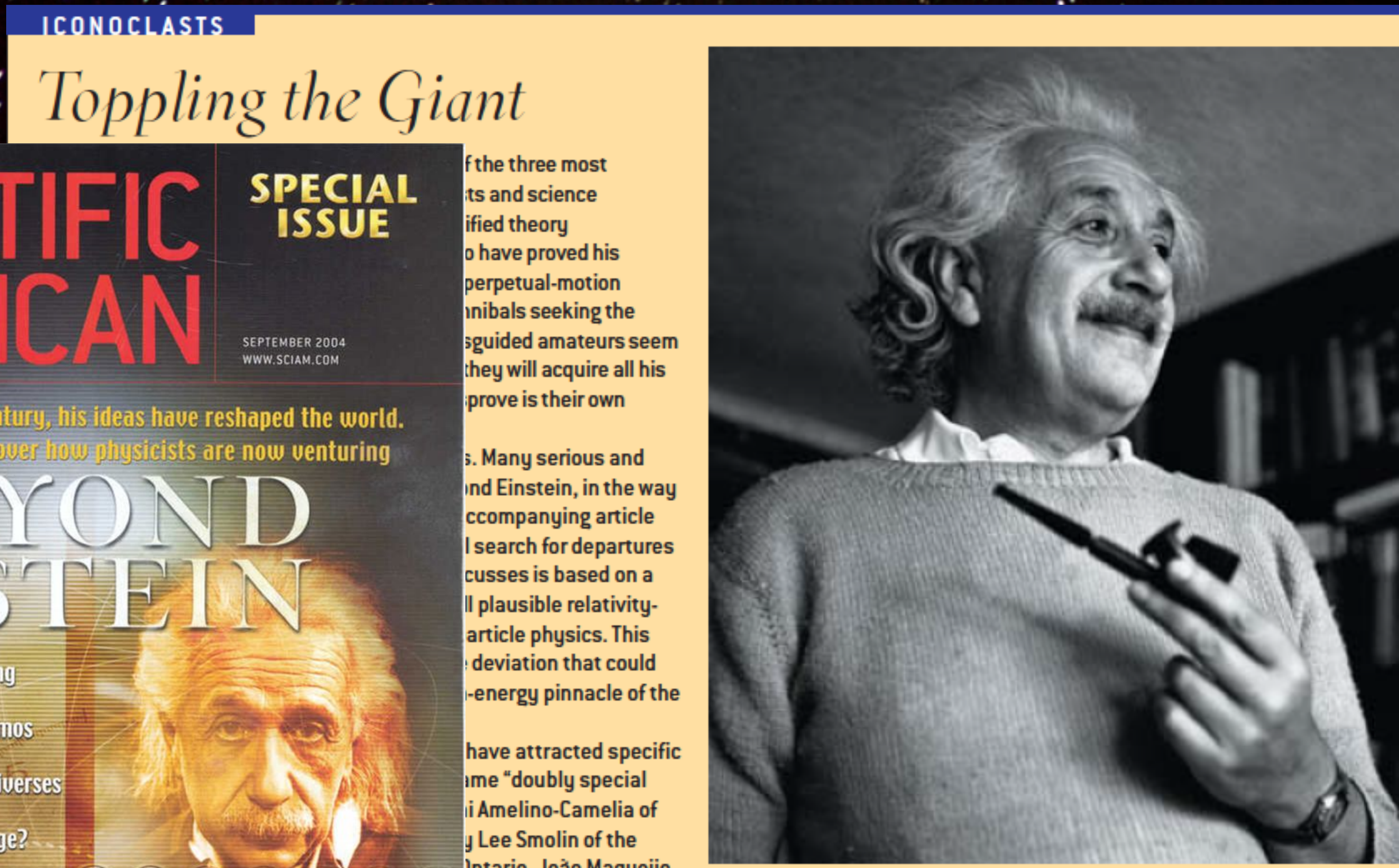
Search of Space-Time Defect: The Race to Defeat Einstein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Toppling the Giant

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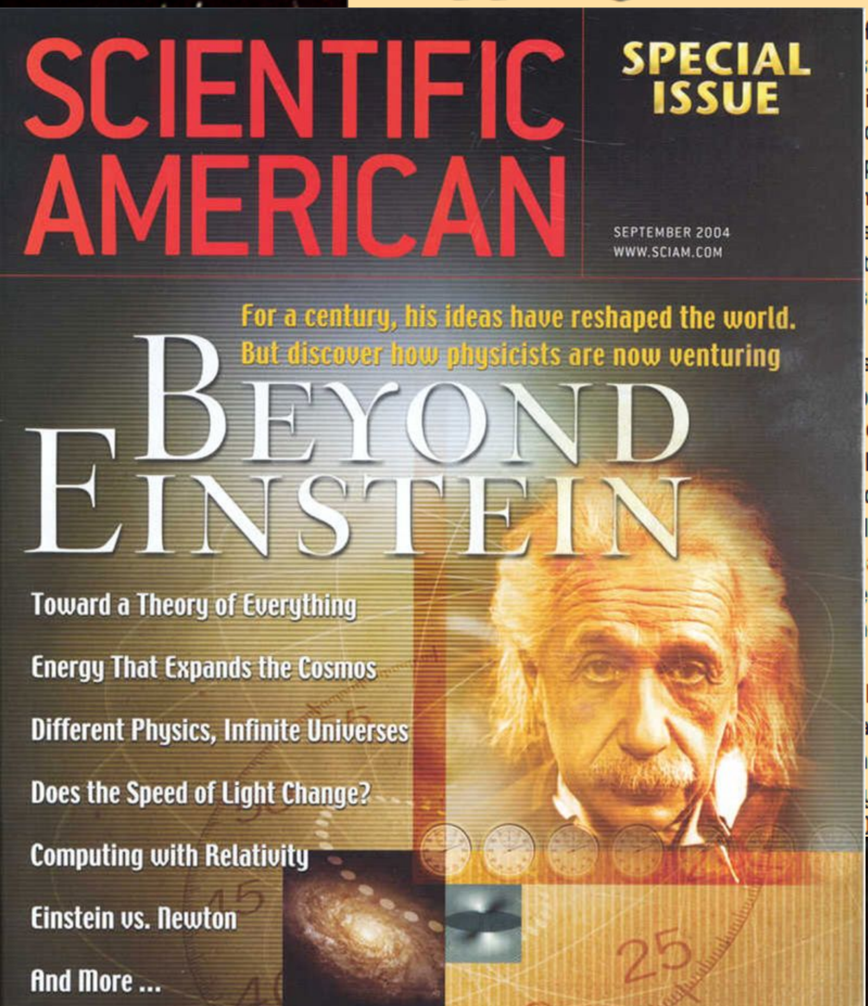

Teppei Katori
Queen Mary University of London
Feb. 1, 2017

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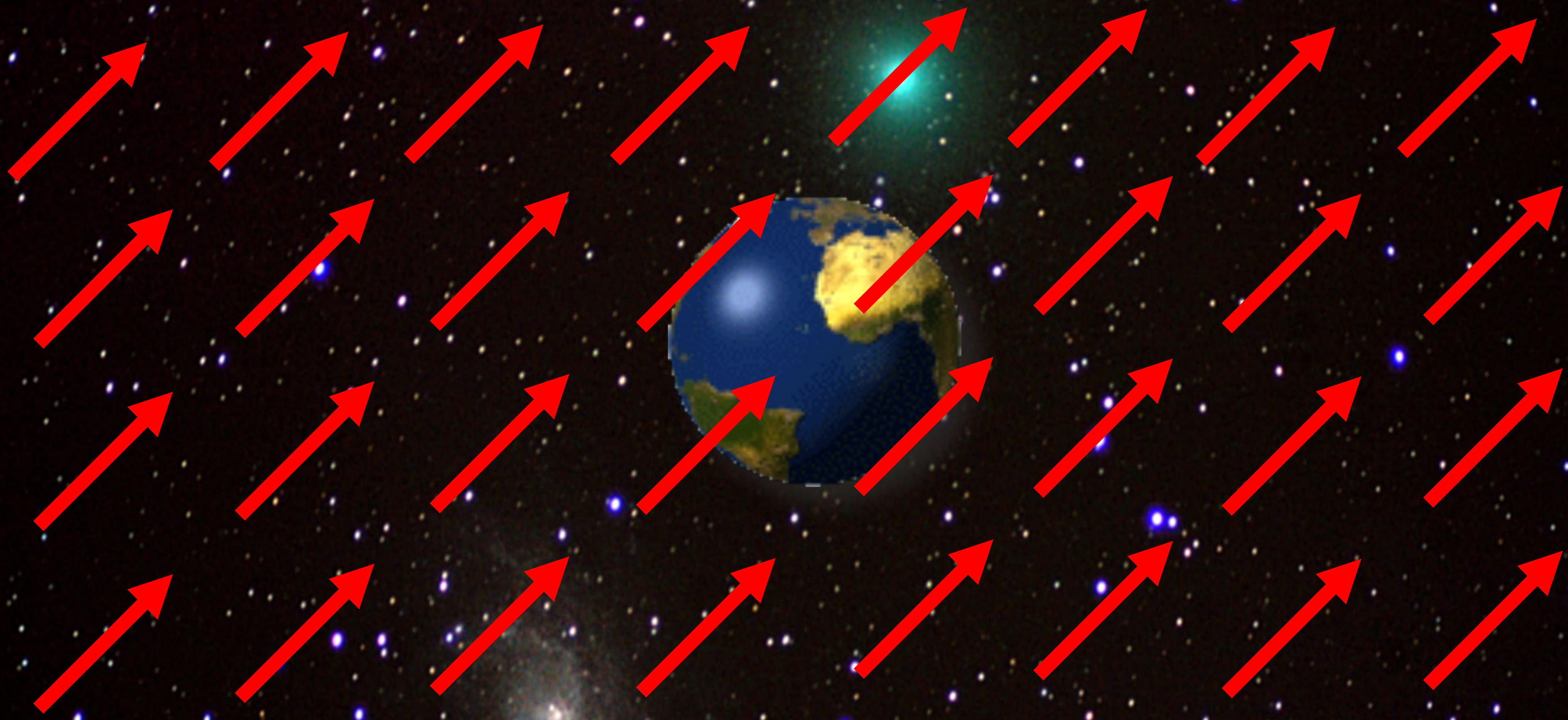

Teppei Katori
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Feb. 1, 2017

Emmy Noether (1882-1935)

Mathematician from Germany

Noether's Theorem
"Every conservation law is a consequence of corresponding symmetry"

- conservation of energy
- conservation of electric charge
- prediction of Higgs boson

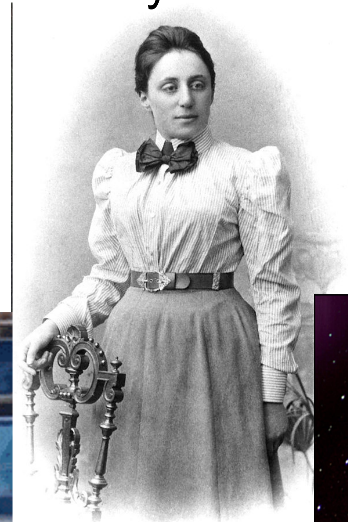
etc

Conservation of Angular Momentum

Rotating object keep rotating

Conservation of
angular momentum

Isaac Newton
Emmy Noether



Universe has
no special direction
→ Universe has
rotation symmetry
(Lorentz symmetry)

Yulia Lipnitskaya (Russia)

→

Isotropy of the Space
(no directionality)

Lorentz Symmetry and Special Relativity

Einstein's theory of special relativity is based on the Lorentz symmetry

Lorentz symmetry assumes isotropic space-time

Einstein and Lorentz

If the universe has a special direction
Space doesn't have Lorentz symmetry
→ Lorentz transformation is violated, or Lorentz violation

Angular momentum is not conserved,
so Yulia Lipnitskaya cannot spin so much!

Since Yulia Lipnitskaya CAN spin so much,
Lorentz violation is very weak effect, even if existed

→ you need very precise machines to find it

Lorentz Symmetry and Theory of Everything

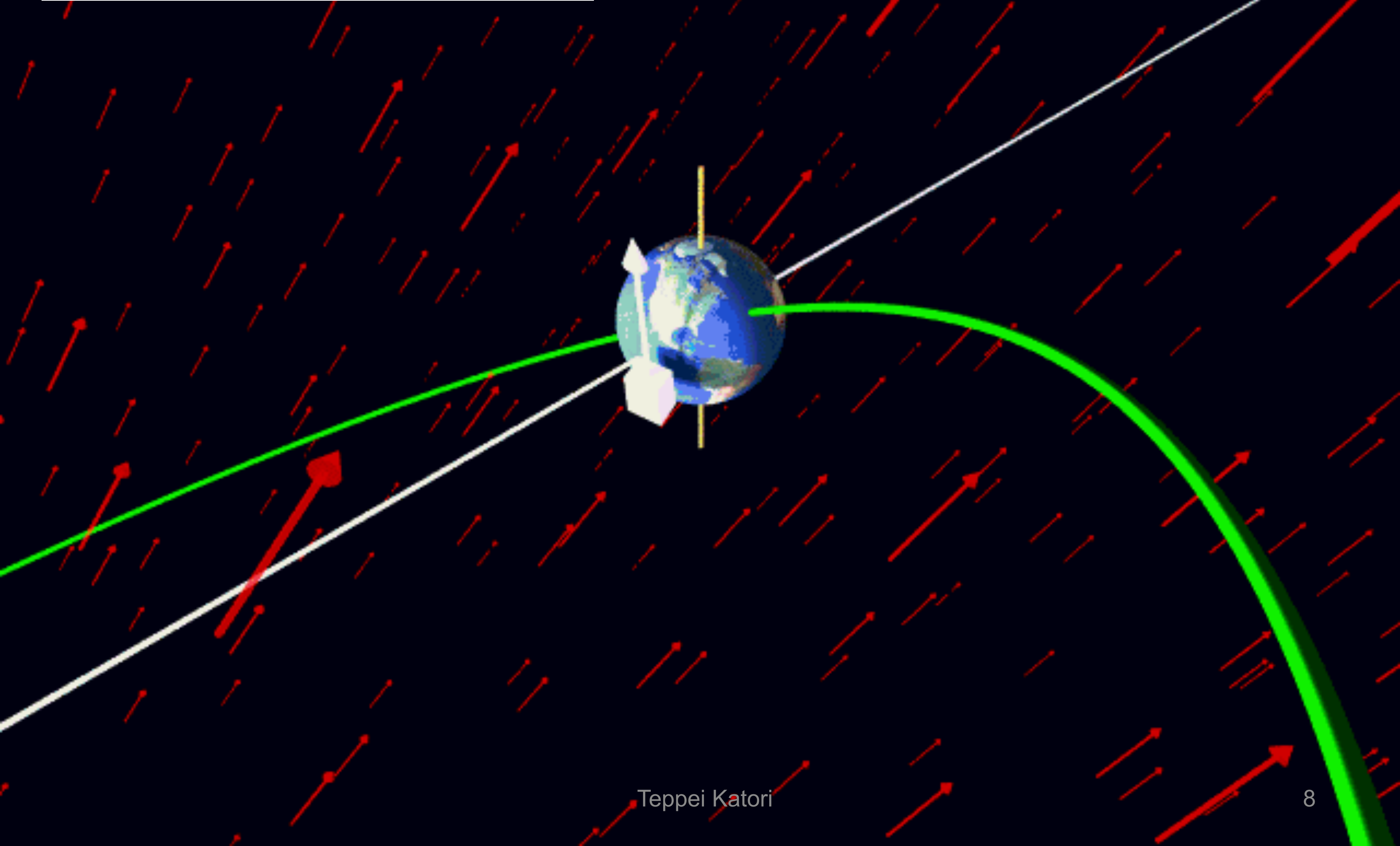
Quantum Gravity or "Theory of Everything" (such as superstring theory, quantum loop gravity, etc) allow tiny amount of Lorentz violation
→ Discovery of Lorentz violation could be the first evidence of Theory of Everything!

Einstein and Lorentz

Stephen Hawking imposter and someone

Bluhm, Kostelecky, Lane, Russell PRL 2002

Lorentz violation
→ Universe has a “direction”, and physics law depends on this



The race to defeat Einstein

Most precise something

The race to defeat Einstein

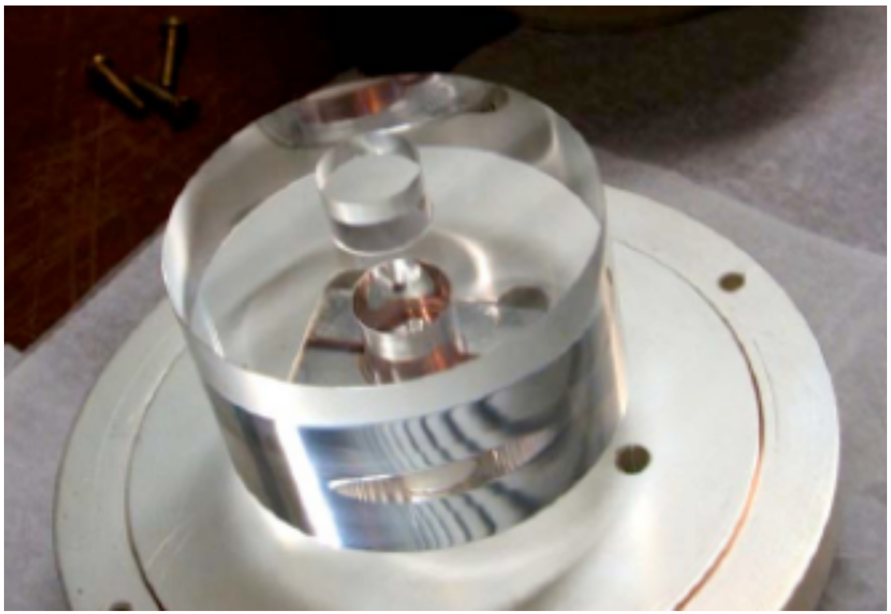
Most precise speed of light measurement

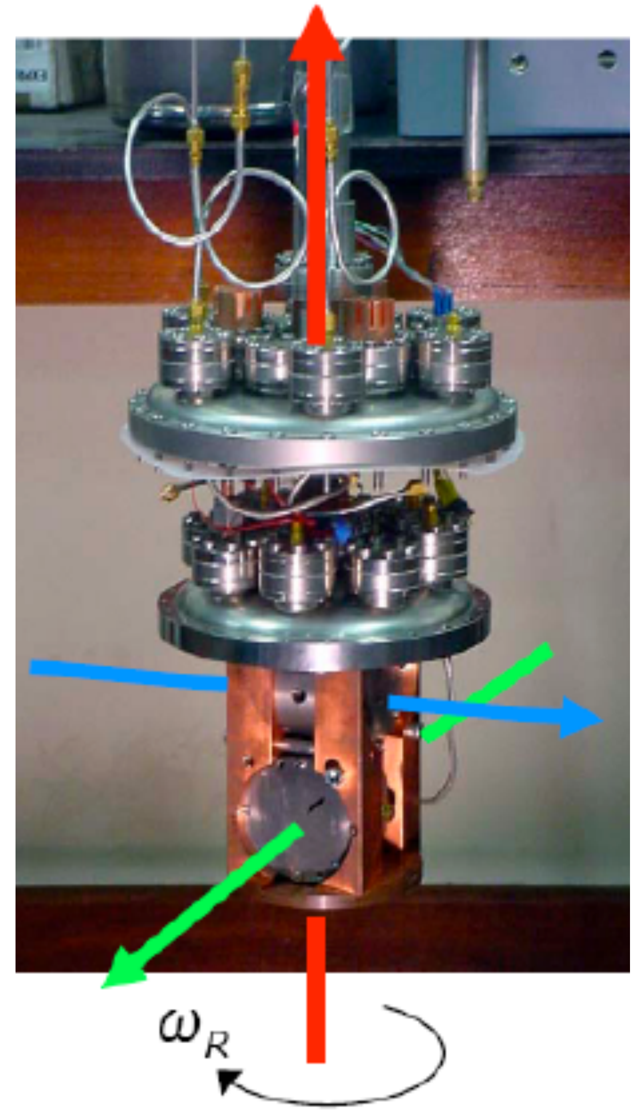
Cryogenic crystal resonator

Cryogenic Sapphire Crystal Resonator

Group from University of Western Australia can measure speed of light with the highest accuracy by this device

→ Lorentz violation is not discovered





The race to defeat Einstein

Most precise pendulum

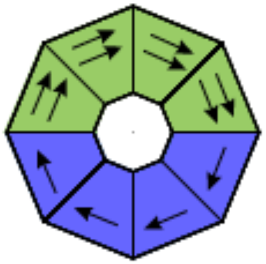
Spin pendulum

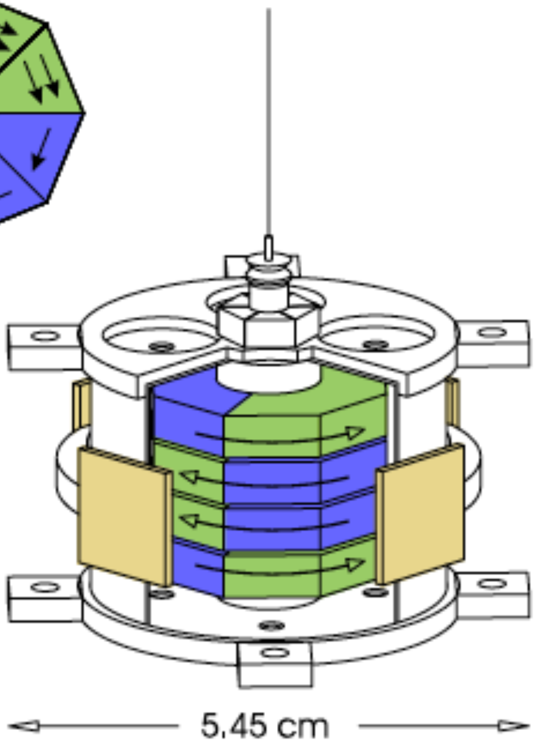
Cryogenic crystal resonator

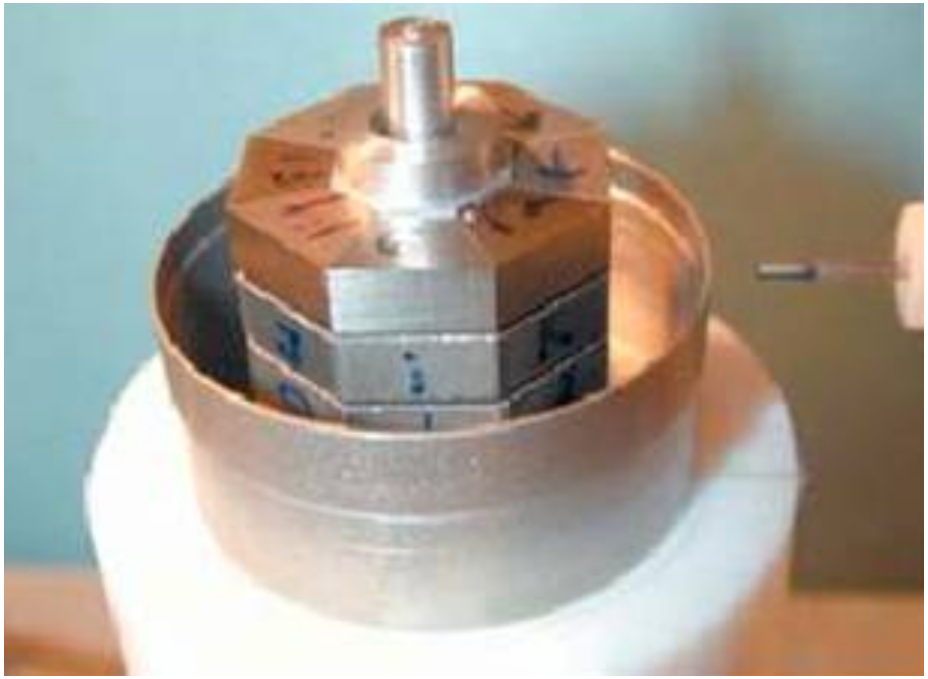
Double Alloy Spin Torsion Pendulum

University of Washington has a technology to make the highest precision pendulum. The pendulum made of clever combination of special alloys is very sensitive of Lorentz violation of atomic electrons

→ Lorentz violation is not discovered







The race to defeat Einstein

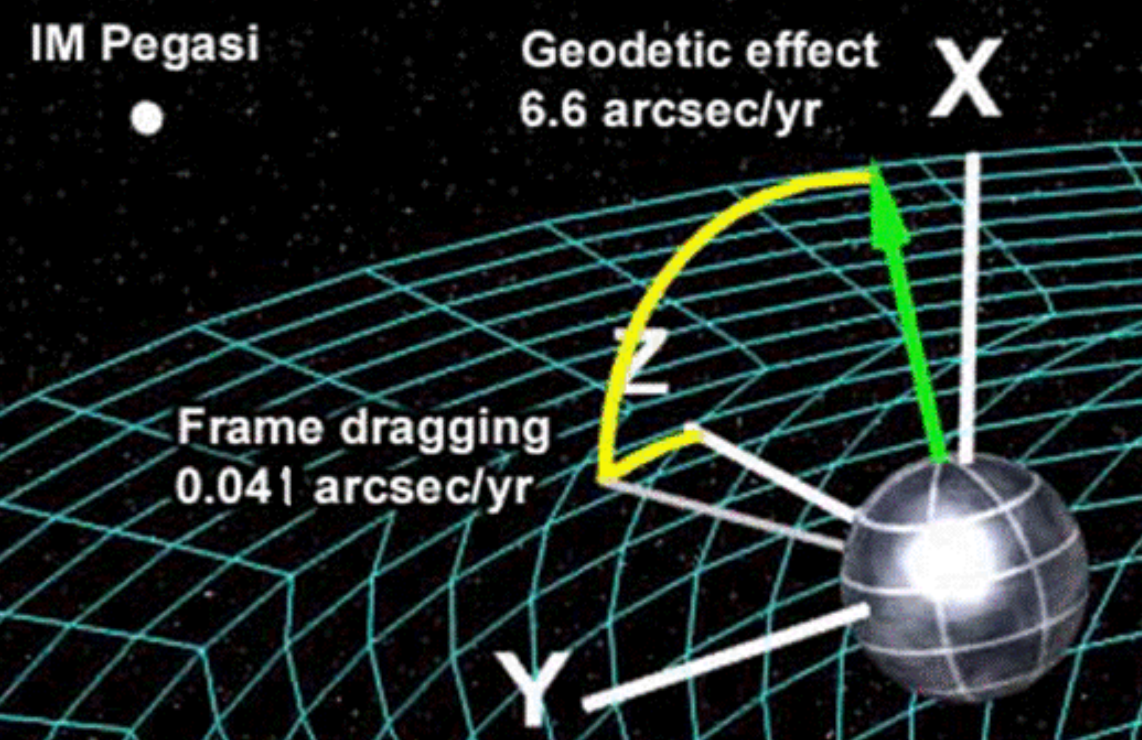
Most precise gyroscope

Spin pendulum

Cryogenic crystal resonator

Space test

Highest precision gravity test in the space



Gravity Probe B tests tiny special gravitational effect in a satellite by the gyroscope, according to Guinness record “the most spherical man-made object”

→ Lorentz violation is not discovered

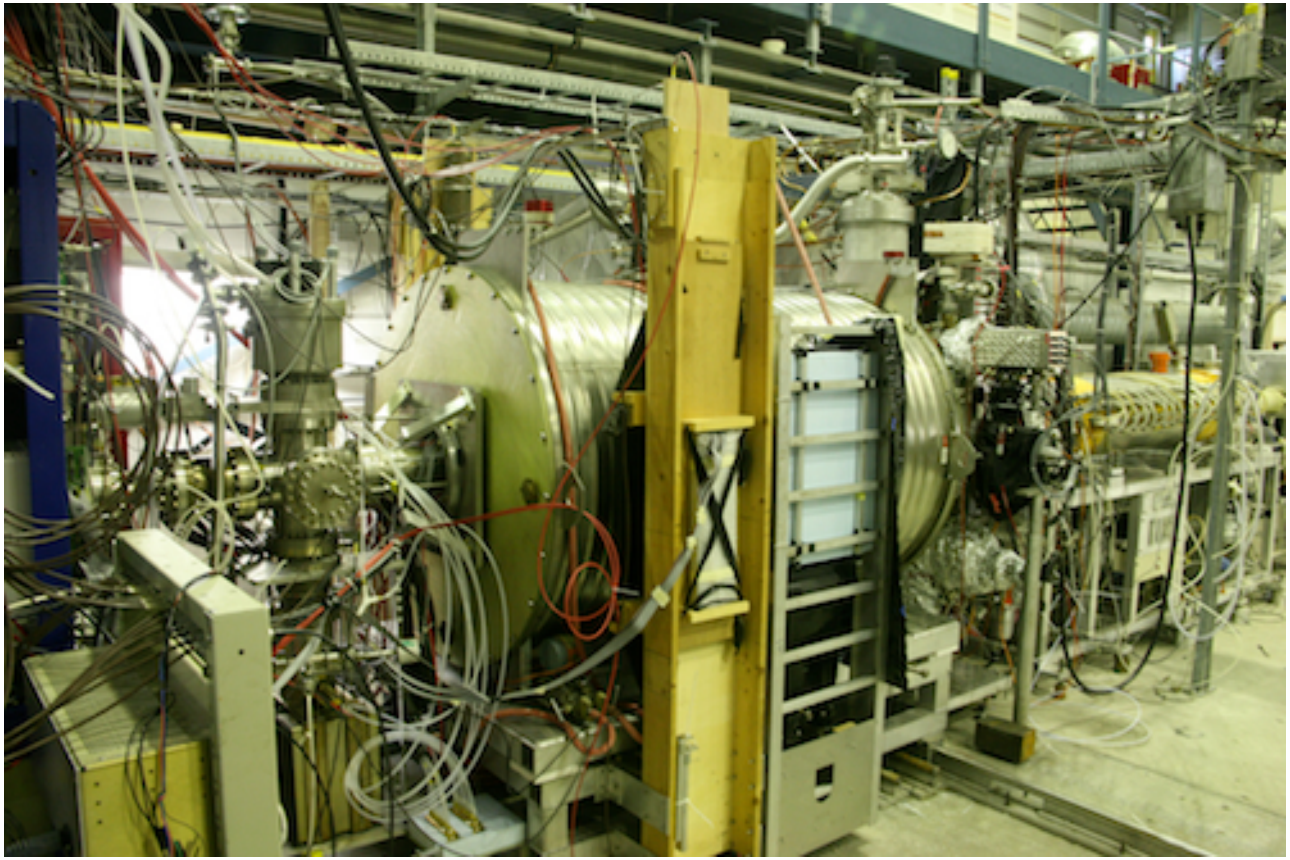
The race to defeat Einstein

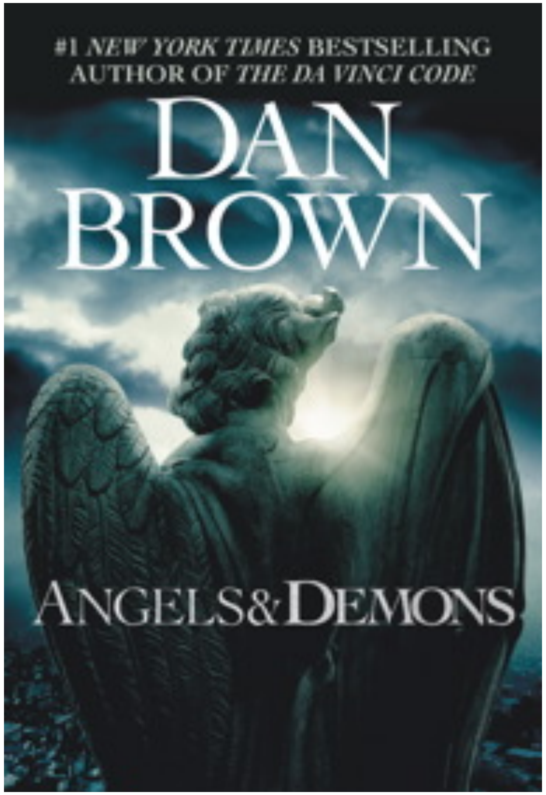
Largest amount of anti-hydrogen

Antiproton decelerator at CERN

CERN has an ability to perform the highest precision antimatter test (matter-antimatter asymmetry induces Lorentz violation)

→ Lorentz violation is not discovered





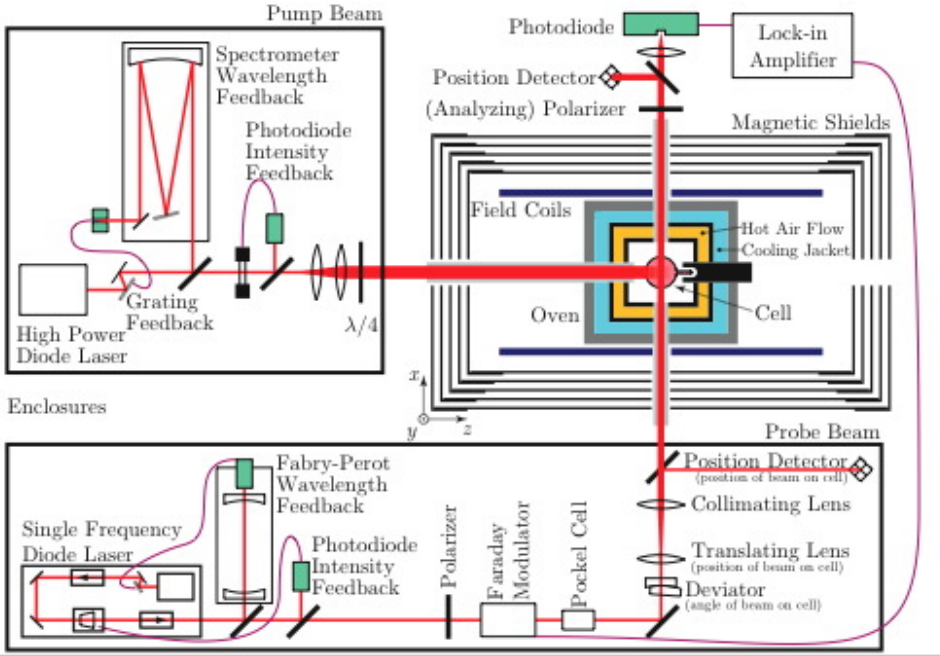
The race to defeat Einstein

Most precise magnetic field measurement

Double Noble Gas Maser

A type of atomic clock very sensitive to a tiny magnetic field

→ Lorentz violation is not discovered



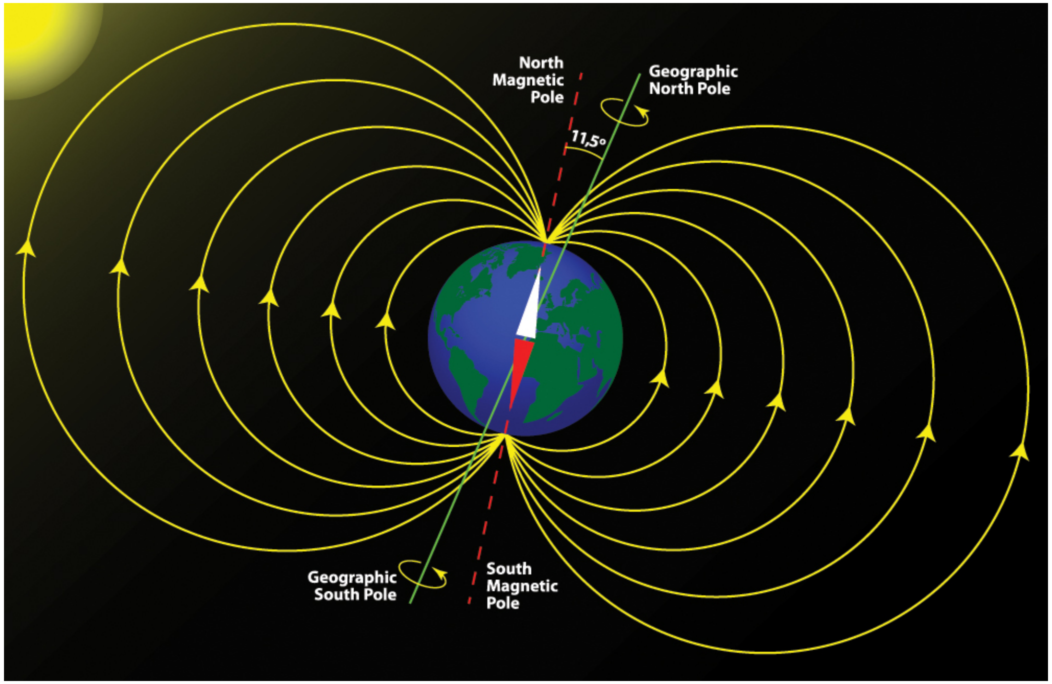
Double Noble Gas Maser

A type of atomic clock very sensitive to a tiny magnetic field

→ Lorentz violation is not discovered

The earth magnetic field gives error. To improve sensitivity, scientists want to repeat the measurement at special location on the earth (special earth magnetic field configuration)

Princeton university group vs. Amherst college group



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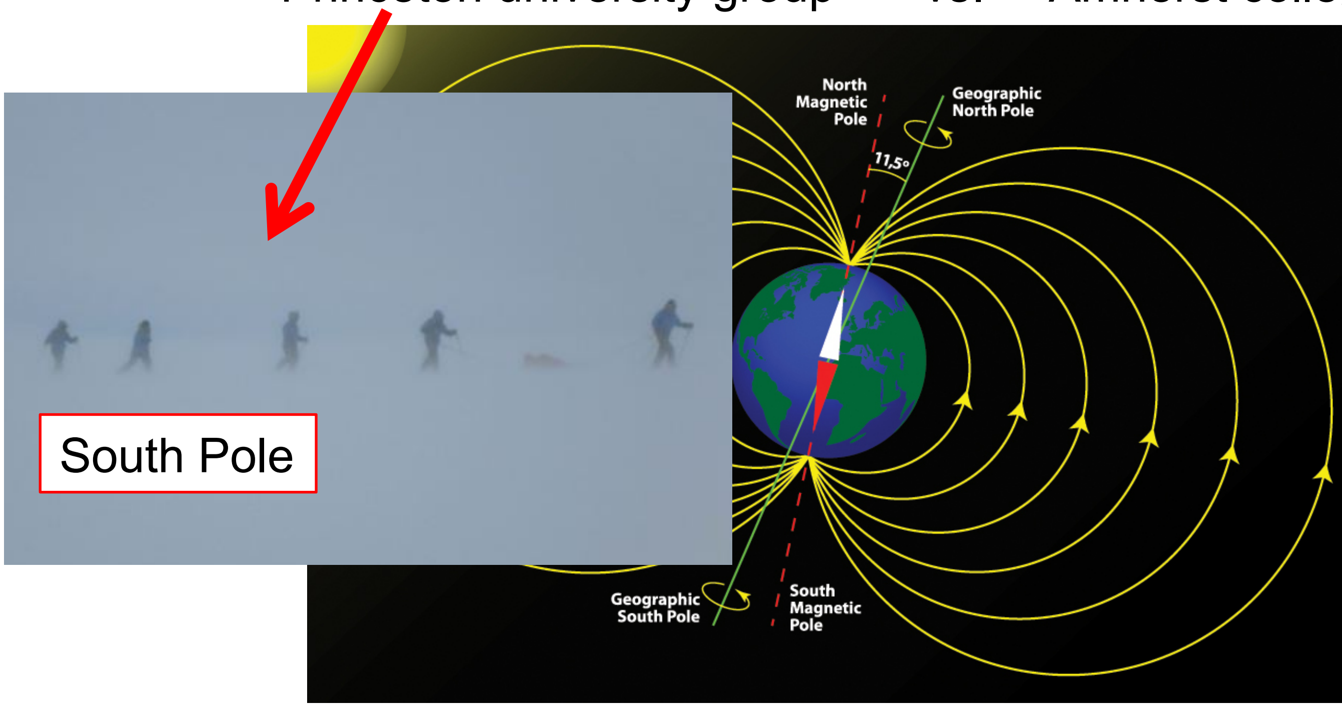

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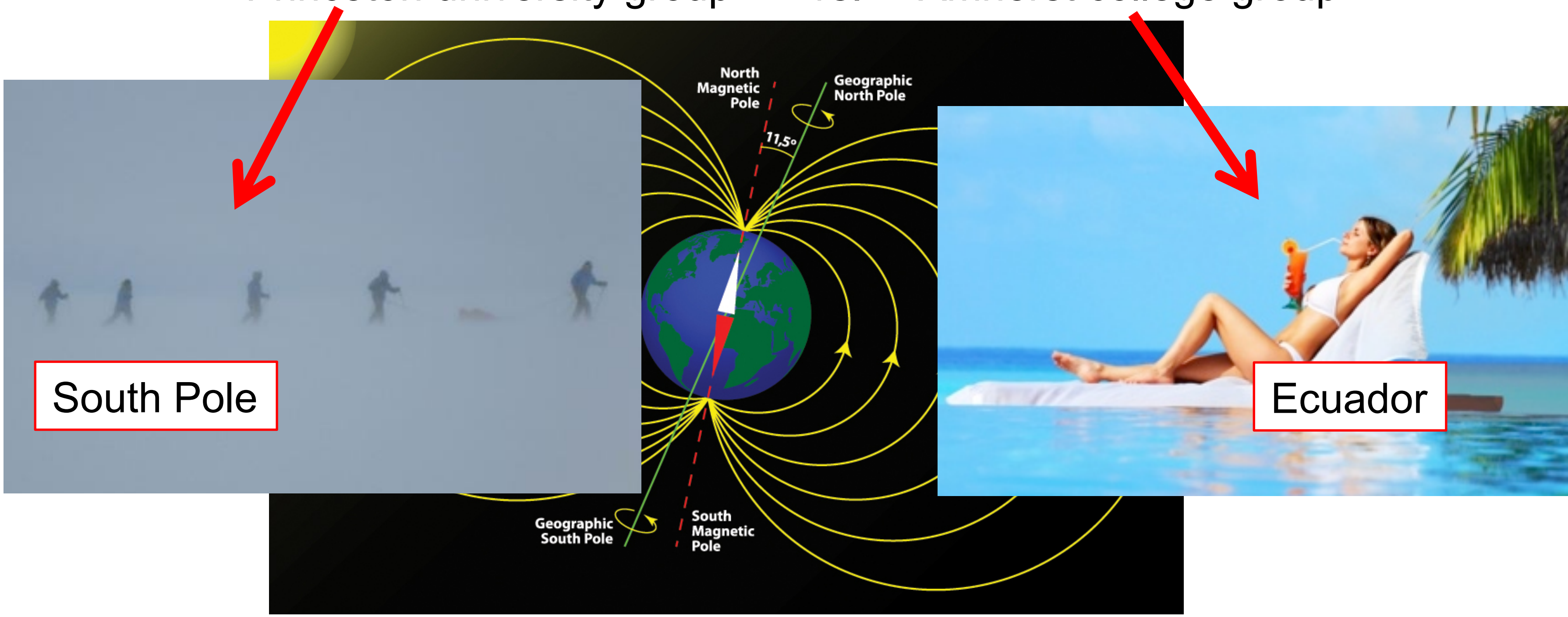

The race to defeat Einstein

Most precise something

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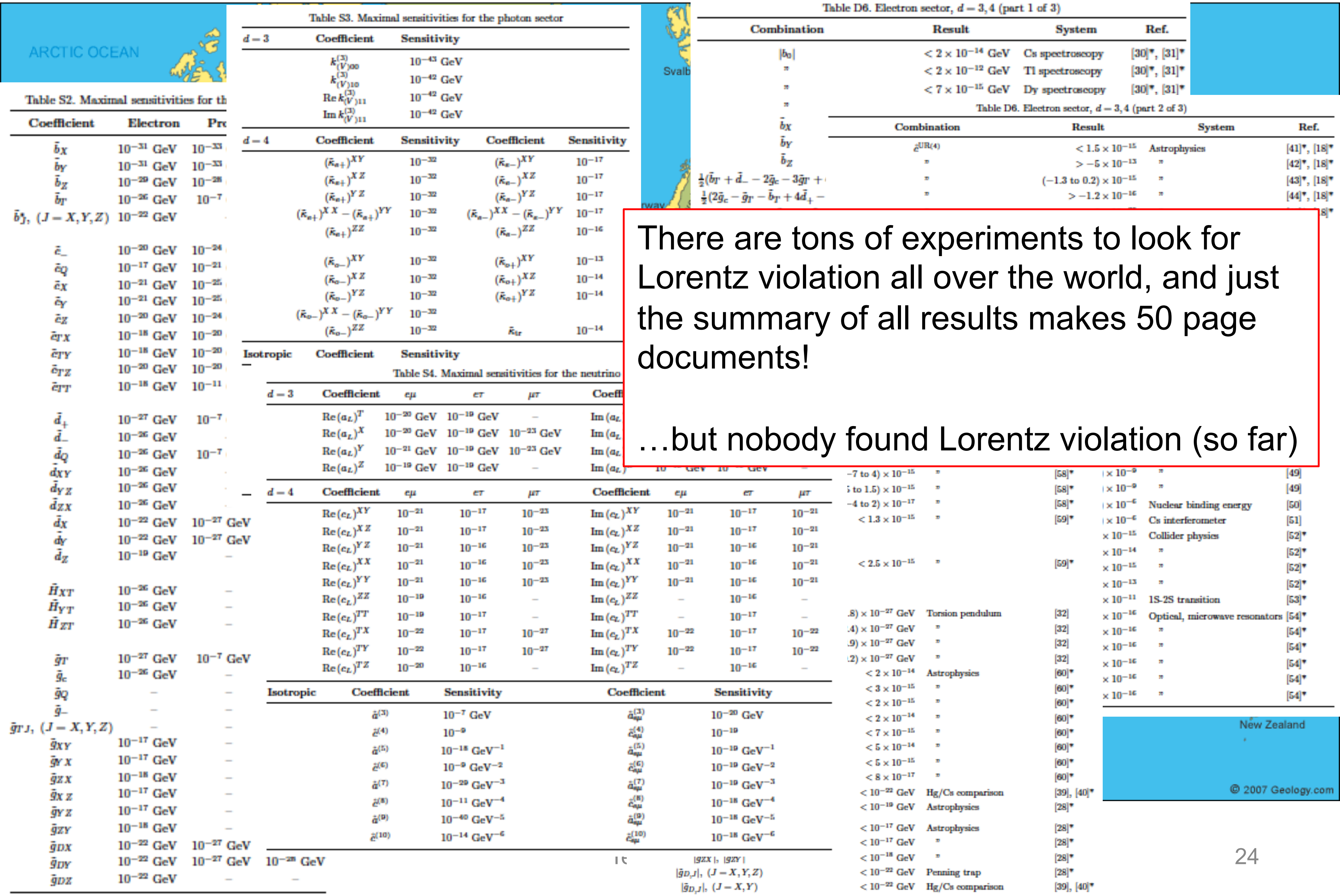
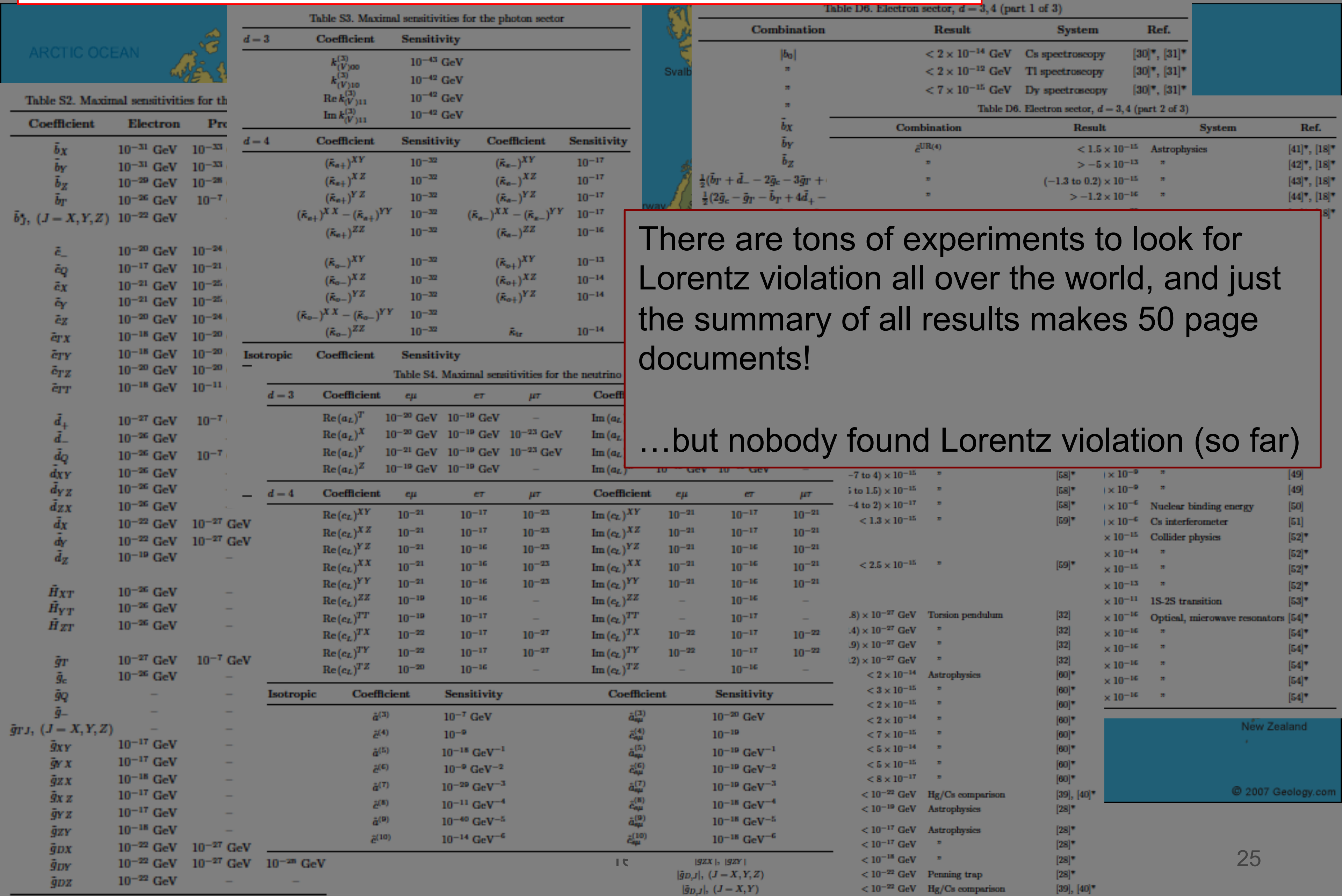


There are tons of experiments to look for Lorentz violation all over the world, and just the summary of all results makes 50 page documents!

…but nobody found Lorentz violation (so far)

So far no experiments find Lorentz violation…

ost precise something



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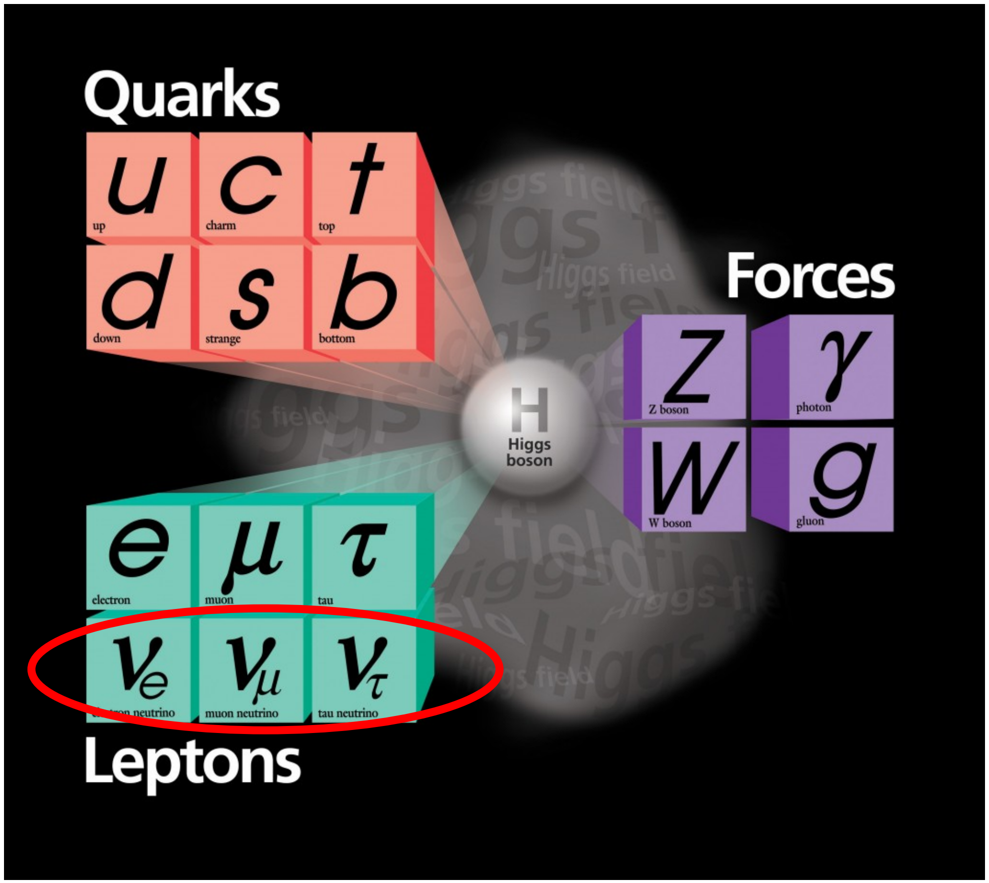
Neutrino!

Search of Lorentz Violation with Neutrino

People use ordinary particles to look for Lorentz violation, but cannot find
→ Maybe we should use extraordinary particles, such as neutrinos



Neutrinos
- 3 types
- neutral (no electric charge)
- extremely tiny mass
- second most abundant particles in the universe (after photon)

- neutrinos interact very very weakly with matters, so extremely difficult to detect

ex) Neutrinos from the Sun
~1 trillion neutrinos pass through your body every second, and you have 25% chance to hit one neutrino in 80 years

Search of Lorentz Violation with Neutrino

Neutrinos are mysterious particles, and we still don't know much about neutrinos
→ Maybe neutrinos have better chance to find Lorentz violation?

Especially, many neutrino data show some anomaly, it could be Lorentz violation?

Search of Lorentz Violation with Neutrino

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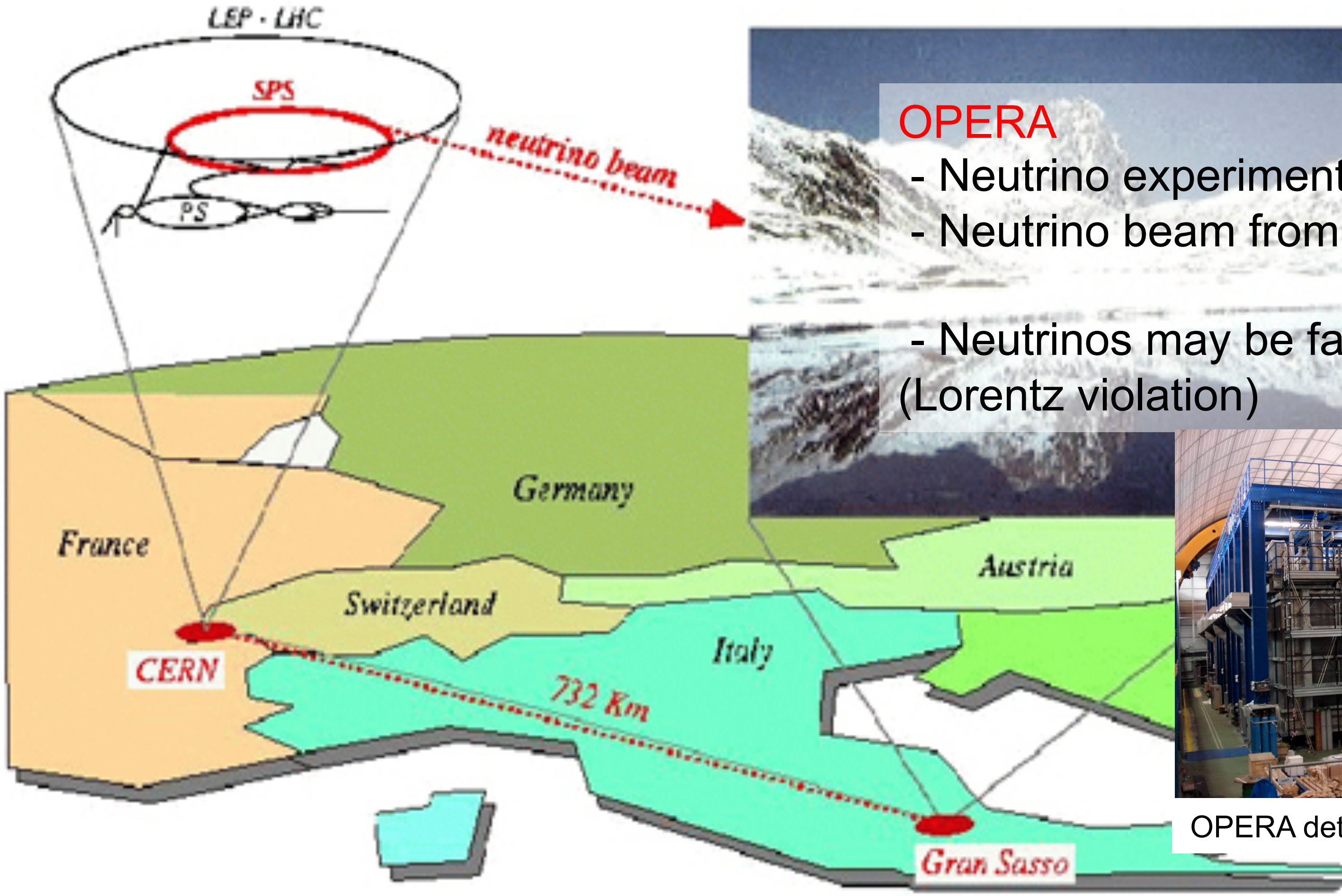


OPERA
- Neutrino experiment at Gran Sasso, Italy
- Neutrino beam from CERN, Switzerland

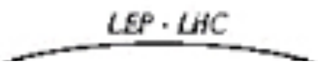
- Neutrinos may be faster than the light?!
(Lorentz violation)

OPERA detector at Gran Sasso

Search of Lorentz Violation

Neutrinos are mysterious particle … out neutrinos
→ Maybe neutrinos have better …

In particular, many neutrino data …



theguardian

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Neutrinos still faster than light in latest version of experiment

Finding that contradicts Einstein's theory of special relativity is repeated with fine-tuned procedures and equipment

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The Washington Post

Posted at 08:25 AM ET, 09/23/2011

Neutrinos may have traveled faster than the speed of light

By Elizabeth Flock

Scientists at CERN, the world's largest physics lab, announced a startling finding yesterday that would be enough to make Albert Einstein roll over in his grave: Subatomic particles, called neutrinos, have been found to be traveling faster than the speed of light.

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Scientists Report Second Sighting of Faster-Than-Light Neutrinos

By DENNIS OVERBYE
Published: November 18, 2011

Few scientists are betting against Einstein yet, but the phantom neutrinos of Opera are still eluding explanation.

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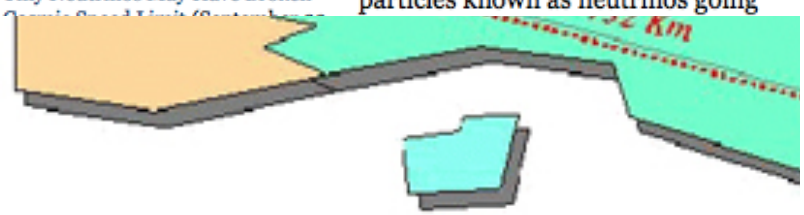
Tiny Neutrinos May Have Broken

Two months after scientists reported that they had clocked subatomic particles known as neutrinos going



Monday 06 February 2012

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Speed of light broken again as scientists test neutrino result

The speed of light appears to have been broken again after scientists carried out a new set of experiments to test measurements that could require the laws of physics to be rewritten.

Search of Lorentz Violation

OPERA

- Neutrinos may be faster than the light?!

(Lorentz violation)

→ experimental error

(Lorentz violation is not discovered)

We should take a look other neutrino data

The Washington Post

Posted

Faste

By Alex

The New York Times

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ENVIRONMENT SPACE & COSMOS

Two Technical Problems Leave Neutrinos' Speed in Question

By KENNETH CHANG

Published: February 23, 2012

Remember those faster-than-light neutrinos that supposedly defied Einstein's speed limit?

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Faster-than-light neutrinos could be down to bad wiring

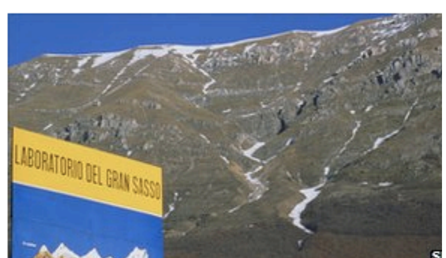
By Jason Palmer

Science and technology reporter, BBC News

What might have been the biggest physics story of the past century may instead be down to a faulty connection.

In September 2011, the Opera experiment reported it had seen particles called neutrinos evidently travelling faster than the speed of light.

The team has now found two problems that may have affected their test in opposing ways: one in its timing gear and one in an optical fibre



The neutrinos are fired deep under the Italian

rewritten.

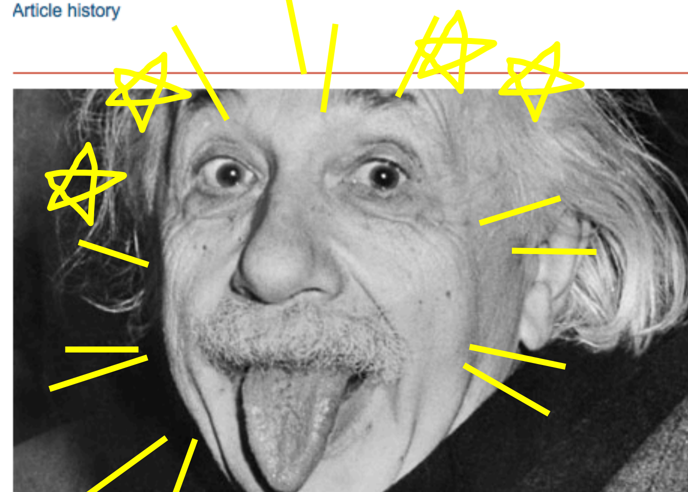
Faster-than-light neutrinos: was a faulty connection to blame?

A dodgy optical fibre connection may have skewed results that appeared to show neutrinos travelling faster than light

Alok Jha, science correspondent

guardian.co.uk, Thursday 23 February 2012 11.05 EST

Article history



Faster-than-light neutrinos would breach Einstein's theory of special relativity.

Search of Lorentz Violation with Neutrino

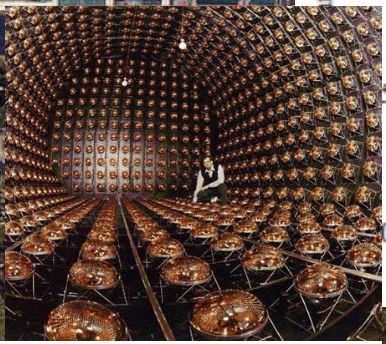
Neutrinos are mysterious particles, and we still don't know much about neutrinos
→ Maybe neutrinos have better chance to find Lorentz violation?

Especially, many neutrino data show some anomaly, it could be Lorentz violation?

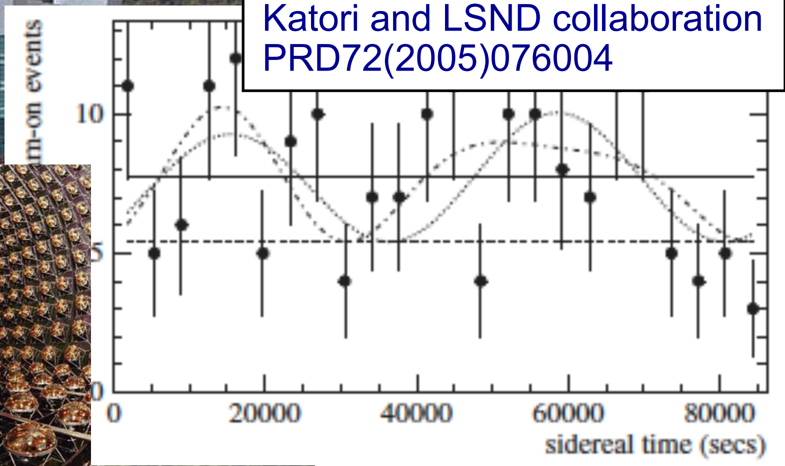
Los Alamos NATIONAL LABORATORY

LSND
- Neutrino experiment at Los Alamos laboratory, USA
- Data show some anomaly

→ This is not due to Lorentz violation



Inside of LSND detector



Katori and LSND collaboration
PRD72(2005)076004

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Fermilab

MiniBooNE
- Neutrino experiment at Fermilab, USA
- Data show some anomaly

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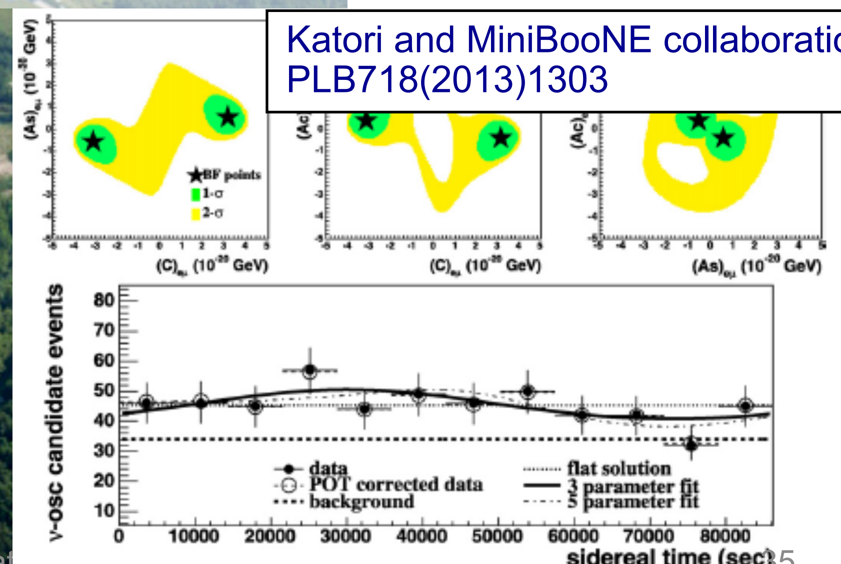
MiniBooNE detector

Katori and MiniBooNE collaboration
PLB718(2013)1303



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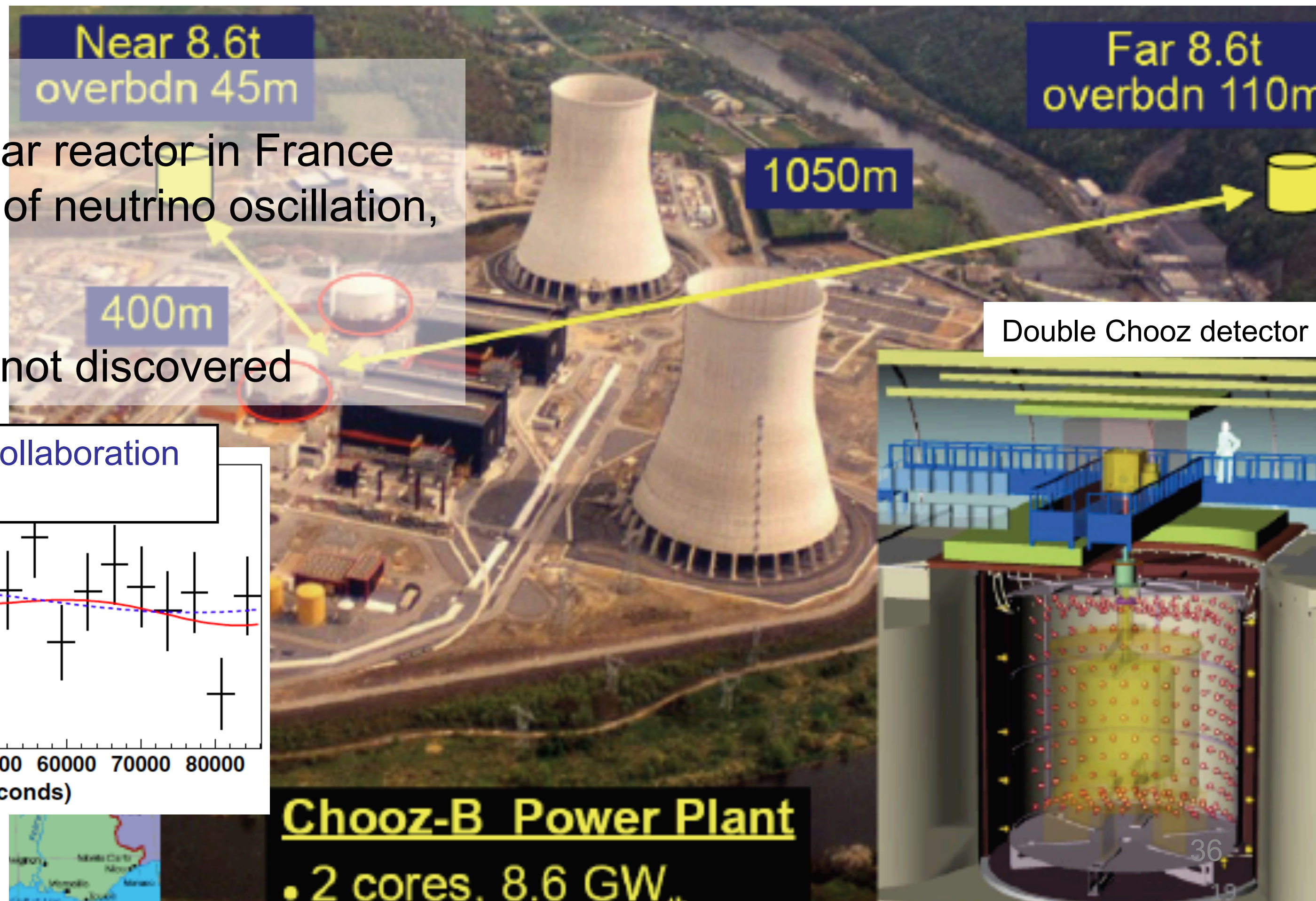
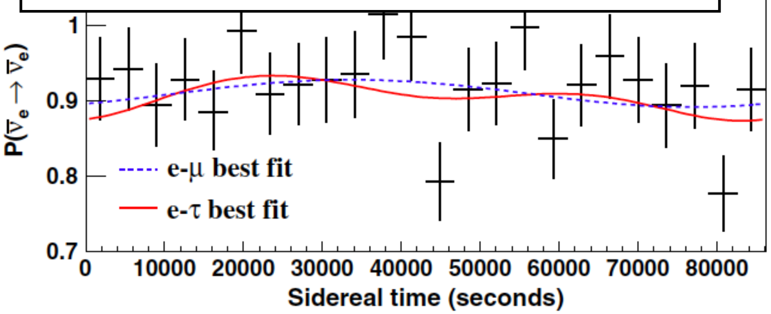


Double Chooz
- Neutrinos from nuclear reactor in France
- Data show new type of neutrino oscillation, could be new physics

→ Lorentz violation is not discovered

Katori and Double Chooz collaboration
PRD86(2012)112009



Double Chooz detector

So far, no neutrino experiments find Lorentz violation…

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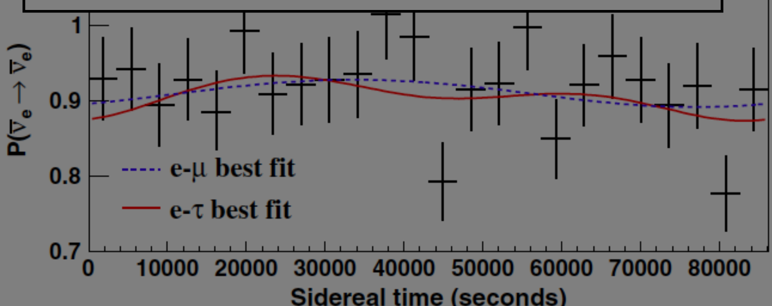


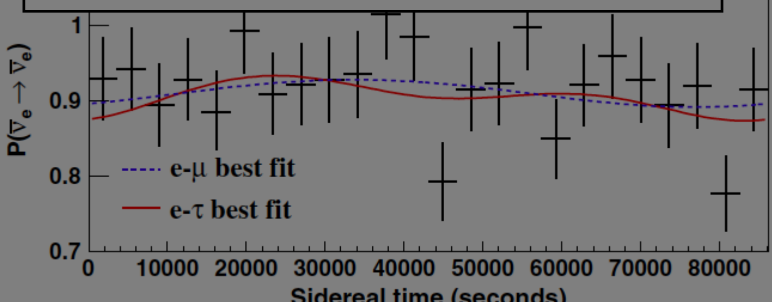
So far, no neutrino experiments find Lorentz violation…

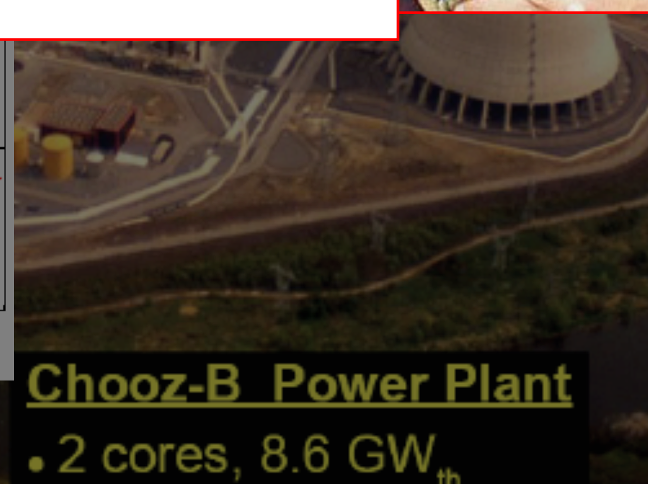
"Extraordinary discovery requires extraordinary evidence"
- Carl Sagan

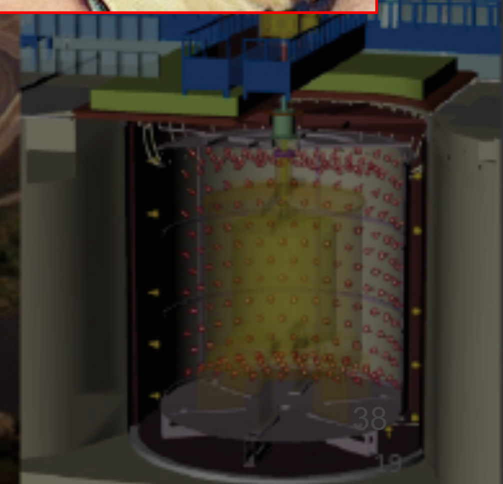
↓

"Extraordinary discovery requires extraordinary particles"
- Teppei

…may be this is not extraordinary enough?







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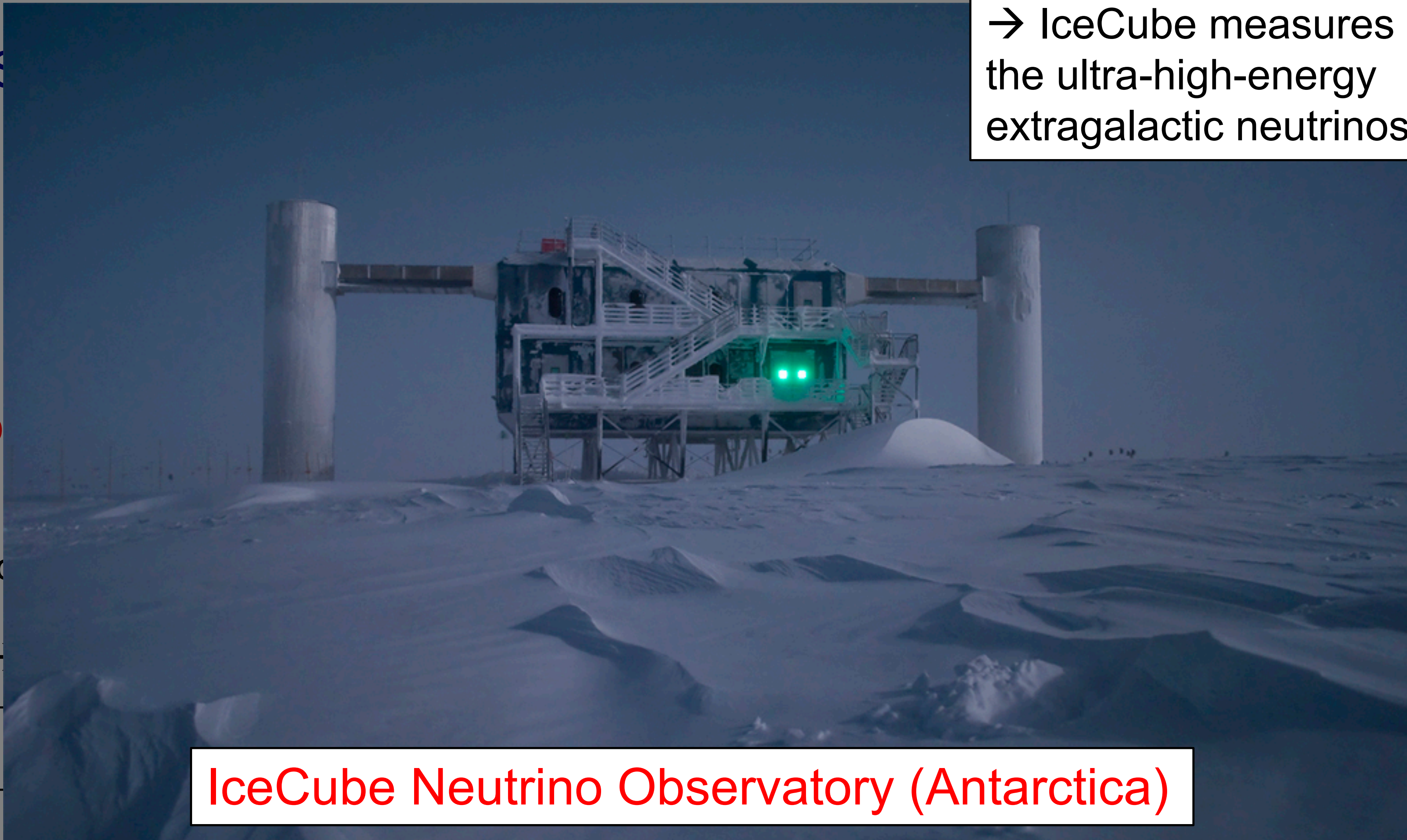
"Extraordinary discovery requires extraordinary particles with the extraordinary energy and extraordinary propagation distance"
- Teppei

→ IceCube measures the ultra-high-energy extragalactic neutrinos



IceCube Neutrino Observatory (Antarctica)

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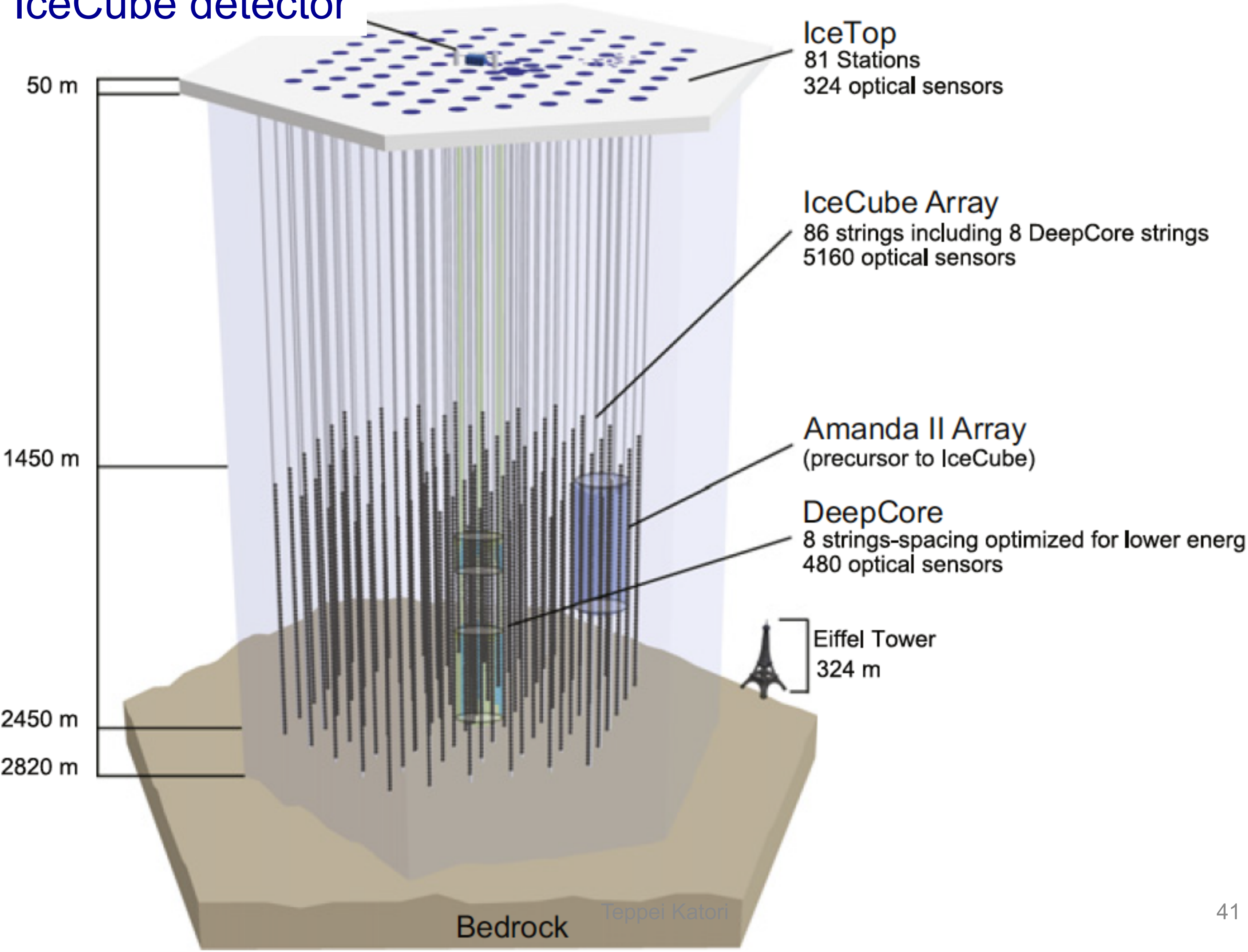
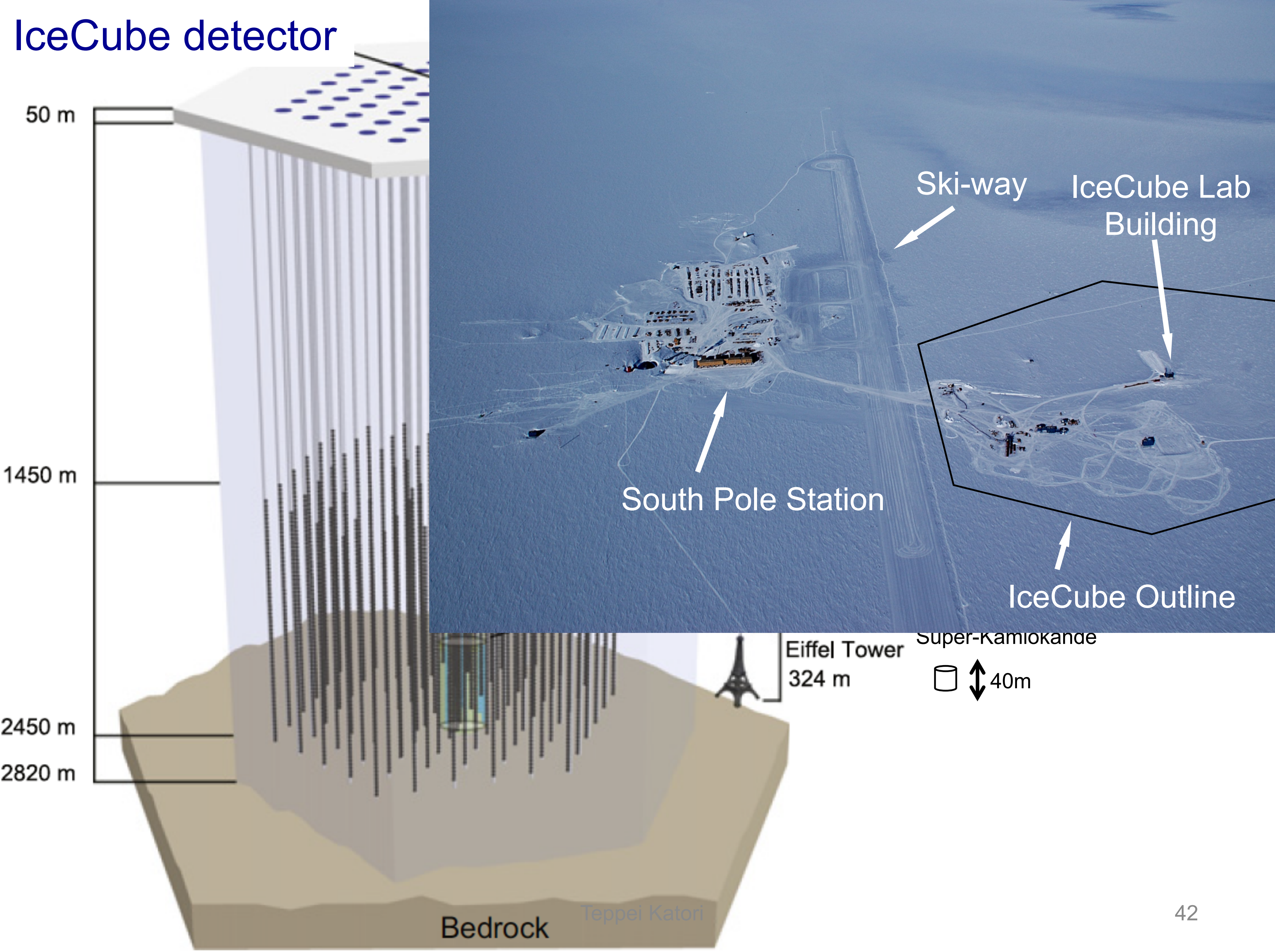
- Teppei

IceCube detector



IceCube detector



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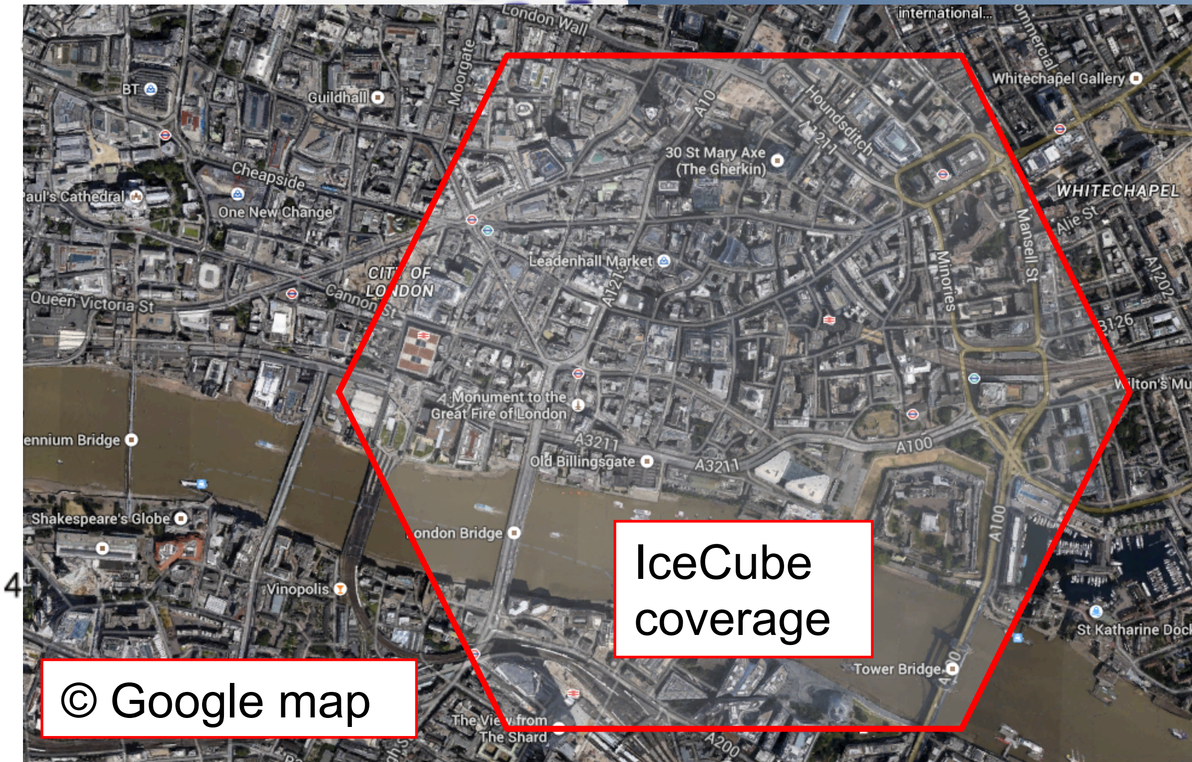

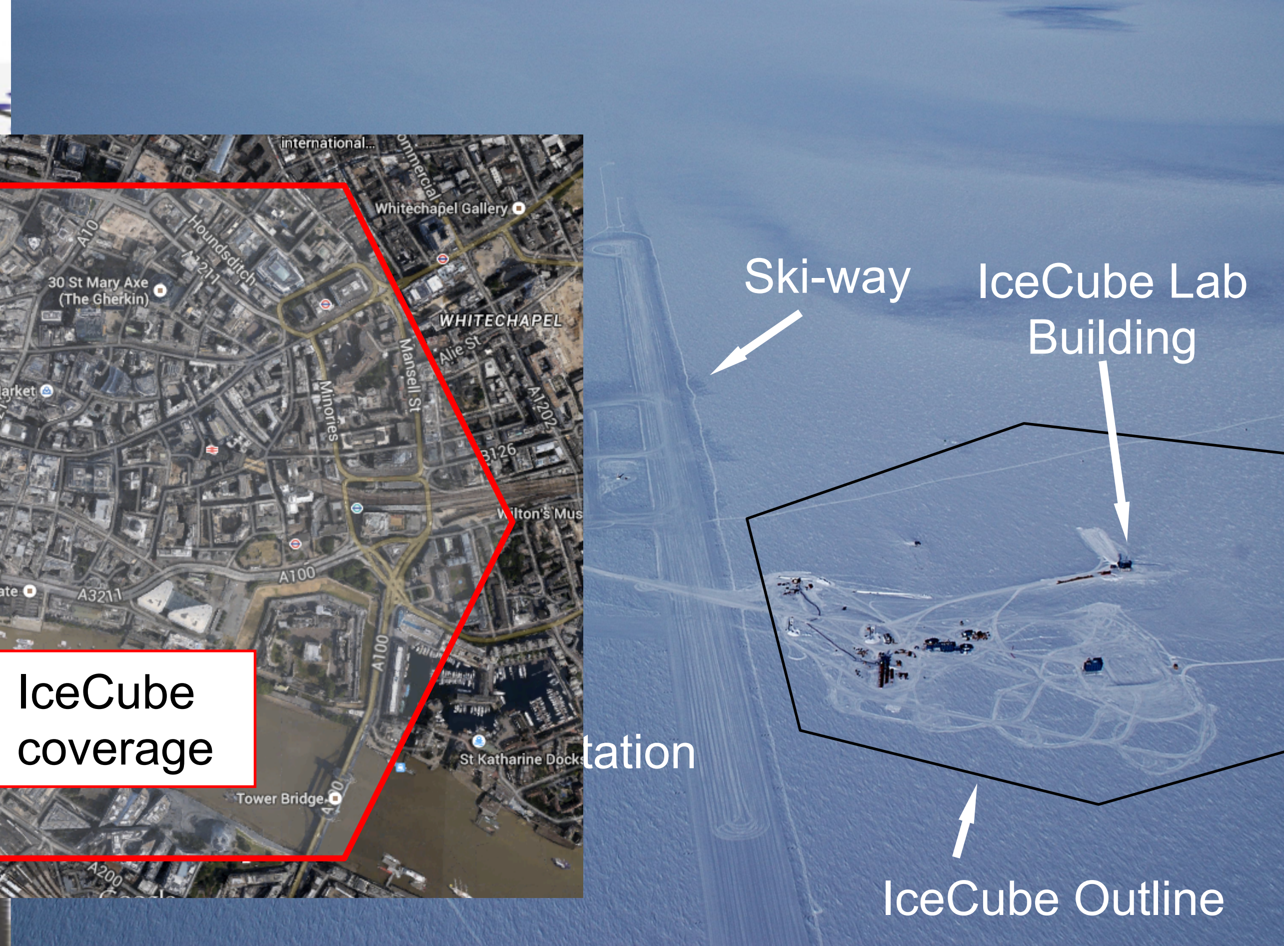

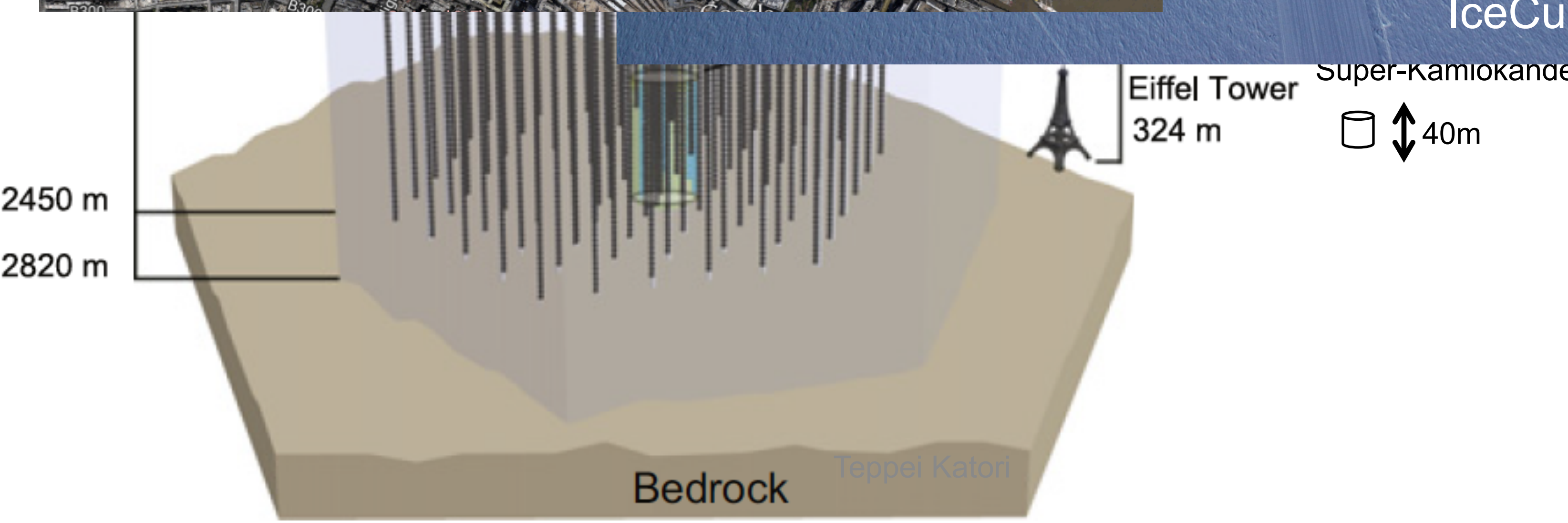

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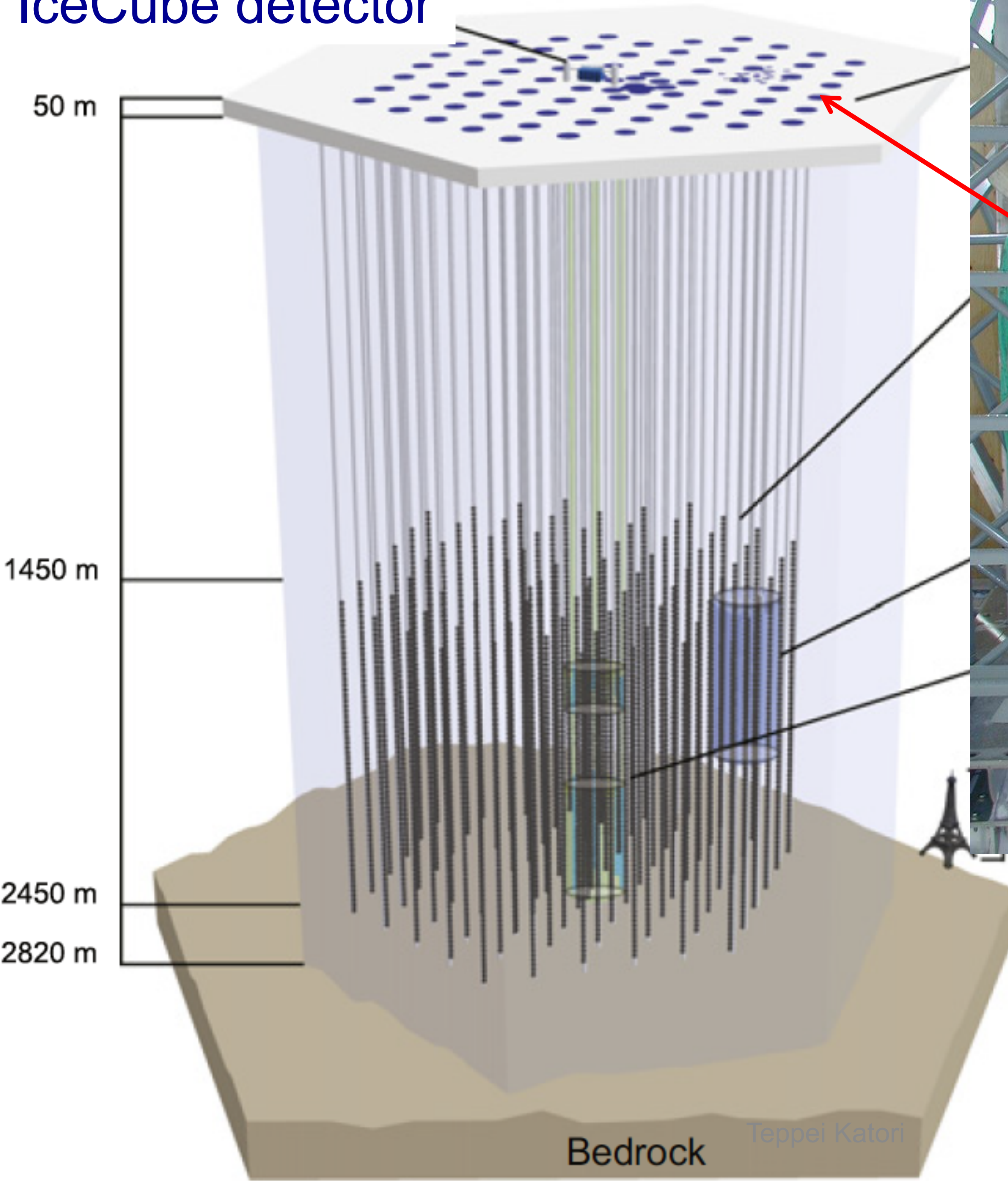

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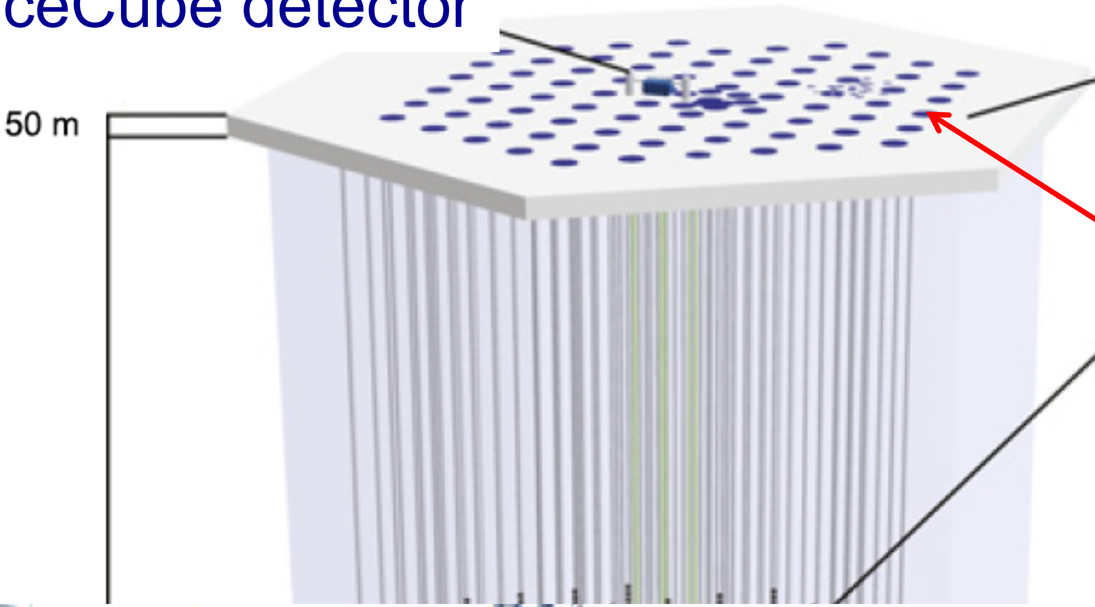
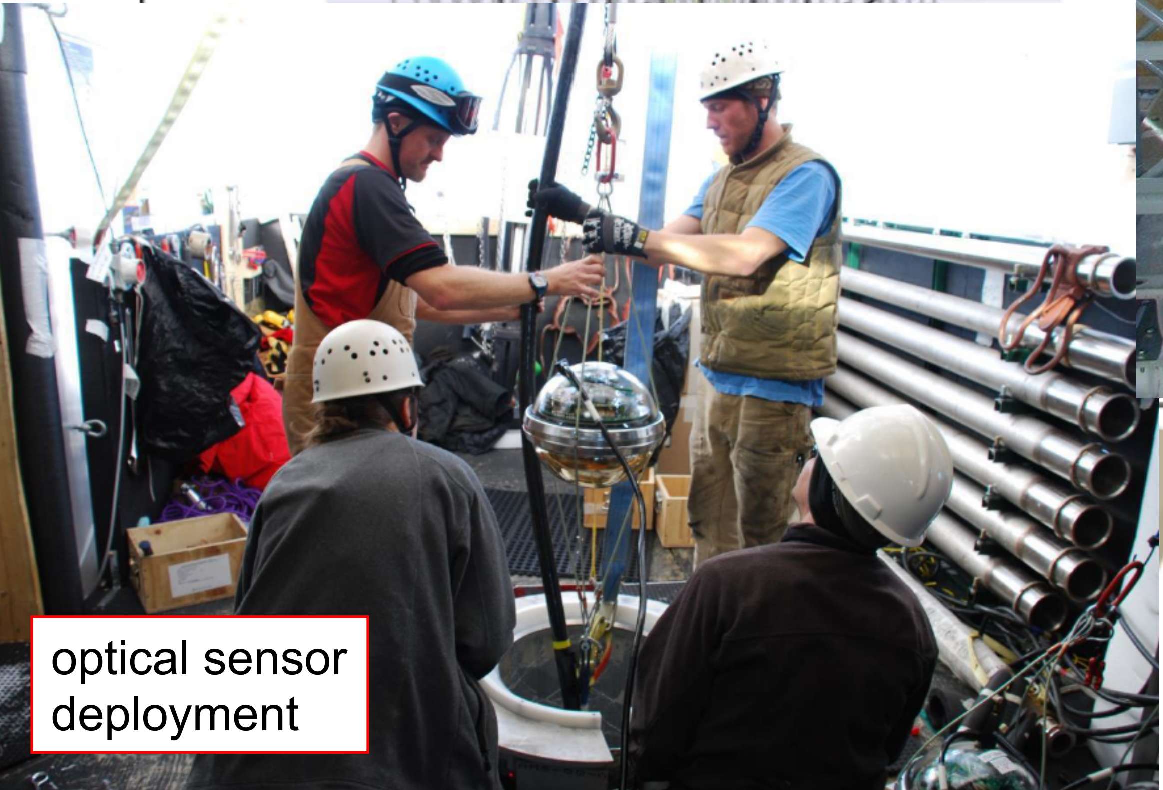
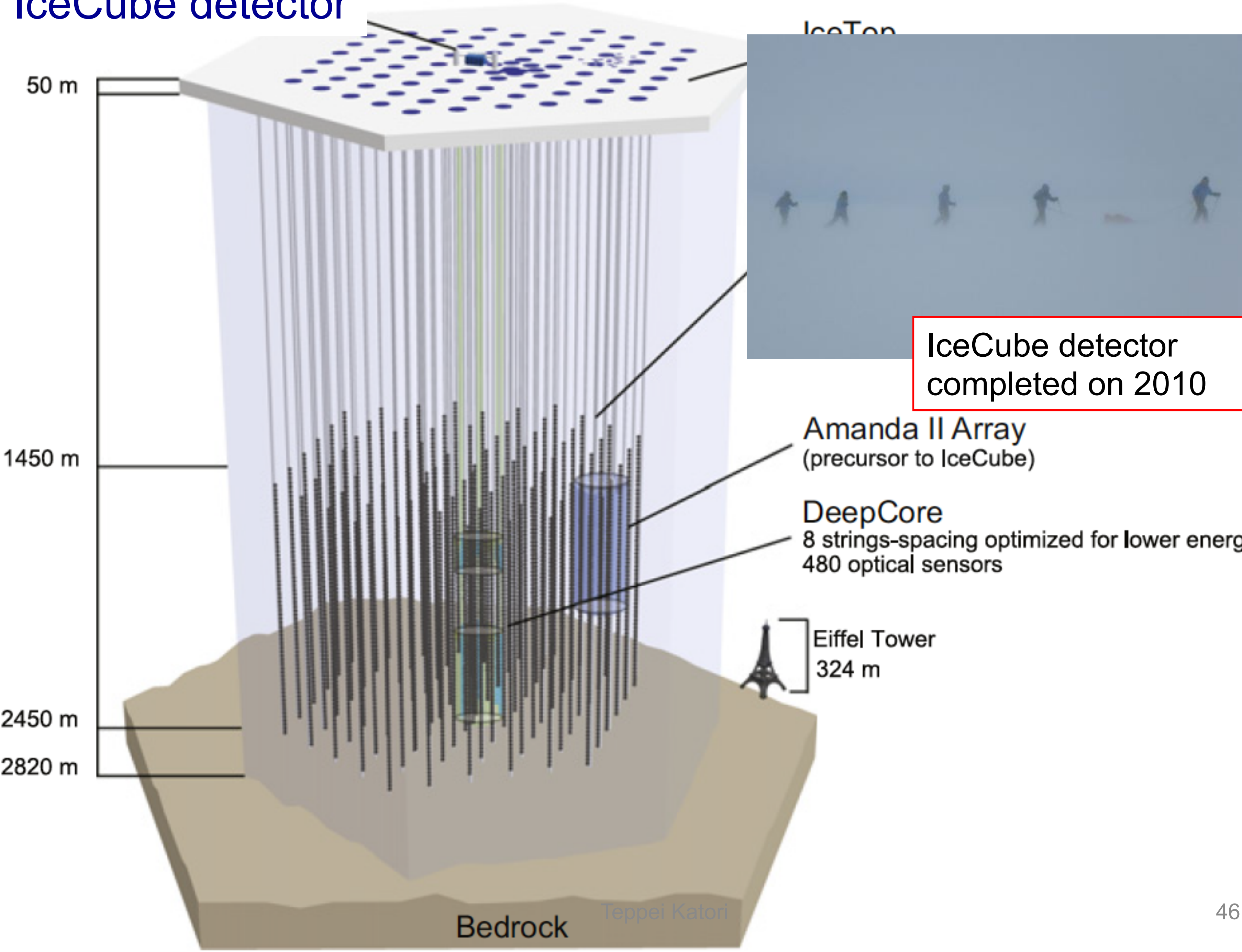


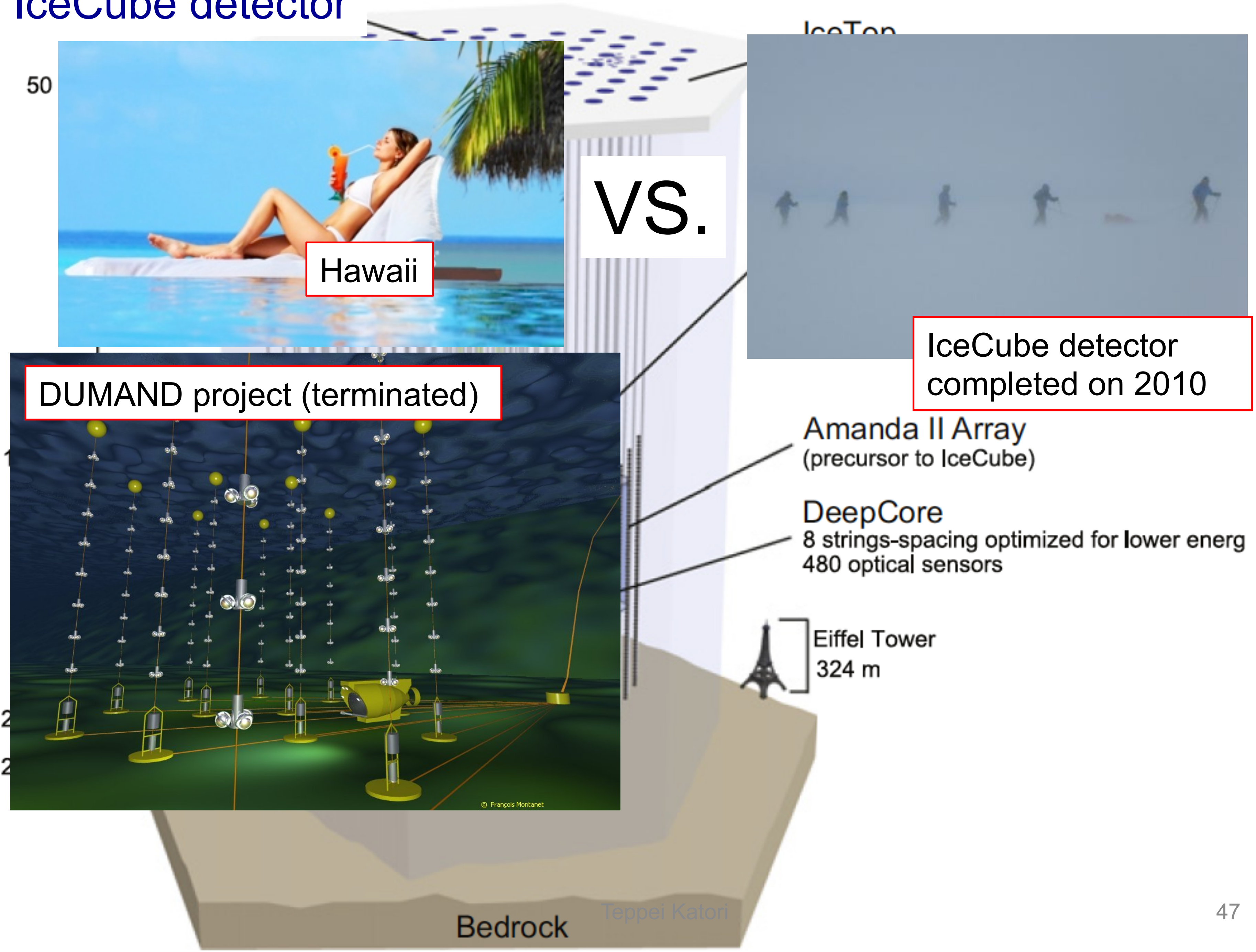


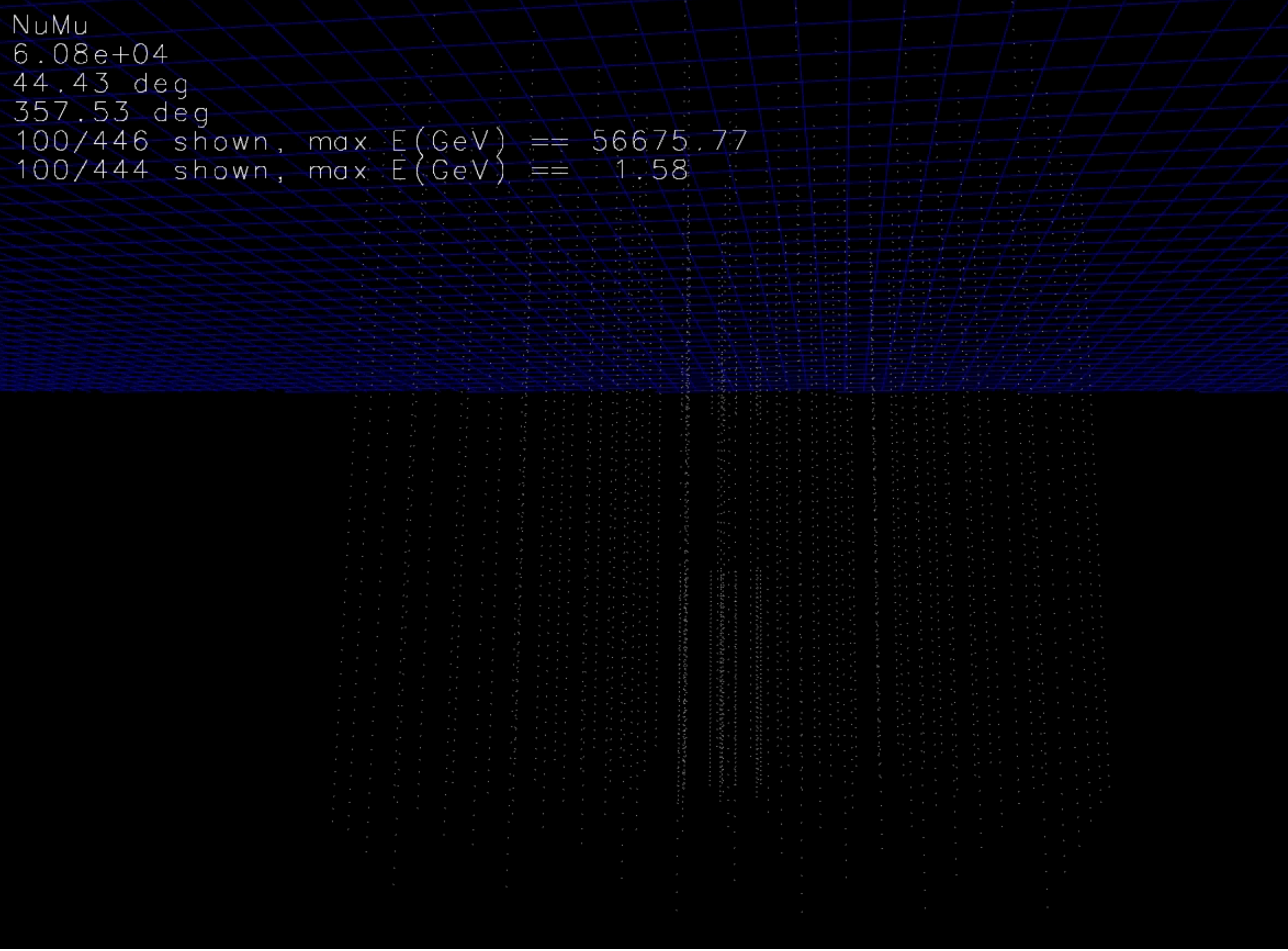
IceCube detector



IceCube detector completed on 2010

IceCube detector

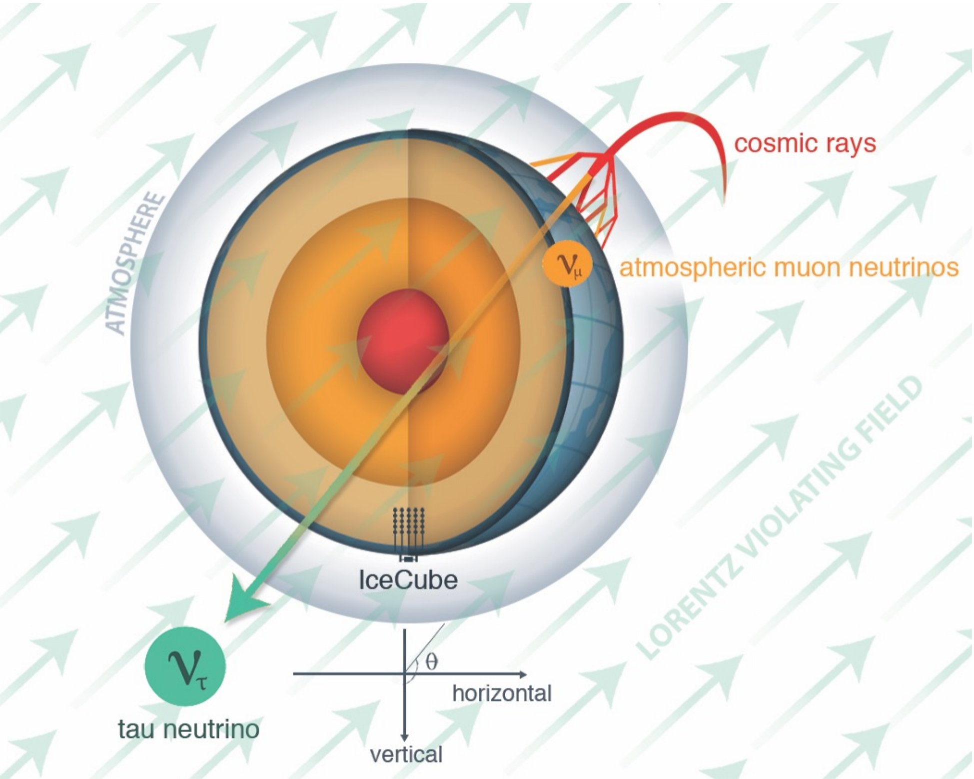


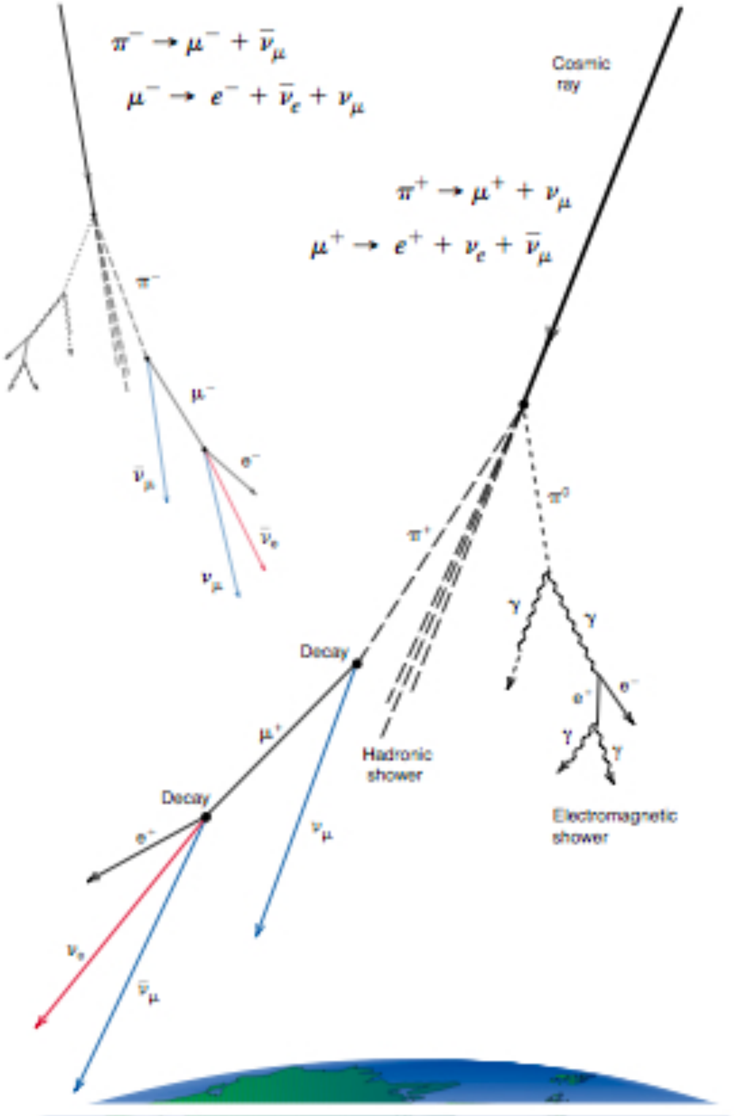

NuMu
6.08e+04
44.43 deg
357.53 deg
100/446 shown, max E(GeV) == 56675.77
100/444 shown, max E(GeV) == 1.58

Test of Lorentz violation with Atmospheric neutrino at IceCube

We start to look for Lorentz violation from abundant atmospheric neutrinos

Lorentz violation may change the signal of neutrino oscillations (Nobel prize 2015)





Test of Lorentz violation with Atmospheric neutrino at IceCube

Carlos Argüelles

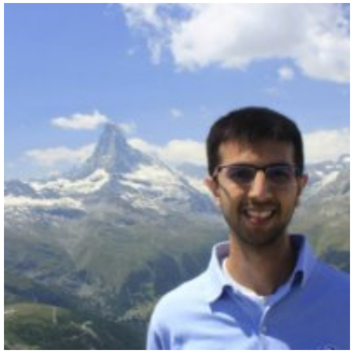
Gabriel Collin

Janet Conrad

MIT

Ali Kheirandish

U. Wisconsin, Madison



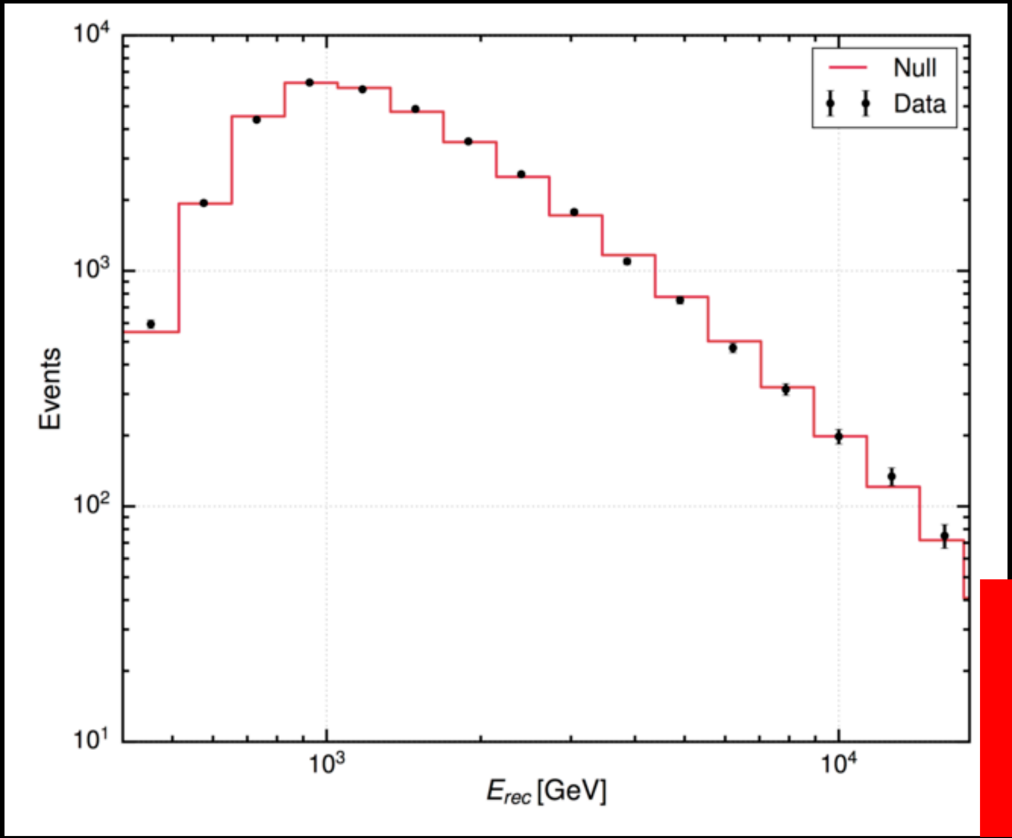
Shivesh Mandalia

Queen Mary U. of London

Test of Lorentz violation with Atmospheric neutrino at IceCube

1 to 20 TeV high energy neutrinos (Large Hadron Collider ~ 7 TeV)

Neutrino signal looks normal…, Lorentz violation is not discovered
→ We set limit on dimension-6 new pysics operator down to 10^{-36} GeV^{-2}



?

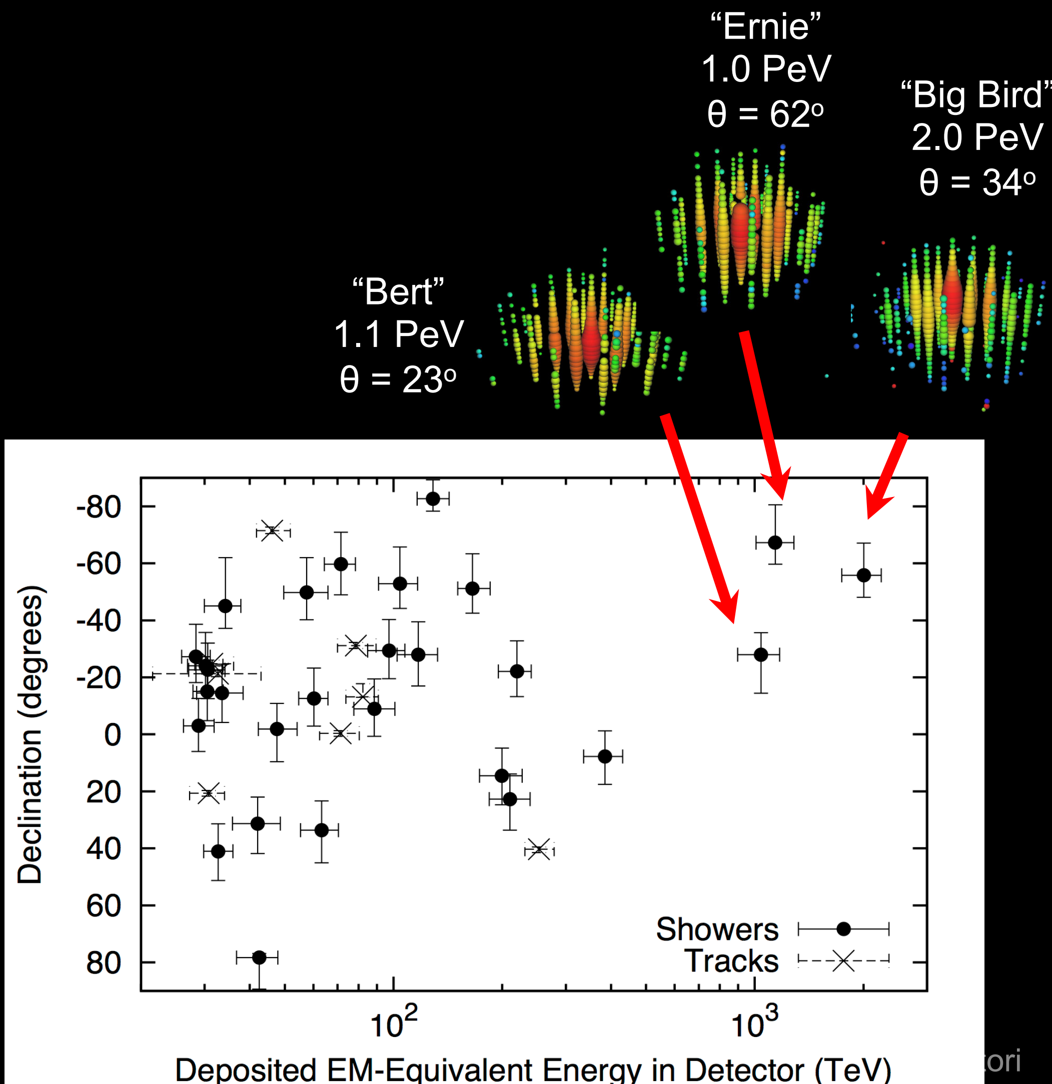
We need much higher energy neutrinos...

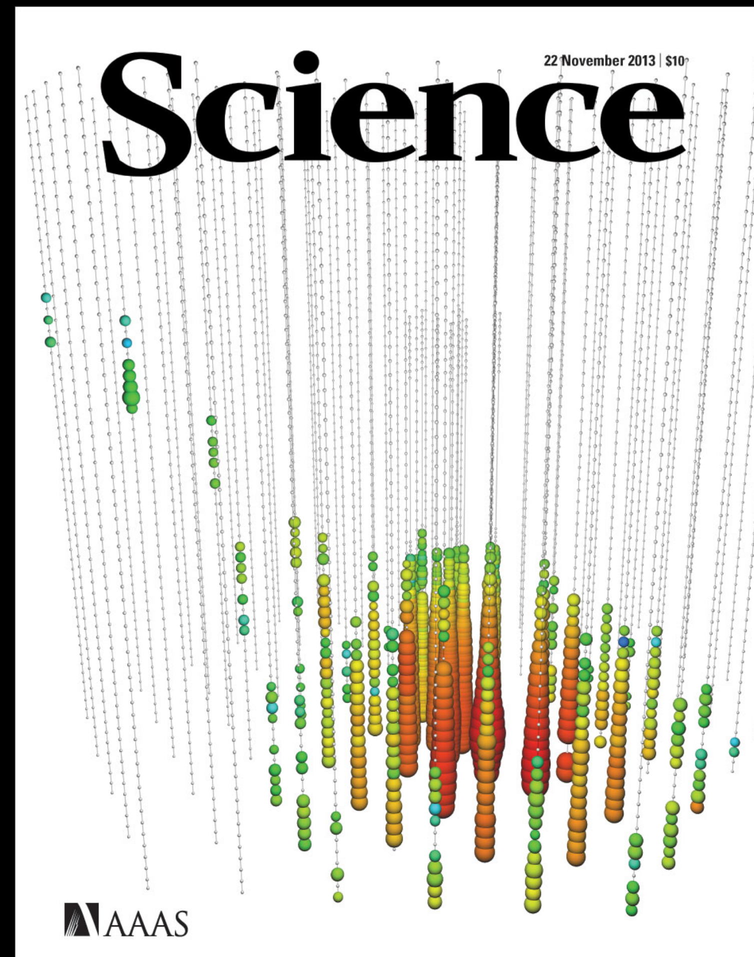
Shivesh Mandalia
Queen Mary U. of London

this is the existing highest precision test of Lorentz violation! (to be published)

Discovery of High-Energy Astrophysical Neutrinos (2012)

30 TeV to 2000 TeV very-high-energy neutrinos (Large Hadron Collider ~ 7 TeV)





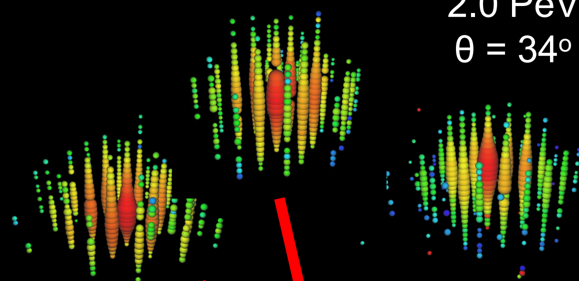
Discovery of High-Energy Astrophysical Neutrinos (2012)

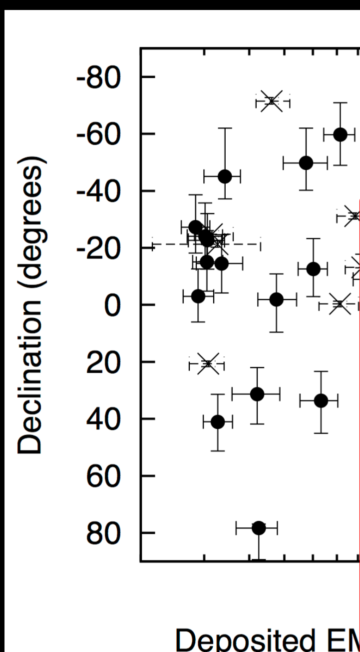
30 TeV to 2000 TeV very-high-energy neutrinos (Large Hadron Collider ~ 7 TeV)

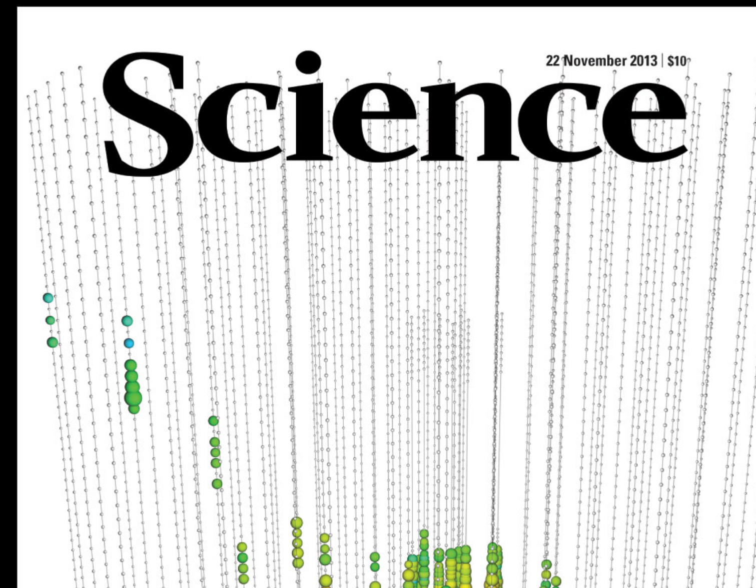
"Ernie"
1.0 PeV
θ = 62°

"Big Bird"
2.0 PeV
θ = 34°

"Bert"
1.1 PeV
θ = 23°







IceCube V-neck high energy neutrino t-shirt

$15.00

The "Bertshirt" in V-neck style. Soft, 100% ring spun cotton with a longer torso length makes it comfortable for all wearers. IceCube logo on the back. Black, V-neck, pre-shrunk 3.2 oz cotton. Available in sizes S-2XL.

https://charge.wisc.edu/icecube/wipac_store.aspx

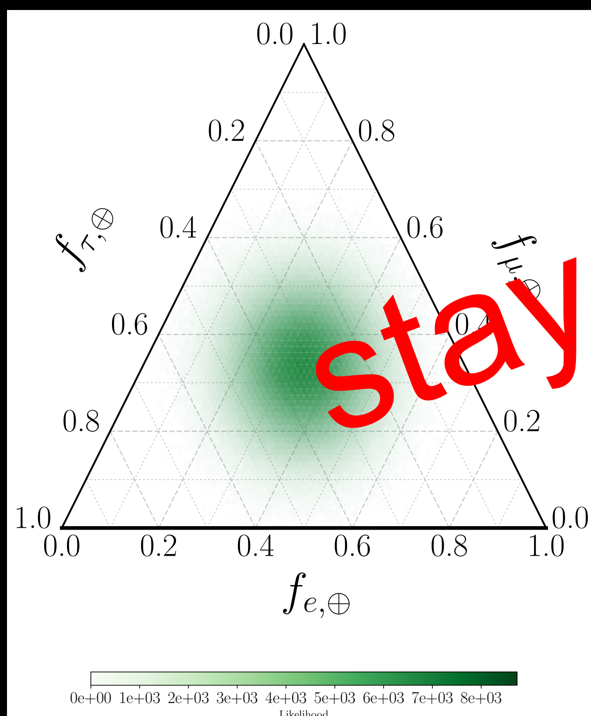
Support IceCube!

Discovery of High-Energy Astrophysical Neutrinos (2012)

30 TeV to 2000 TeV very-high-energy neutrinos (Large Hadron Collider ~ 7 TeV)

Currently, Queen Mary IceCube group is looking for Lorentz violation from astrophysical neutrinos using Markov Chain Monte Carlo (MCMC) based analysis. The result will be presented in 2018.

MARKOV

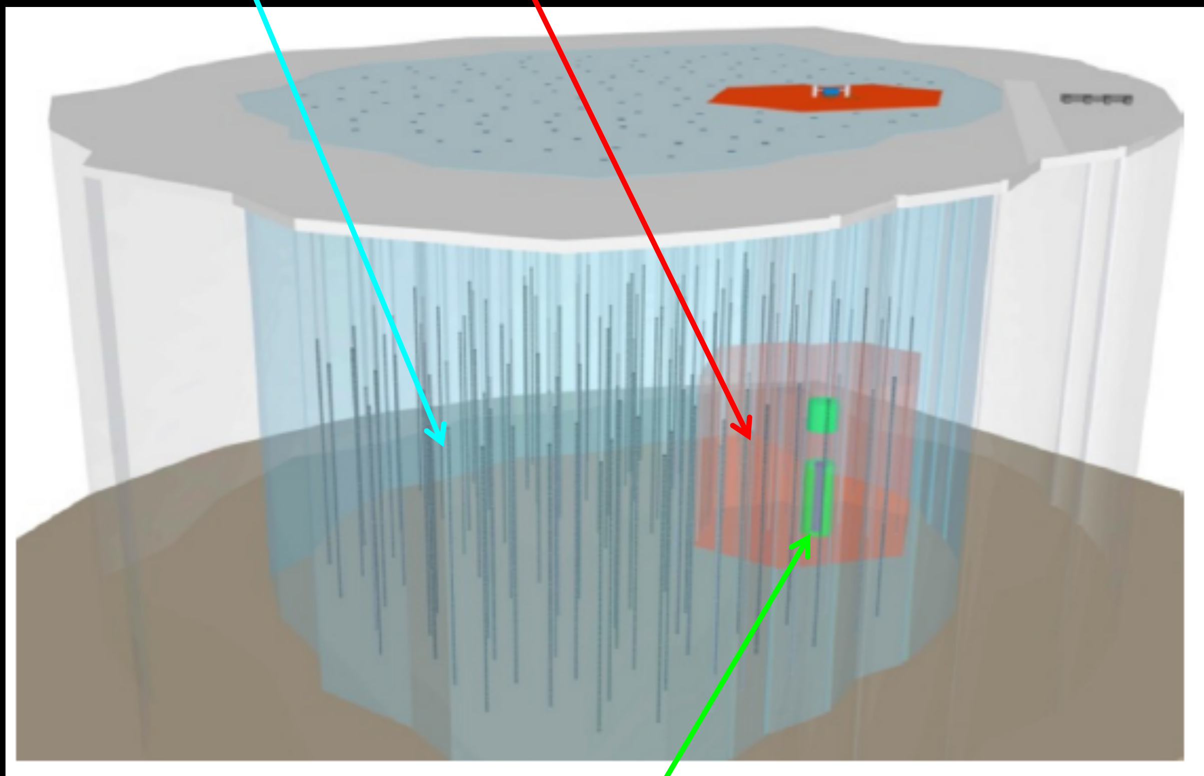


stay tuned

IceCube-Generation 2 (Gen2)

Gen2

IceCube



PINGU

To study astrophysical neutrinos more carefully, we need a bigger IceCube

Gen2
Larger string separations to cover larger area

PINGU: special region to study low energy neutrino

UK members: Queen Mary Oxford, Manchester

IceCube-Generation 2 (Gen2)

IceCube-Gen2 collaboration

To study astrophysical neutrinos more carefully, we need a bigger IceCube

Gen2
Larger string separations to cover larger area

PINGU: special region to study low energy neutrino

UK members: Queen Mary
Oxford, Manchester

Conclusion

Lorentz violation may be the first evidence of Theory of Everything

There is a worldwide effort to look for Lorentz violation, using various state-of-the-art techniques, but so far nobody found Lorentz violation

Neutrinos, especially ultra-high-energy astrophysical neutrinos have a great potential to discover Lorentz violation

Thank you for your attention!