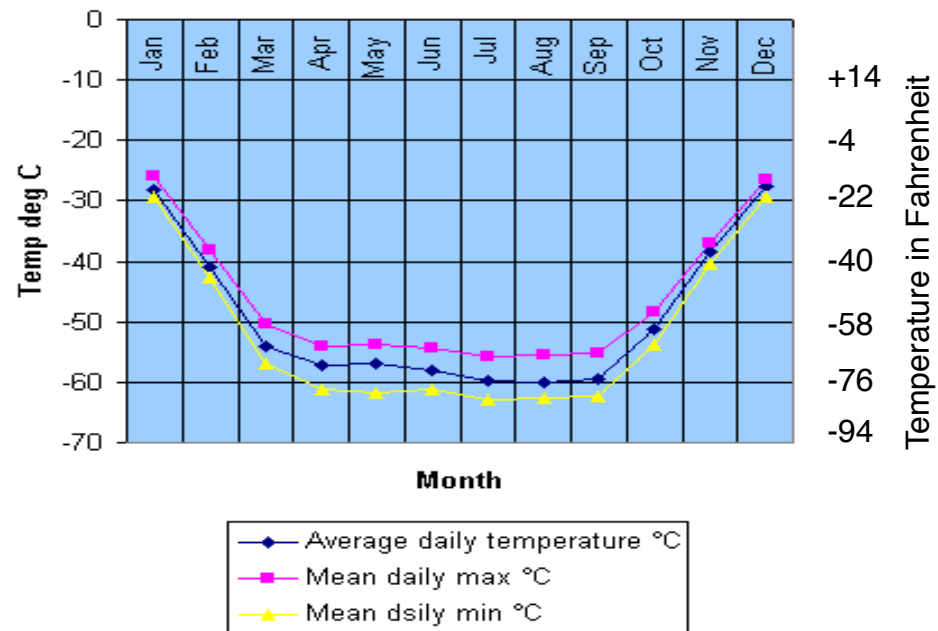
more

- Course lists of Dept. of Energy Science 2015 Sprin...
- Announcement to New International Students
- [Dormitory] 2015 Spring Myeongnyunhaksa Admi...

At the geographic South Pole you stand on top of
three kilometers of ultra pure ice



South-Pole, Annual Temperature



Laboratory at the South Pole



Geographic South Pole

Amundsen Scott
South Pole
Station

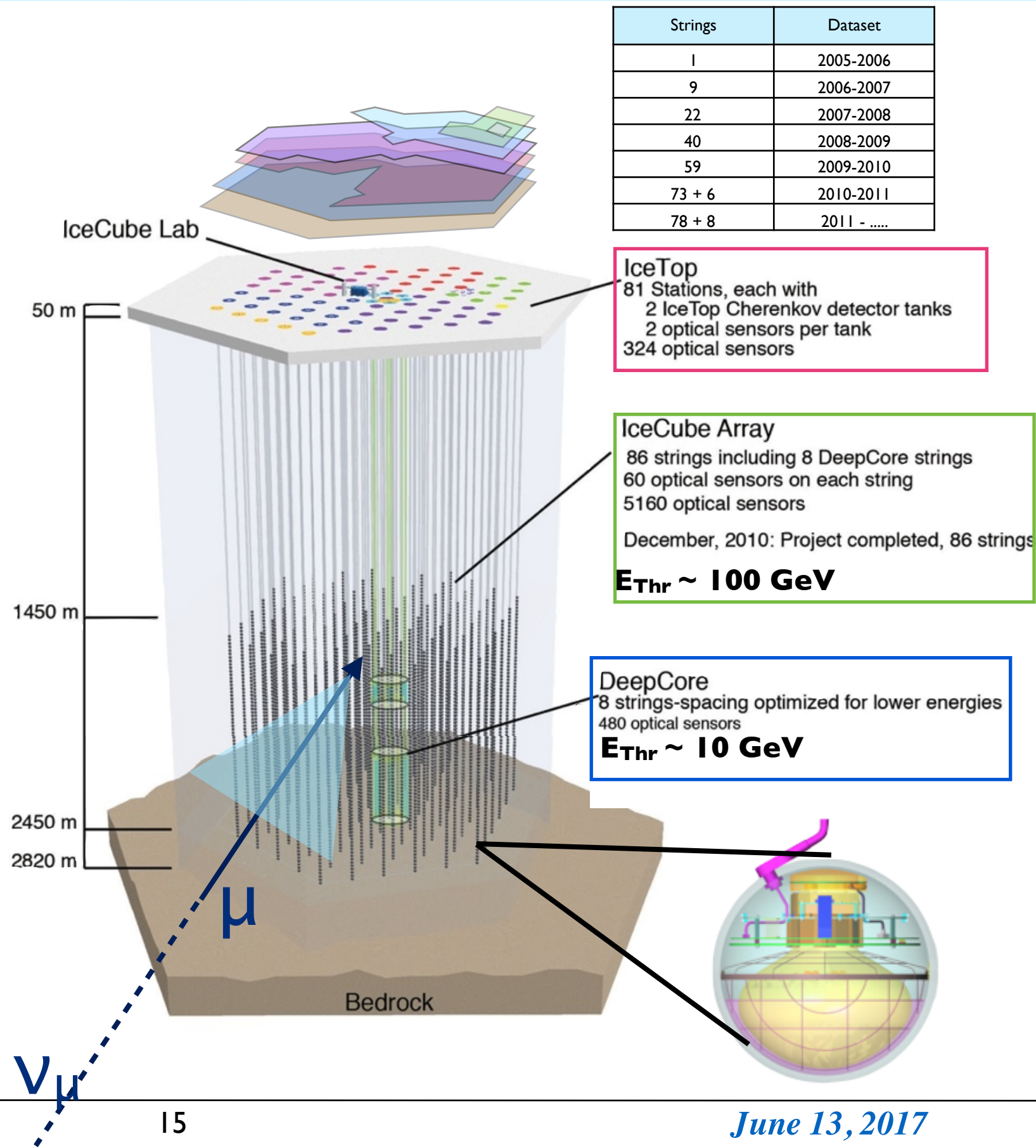
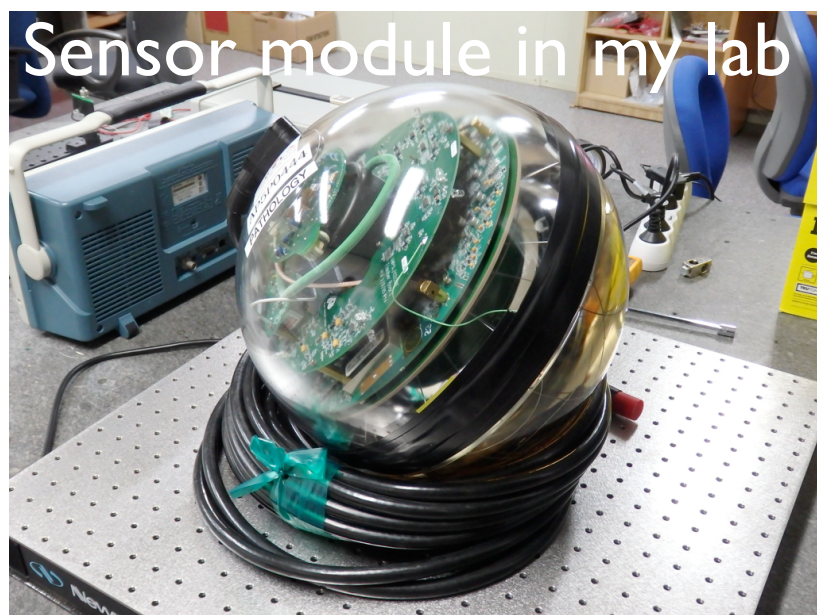
Road to work
Skiway

1 km

IceCube

The IceCube Neutrino Telescope

- Gigaton Neutrino Detector at the Geographic South Pole
- 5160 Digital optical modules distributed over 86 strings
- Completed in December 2010, start of data taking with full detector May 2011
- Neutrinos are identified through Cherenkov light emission from secondary particles produced in the neutrino interaction with the ice



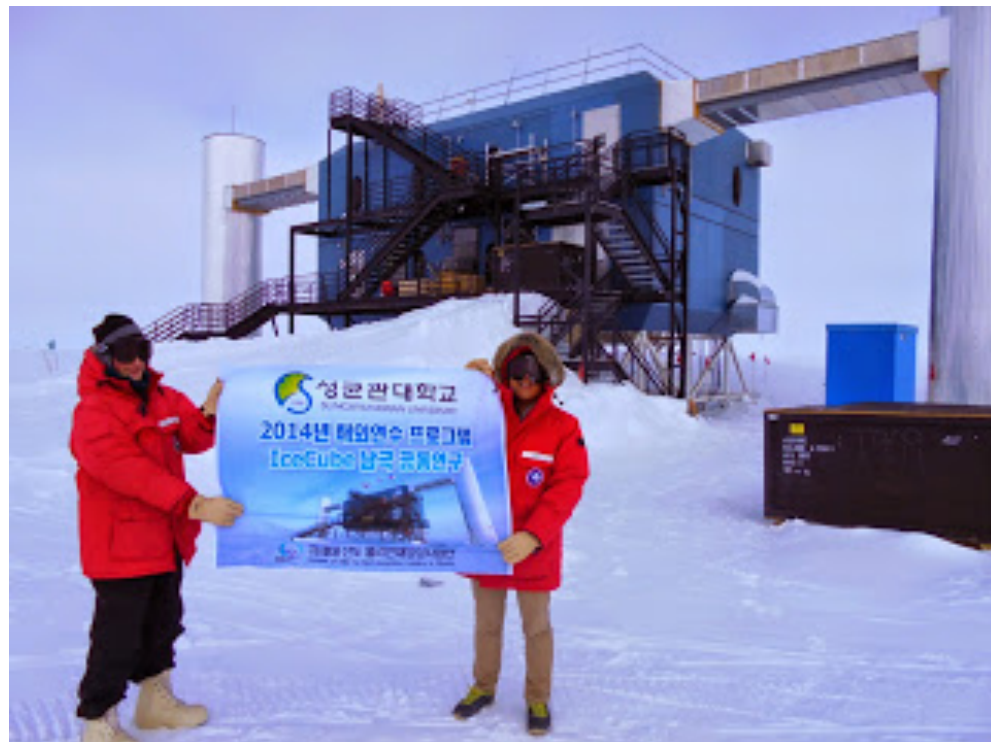
Online Processing



Processing power at present

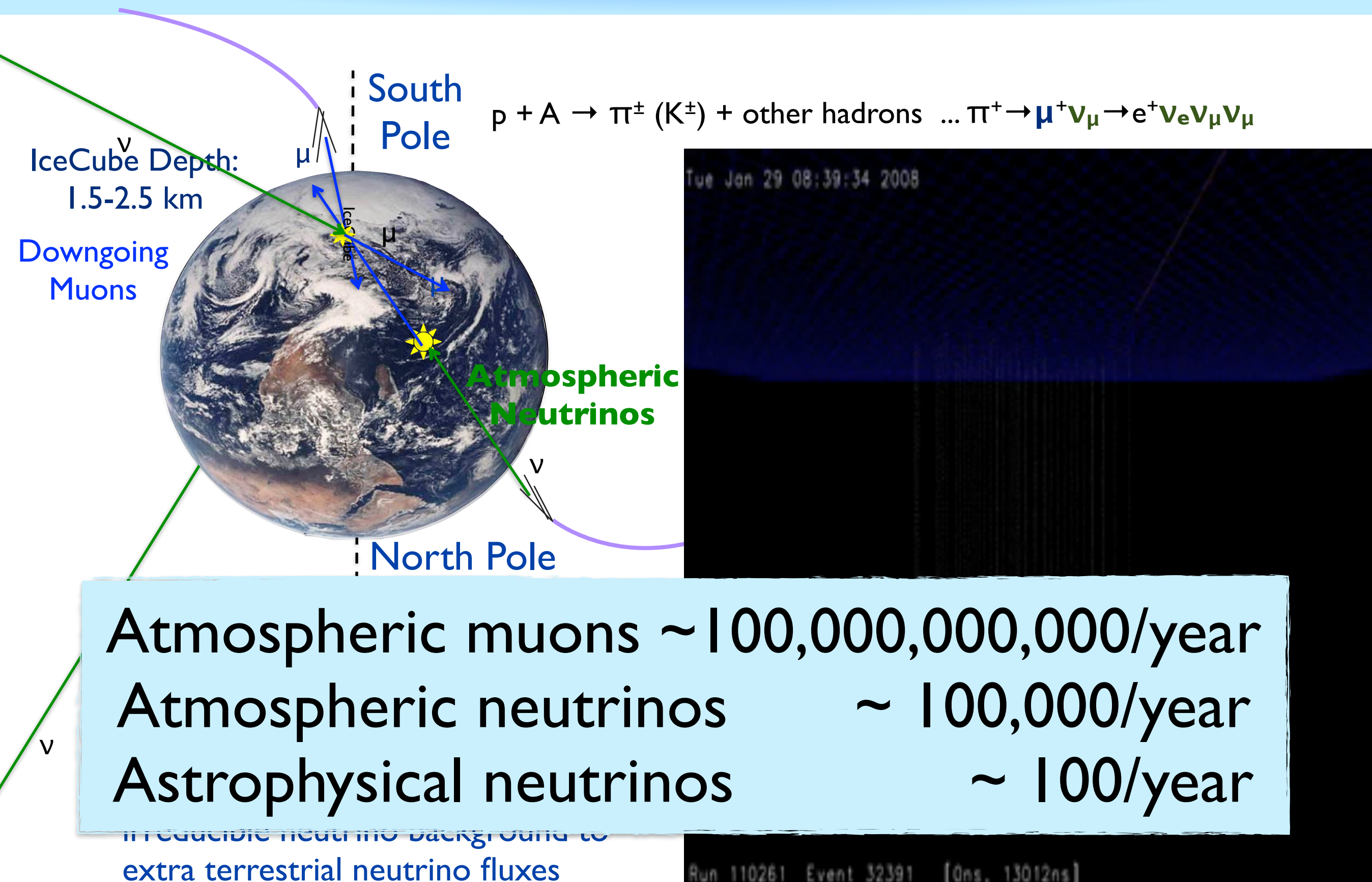
26 DELL PowerEdge 720 servers with 2 Intel Xeon E5-2690 0 @ 2.90GHz CPUs (8 cores each) and 128 GB RAM

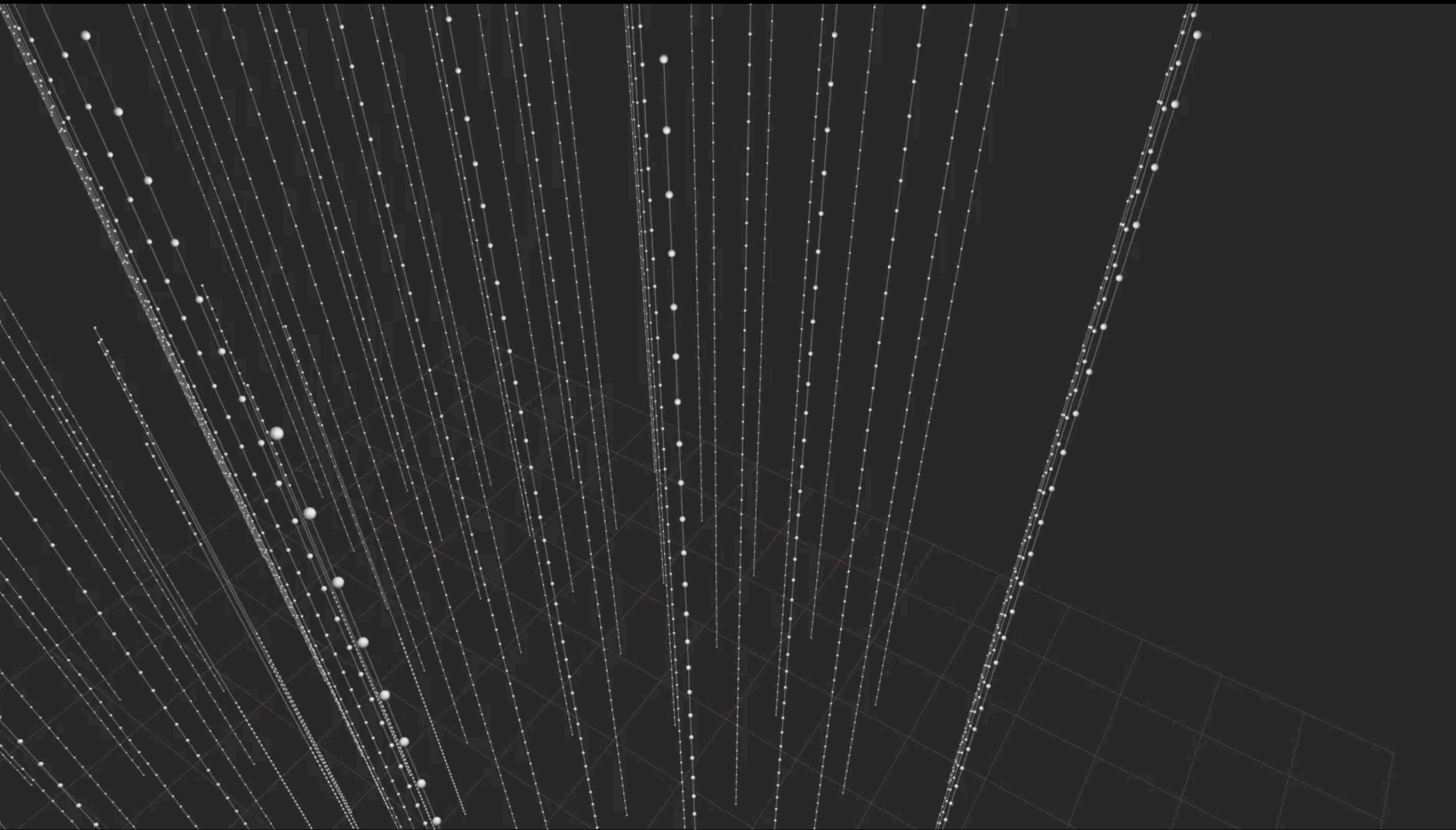
21 processing server
5 infrastructure servers



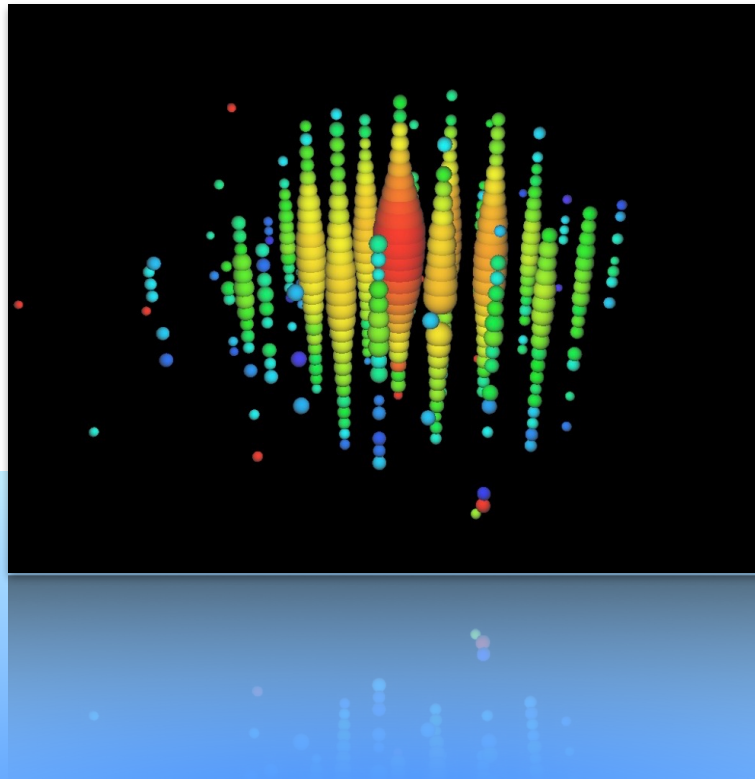
My student at South Pole 2014/2015

Signals in IceCube





Color indicates on-time or delayed

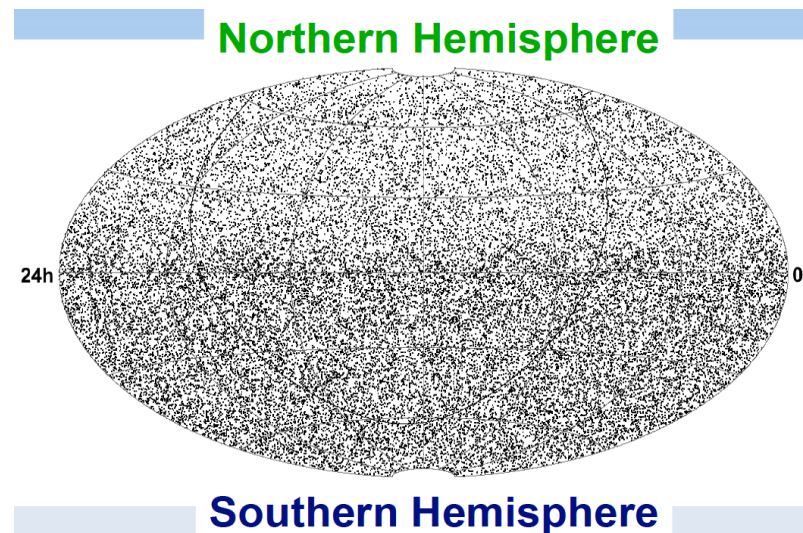


Astro-physical Neutrino Search

Finding Astrophysical Neutrinos

- How to overcome the large atmospheric neutrino background
- We need to rely on statistical methods to pick out neutrinos from this mess
 - Do neutrinos cluster anywhere in space, time, or arriving in coincidence with astronomical events or objects ?
 - Do we see any spectral features ?

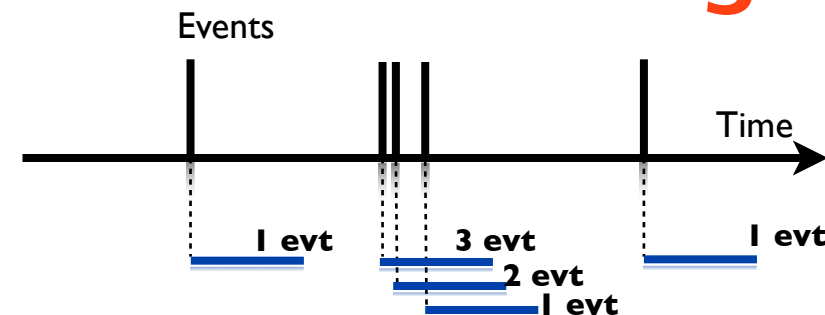
1. Point Source



single dominant source

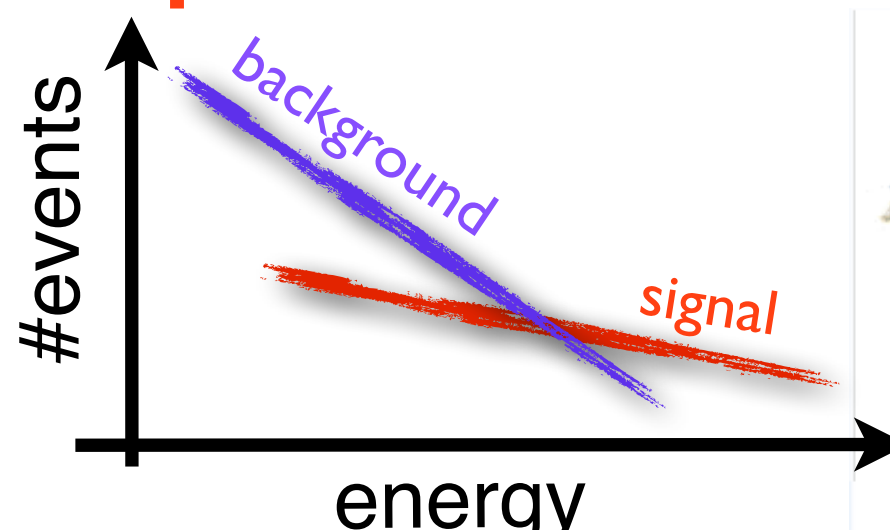


2. Time clustering

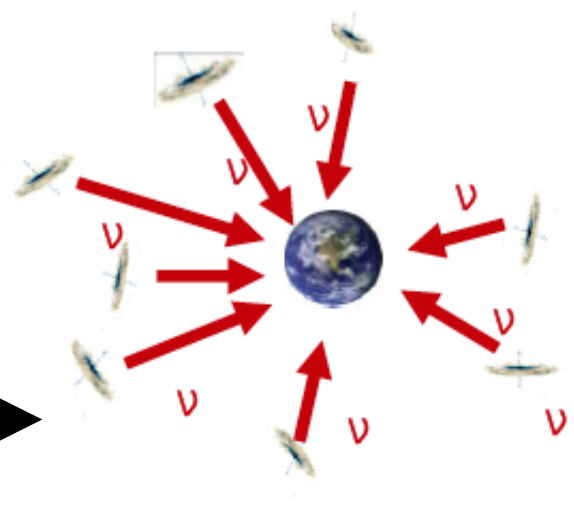


transient source

3. Spectral feature



cumulative flux



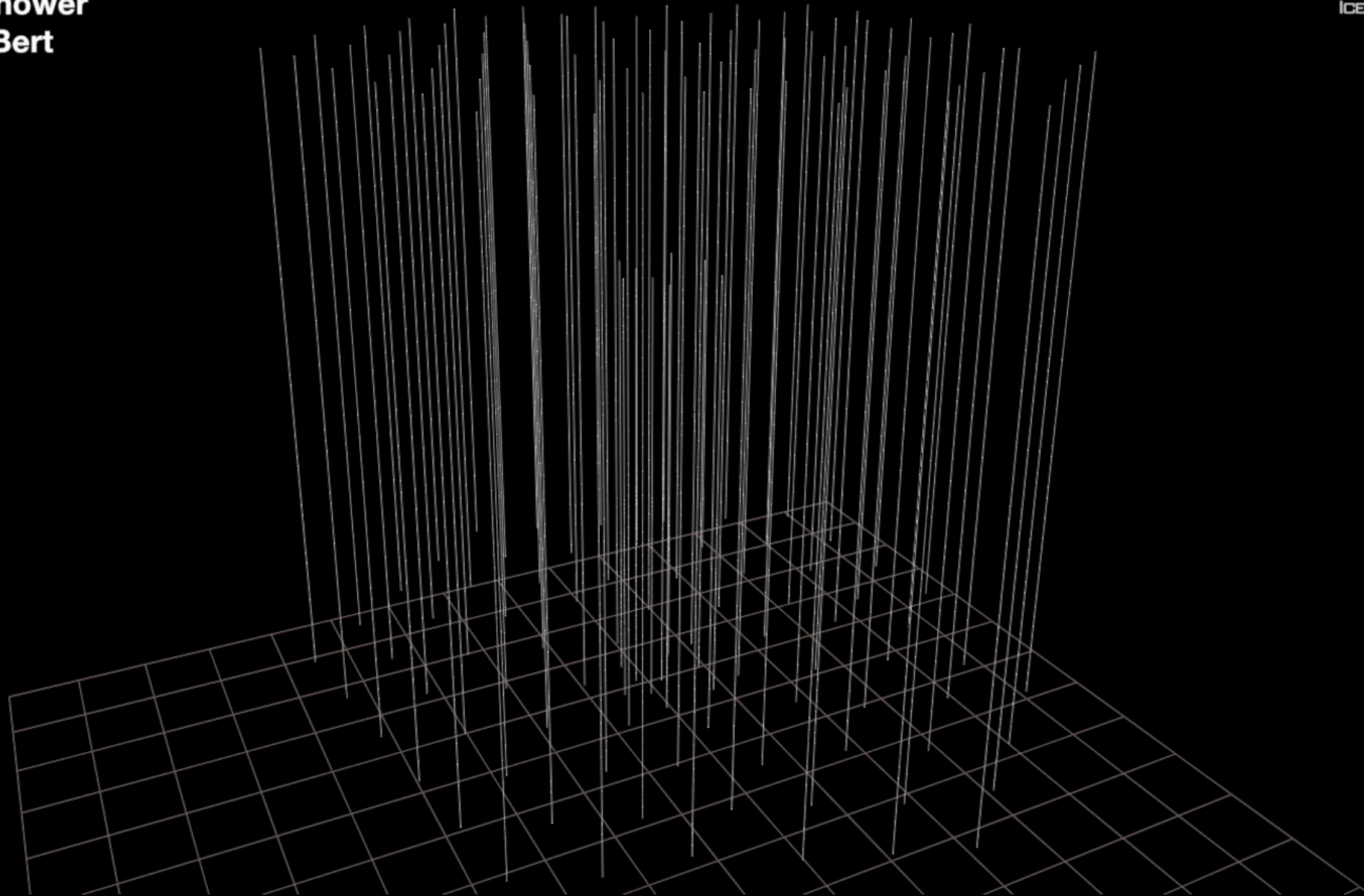
A cosmic neutrino interacts INSIDE the detector: it is too energetic to be produced in the atmosphere

date: **August 9, 2011**

energy: **1.04 PeV**

topology: **shower**

nickname: **Bert**



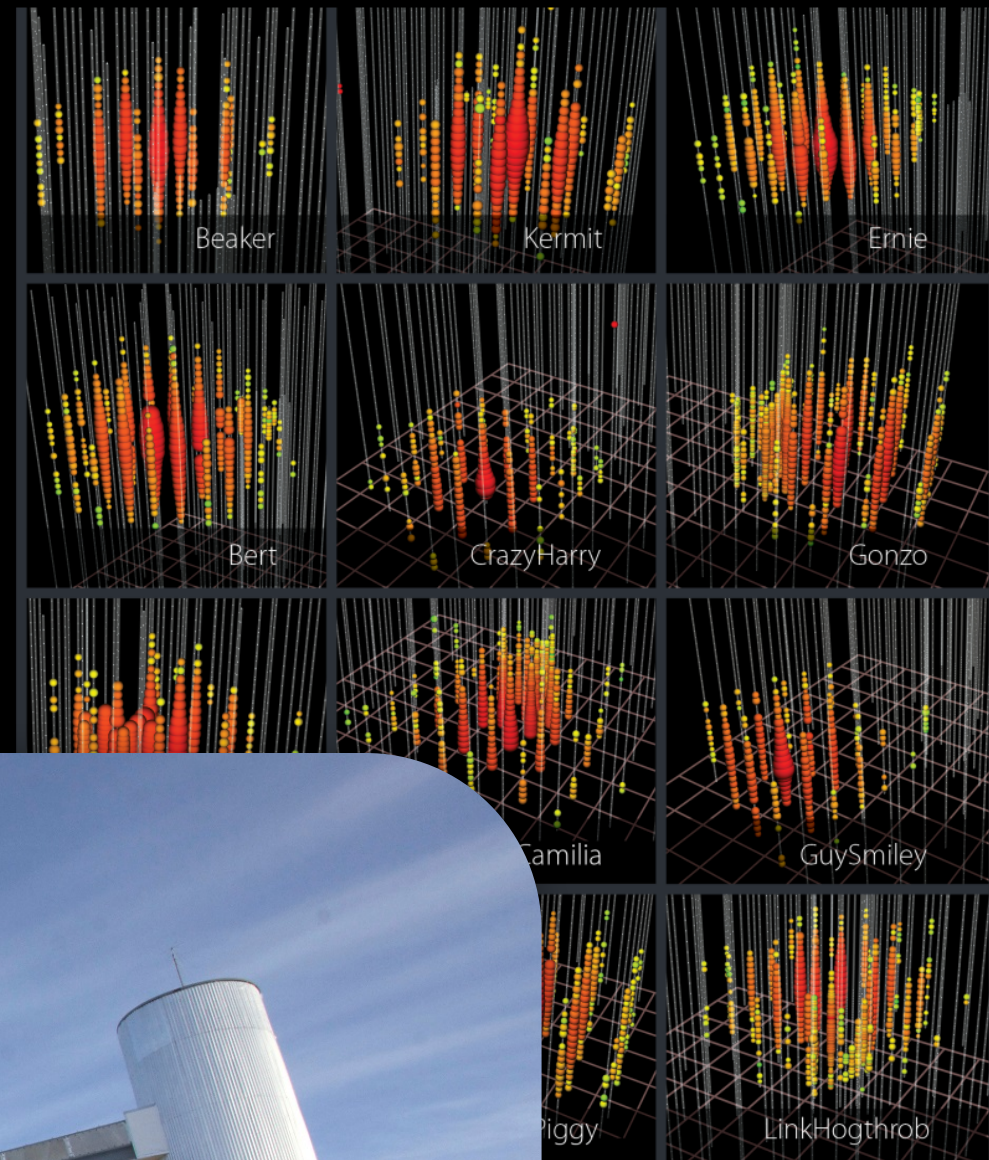
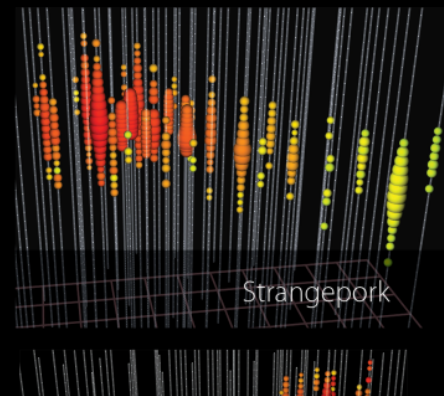
> 300 optical sensors; > 100,000 photons; 2 nanosec time resolution

RESEARCH

Evidence for High-Energy Extraterrestrial Neutrinos at the IceCube Detector

IceCube Collaboration*

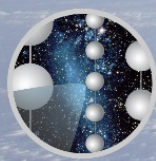
28 High Energy Events



physicsworld

**BREAKTHROUGH
OF THE YEAR**

2013



ICECUBE



Press coverage

<이 기사는 2014년 01월 06일자 신문 23면에 게재되었습니다.>

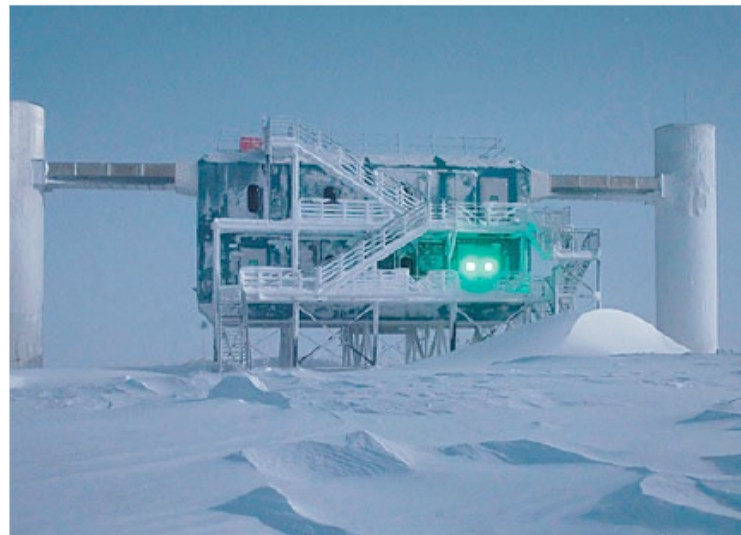
“한국 ‘세계적 리더’ 될 좋은 기회”

기초과학 투자 의지 촉발, 한국에 새 연구 터전 등지.. 연구자·학생 영입해 연구



우주서 날라온 ‘유령입자’ 원가봤더니

다지털타임즈 | 기사입력 2013-11-24 20:51 | 최종수정 2013-11-25 11:33



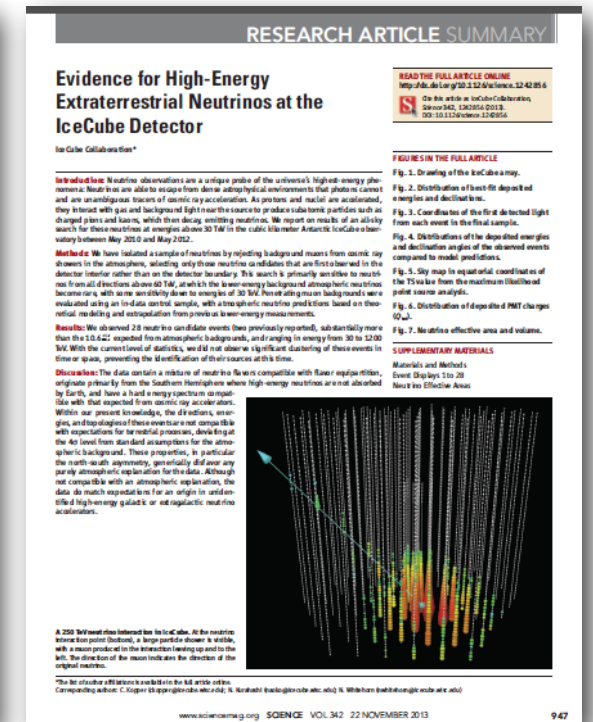
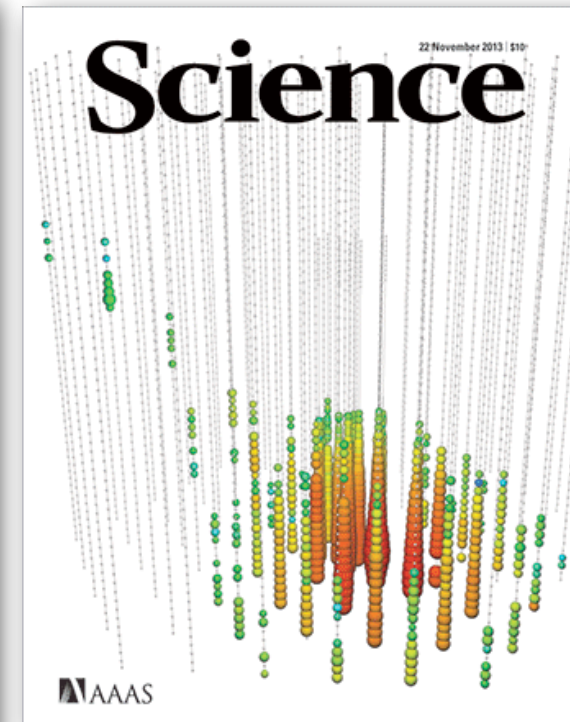
아이스큐브 공동연구팀, 남극서 초고에너지 중성미자 최초로 포착

남극 얼음 깊이 설치된 연구장치에서 우주로부터 날아온 초고에너지 중성미자가 최초로 포착됐다.

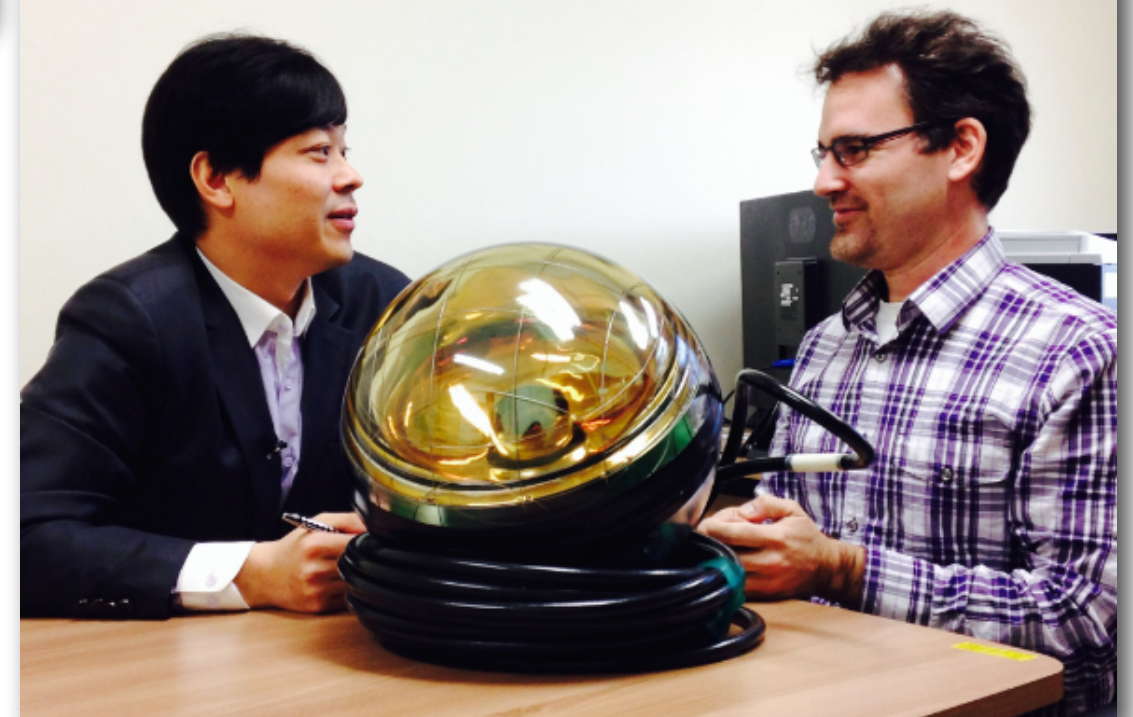
세계 11개국 39개 기관 200여명의 연구자로 구성된 ‘아이스큐브’ 국제공동 연구팀은 남극 얼음층에서 우주로부터 날아온 초고에너지 중성미자의 흔적을 최초로 포착, 세계적인 과학저널인 사이언스에 22일 발표했다. 국내에서는 카르스텐 로트 성균관대 물리학 과 교수가 연구에 참여했다.

로트 교수가 빙하 속 구형 디텍터를 활용에 중성미자를 검출

문 시기다. 한국 과학계가 지금 이 새로운 분야 수 있다.”

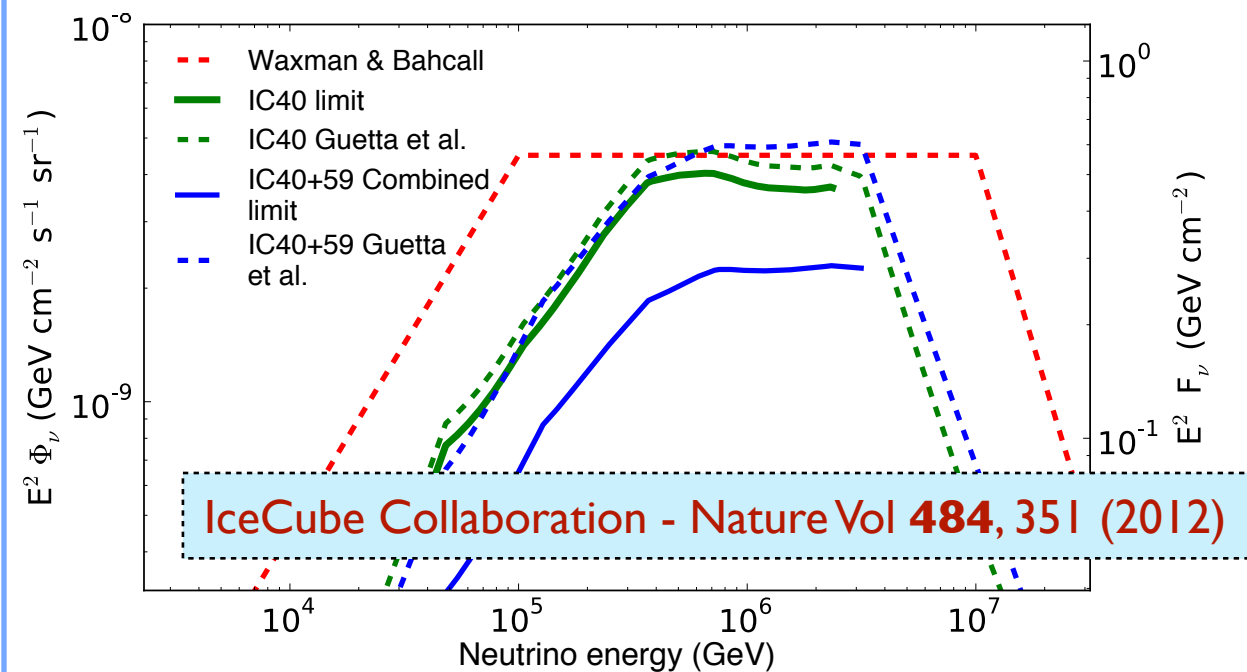


YTN Science (TV)



Origin of the high-energy neutrinos ?

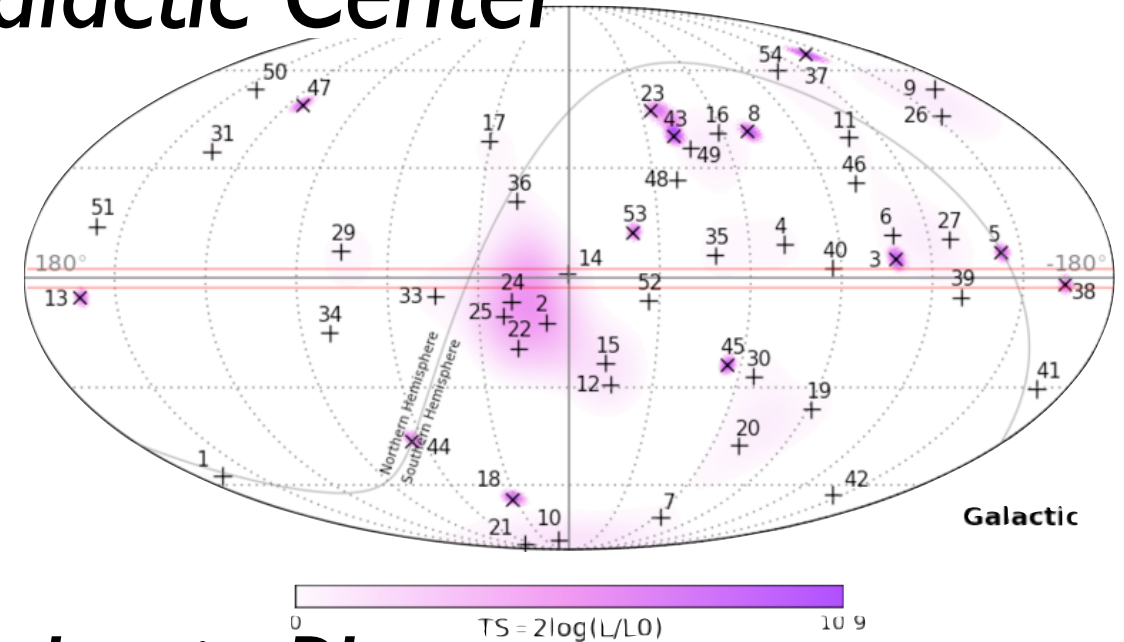
Extra Galactic Gamma Ray Burst



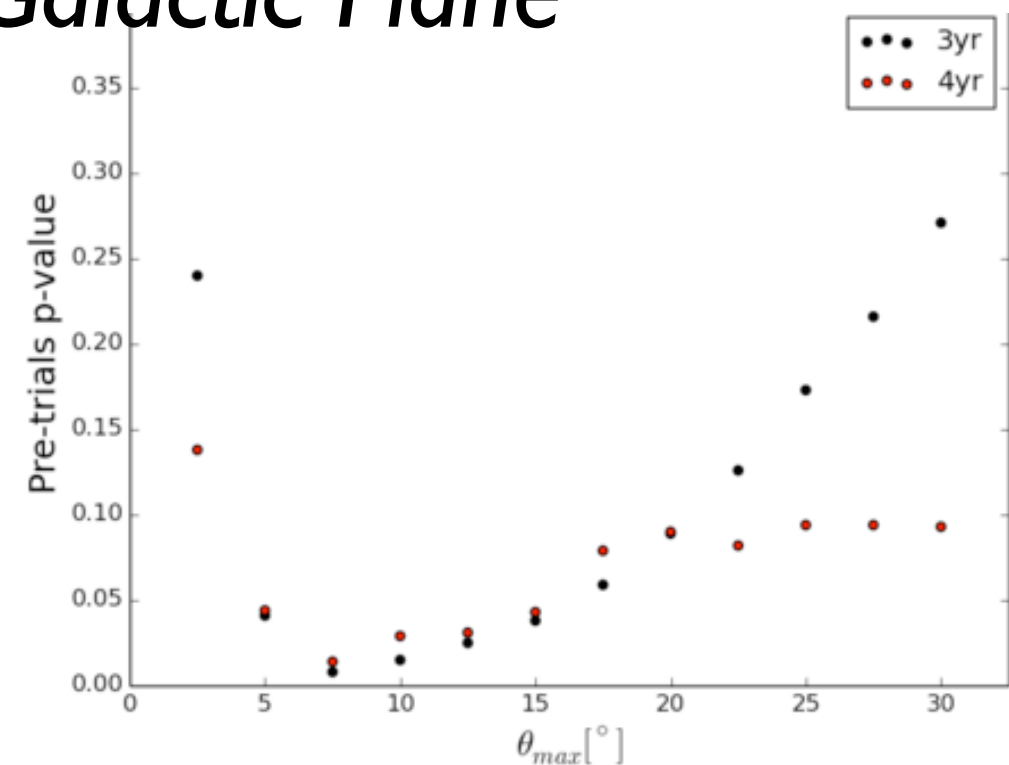
Active Galactic Nuclei / Starburst Galaxies

Starburst	M82	148.97	69.68	0.07	0.15
Radio Galaxies	NGC 1275	49.95	41.51	0.0	—
	Cyg A	299.87	40.73	0.9	0.03
	3C 123.0	69.27	29.67	0.0	—
	M87	187.71	12.39	0.0	—
	Cen A	201.37	-43.02	0.03	0.49

Galactic Galactic Center



Galactic Plane



Korean IceCube Groups

SKKU Group



Postdoc Christoph Toennis - (PhD on ANTARES Neutrino Telescope)

- 1 Professor
- 1 postdoc
- 6 graduate students
 - incl. 1 GPF Fellow
- 3 undergraduate students

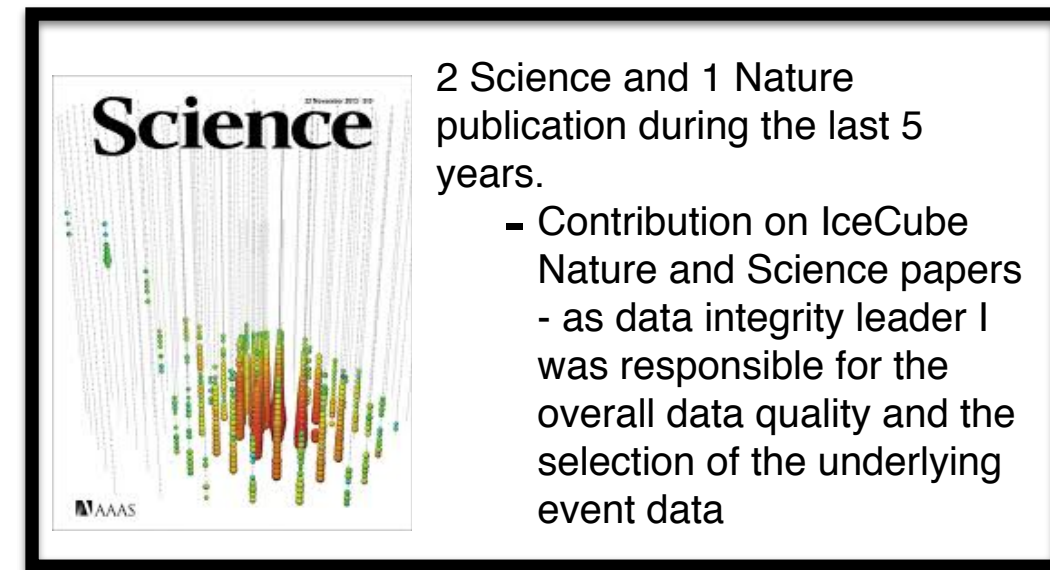
Institutional member since 2013

SNU Group

- 1 Research Professor
- 1 graduate students
- Associate IceCube Members
- Applied for institutional membership

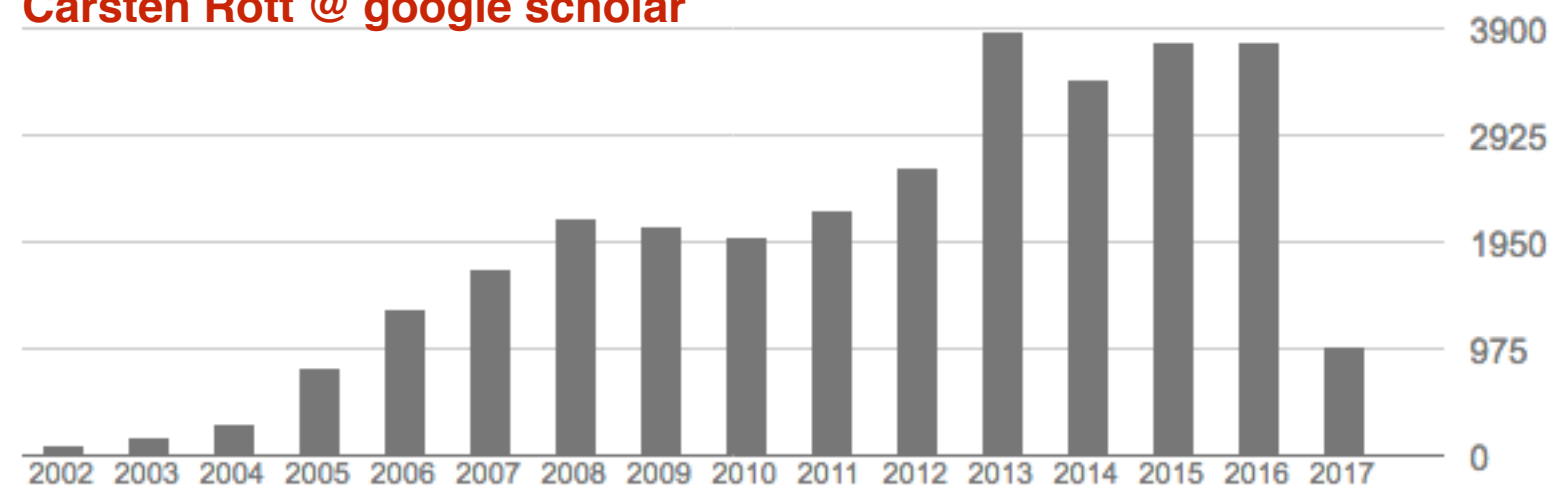
Leadership

- IceCube Collaboration publications ~15-20/year
- SKKU emerged as **8th largest group** of the 47 IceCube Institutional Members
 - Seoul National University (Seon-Hee Seo) plans to join
- Rott **working group leader** of the IceCube Beyond the Standard Model (BSM) Working Group (since 2012)
- Rott member of the IceCube **Speakers Committee**
- Rott member of the IceCube **Institutional Board**



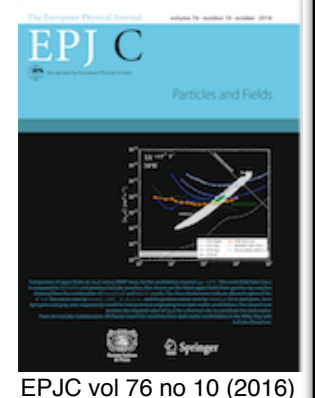
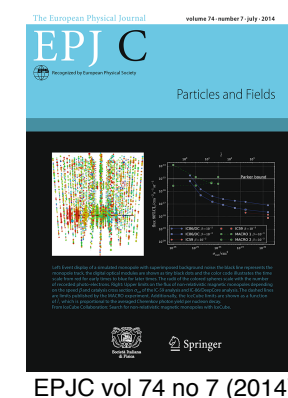
Citations per year

Carsten Rott @ google scholar

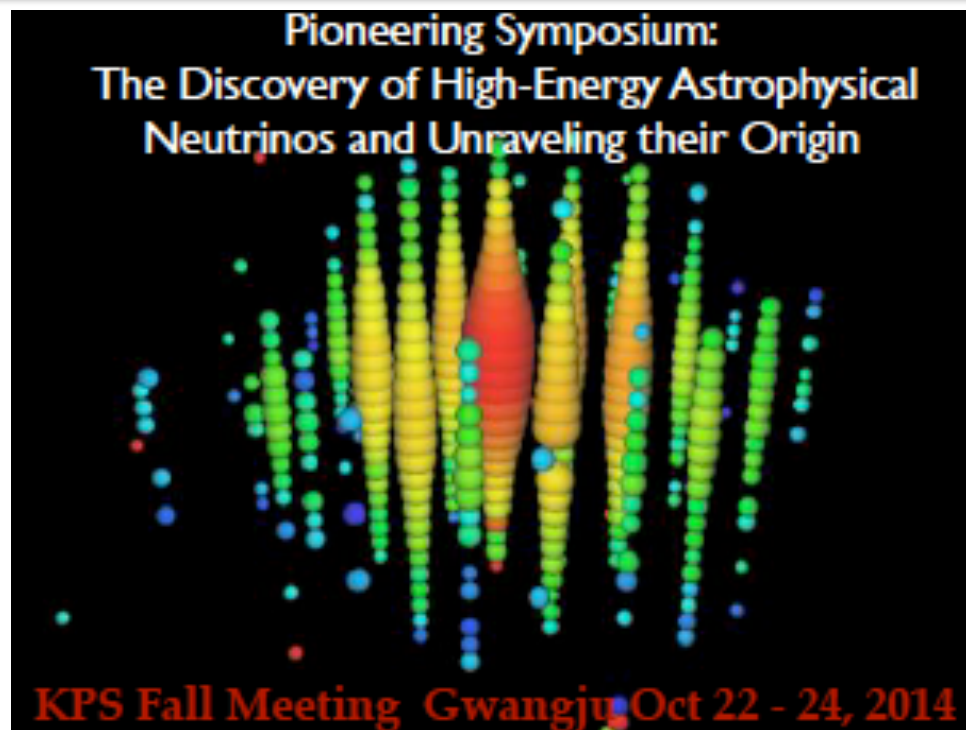


Impact as IceCube BSM Working group leader

- Among **top 3 largest working groups**
- 20 universities
- **40 active members**
- 2-3 PhDs per year
- several publications per year
- Solar Dark Matter Analysis - Physical Review Letters 110 (13), 13130 (**342 citations**) **3rd highest cited IceCube Collaboration scientific publication**



Astroparticle Physics in Korea



- Pioneering Symposium at the KPS Fall Meeting 2014
- Incl. Keynote speaker **“Francis Halzen”** (IceCube PI)
 - Organized by Carsten Rott

Summer lecture series at Sungkyunkwan University 2016 on “Recent discoveries in Astroparticle Physics”

Students from 4 universities including Germany and Sweden

19 Lecturers and guest speakers



KPS Spring Meeting 2017 “Towards multi-messenger astrophysics”

Session Information	F12-as Room 205	Toward multi-messenger astrophysics April 20 (Thursday) 16:00 - 17:36	
Chair	박일홍	성균관대학교	
Presentation No	Time	Presenter	Title
F12.01	2017-04-20 16:00 - 16:24	LEE Jik	Recent Progress in Cosmic Ray Observation and Effort for Multi-messenger Search
F12.02	2017-04-20 16:24 - 16:48	JEONG Soomin	Gamm-ray bursts in the Multi-messenger era
F12.03	2017-04-20 16:48 - 17:12	ROTT Carsten	The Search for Astrophysical Neutrinos
F12.04	2017-04-20 17:12 - 17:36	KIM Chunglee	Multi-messenger Astrophysics with Gravitational-wave Detections

ICRC2017

The Astroparticle Physics Conference
35th International Cosmic Ray Conference

Physicists from the whole world present the results of their research in Astroparticle Physics. The main topics of Astroparticle Physics are Cosmic Ray Physics, Gamma-Ray Astronomy, Neutrino Astronomy, Dark Matter Physics, Solar and Heliospheric Physics, Astroparticle Physics Theory and Models and Experimental Methods, Techniques and Instrumentation.

12 - 20 July, 2017

BEXCO BUSAN KOREA

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ROWELL, Gavin / U. Adelaide
RUFFOLO, David / Mahioli U.
SEO, Seon-Hee / Seoul National U.
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WENIGER, Christoph / GRAPPA, U. Amsterdam
ZAS, Enrique / IGFAE, U. Santiago de Compostela

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PANASYUK, Mikhail / LMSU
SEO, Eun-Suk / U. Maryland
USOSKIN, Ilya / U. Oul

- Worlds largest and most important cosmic-ray conference
- ~ 2000 participants expected

Large interest in Korea in astroparticle physics

IceCube Computing and Data

- **Data**

- The IceCube project generates about 700 TB/year.
 - This data is processed and filtered so that a reduced set can be kept in the data center disks for analysis.
 - Two data centres: DESY Zeuthen and NERSC

- **Computing**

- Distributed computing at member sites and at the computing facility at UW Madison
- The UW Madison cluster delivers about 25 million CPU hours and close to 500,000 GPU hours for IceCube analysis jobs every year

The IceProd Framework: Distributed Data Processing for the IceCube Neutrino Observatory

- Sites contributing to IceCube MC production include:
 - Uppsala University (SweGrid),
 - Stockholm University (SweGrid),
 - University of Alberta (West- Grid),
 - TU Dortmund (PHiDO, LIDO),
 - Ruhr-Uni Bochum (LiDO),
 - University of Mainz,
 - University. Libre de Bruxelles/Vrije Universiteit Brussel,
 - Universiteit Gent (Trillian) Southern University (LONI),
 - Pennsylvania State University (LIONX),
 - University of Wisconsin (CHTC, GLOW, NPX4), Open Science Grid,
 - RWTH Aachen University (EGI), University Dortmund (EGI),
 - Deutsches Elektronen-Synchrotron (EGI, DESY),
 - University Wuppertal (EGI),
 - University of Delaware, Lawrence Berkeley National Laboratory (PDSF, Dirac,Carver),
 - University of Maryland.

Sites participating in IceCube Monte Carlo production by country.

Country	Queue type	No. of sites
Sweden	ARC	2
Canada	PBS	2
Germany	SGE	1
	PBS	3
	CREAM	4
Belgium	PBS	2
USA	HTCondor	4
	PBS	3
	SGE	4
Japan	HTCondor	1

Production

Configuration Files

Datasets

Wiki

Jobs

Job Queues

Graphs

Grids

Nodes

Search

Tickets

Monitors

UW Ganglia Monitor

UW Job Queue

UW GLOW Monitor

Jobs

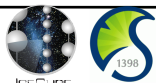
Any MetaprojectAny GeneratorAny GridApply Filters

Dataset 9255PROCESSING

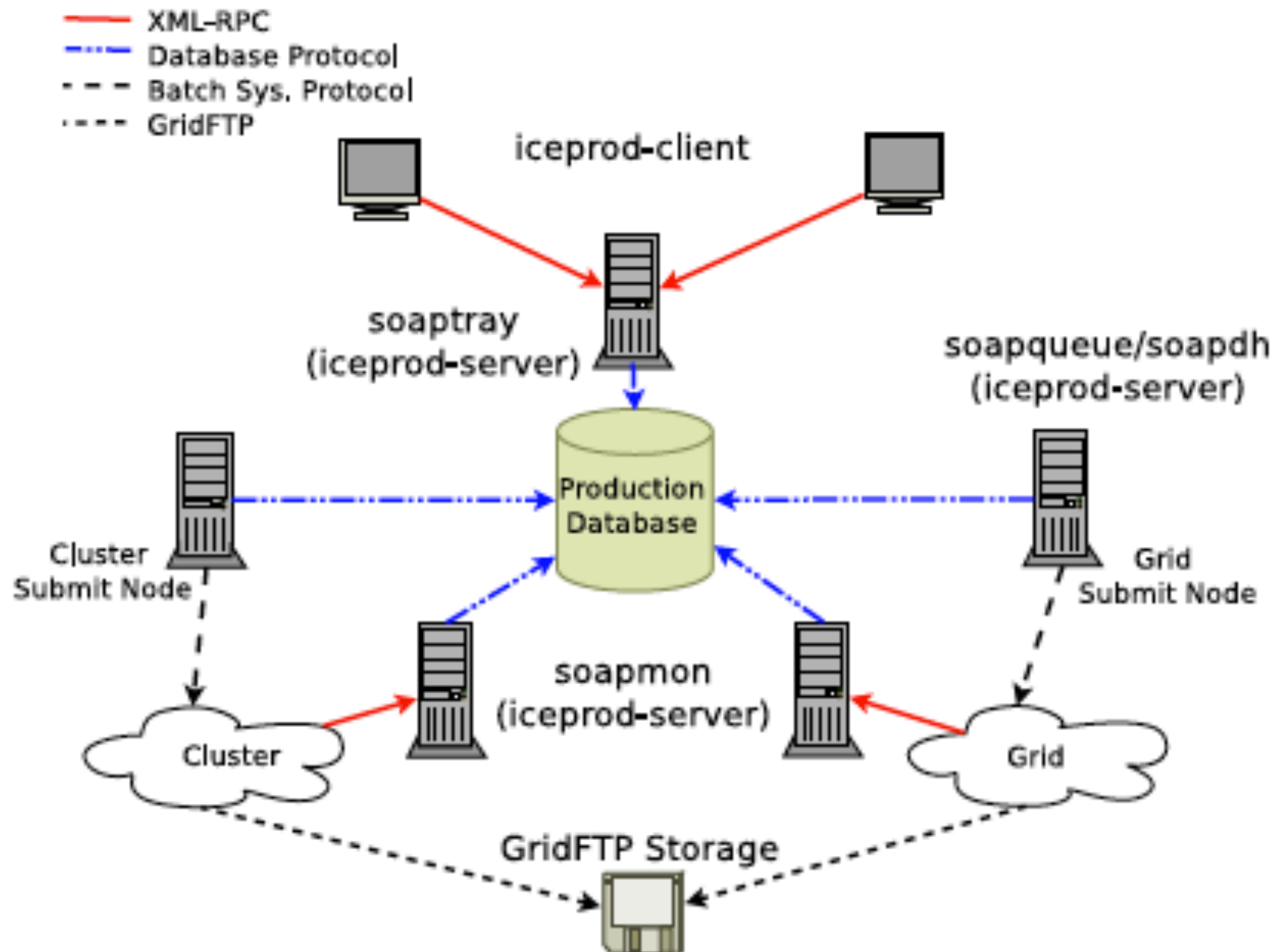
SuspendResume

Page: 1 2 3 4Results 1 – 100 of 328.

ID	Status	Metaproject	Generator	Grid	Host	Errors	Progress
9255.60794	PROCESSING	simulation releases.V03-02-01	CORSIKA-in-ice	IceProdDAG.CA	glow-en66	0 fails 0 evicts	57.14%
9255.61987	PROCESSING	simulation releases.V03-02-01	CORSIKA-in-ice	IceProdDAG.CA	gak9000009	0 fails 0 evicts	71.43%
9255.61988	PROCESSING	simulation releases.V03-02-01	CORSIKA-in-ice	IceProdDAG.CA	e147	0 fails 0 evicts	71.43%
9255.61989	PROCESSING	simulation releases.V03-02-01	CORSIKA-in-ice	IceProdDAG.CA	gak9000009	0 fails 0 evicts	85.71%
9255.61991	PROCESSING	simulation releases.V03-02-01	CORSIKA-in-ice	IceProdDAG.CA	e140	0 fails 0 evicts	85.71%
9255.62008	PROCESSING	simulation releases.V03-02-01	CORSIKA-in-ice	IceProdDAG.CA	gak9000009	0 fails 0 evicts	71.43%
9255.62021	PROCESSING	simulation releases.V03-02-01	CORSIKA-in-ice	IceProdDAG.CA	gak9000009	1 fails 0 evicts	85.71%



The IceProd Framework: Distributed Data Processing for the IceCube Neutrino Observatory



- IceCube has opened up a new window to the Universe
- ... but what's the origin of the high-energy neutrinos ?
 - Let's find out !

