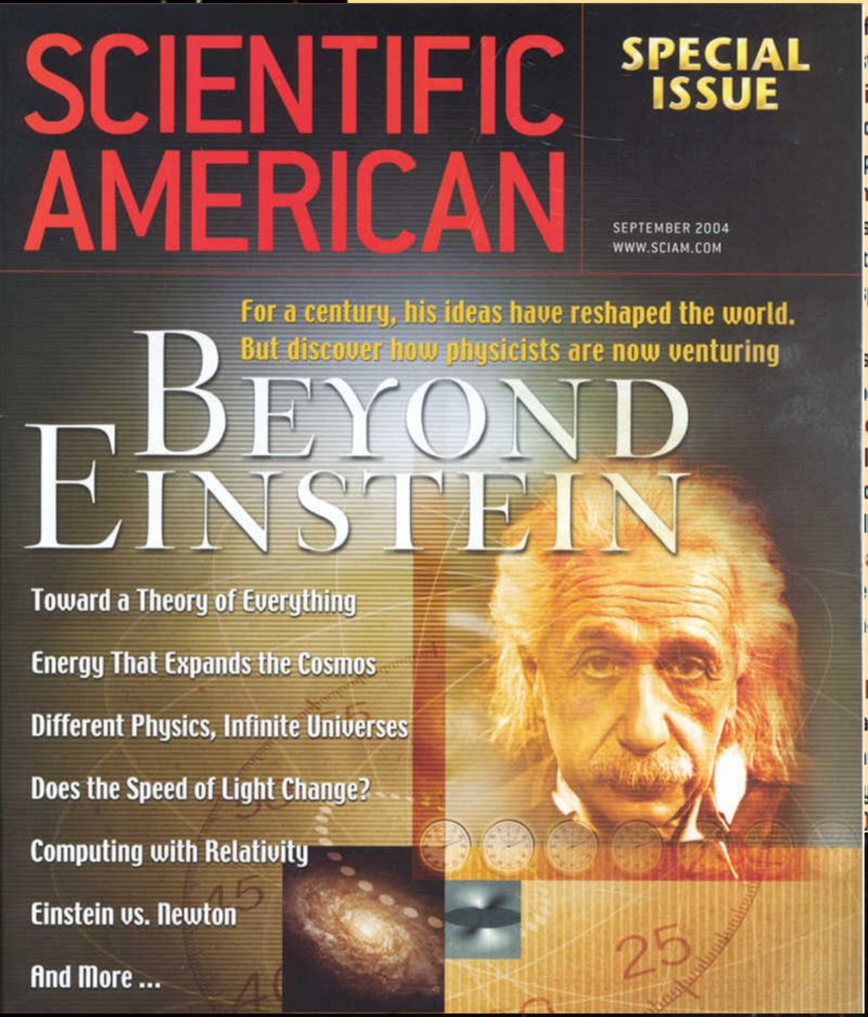
Search of Space-Time Defect: The Race to Defeat Einstein



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Toppling the Giant

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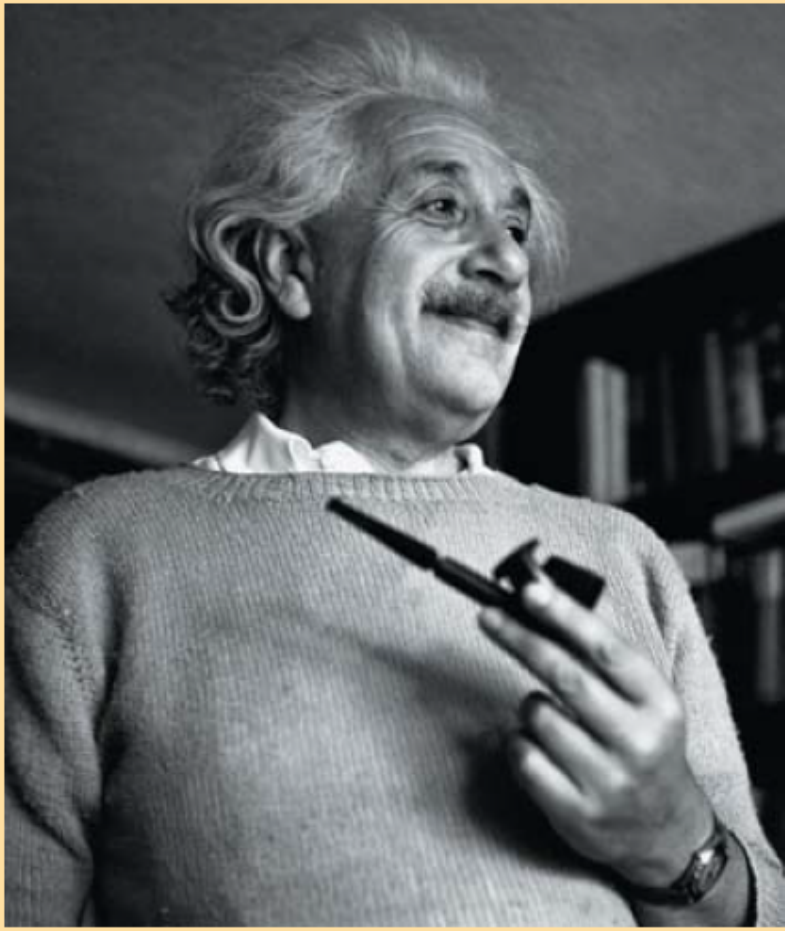

Teppei Katori
Queen Mary University of London
Pint of Science, The Water Poet, London
May 18, 2015

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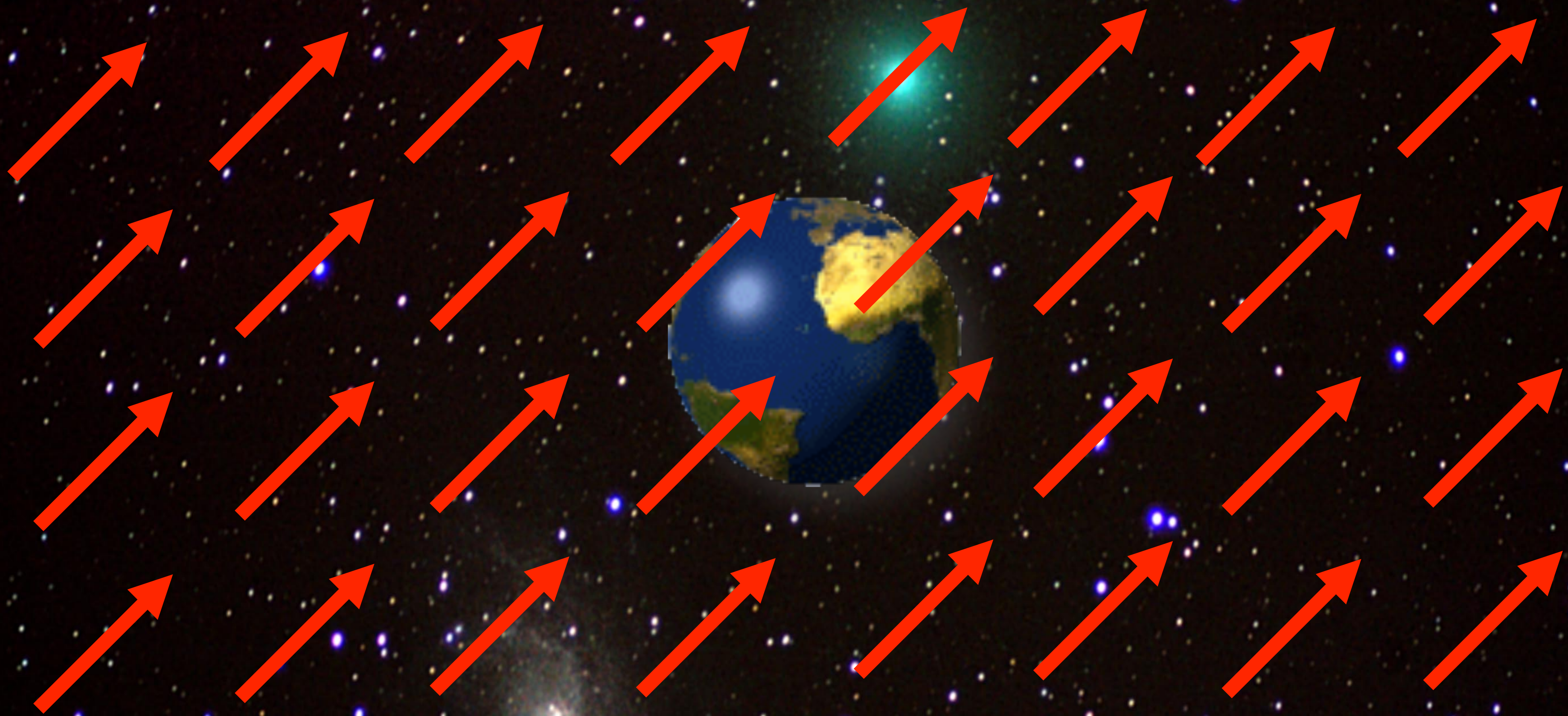


Teppei Katori
Queen Mary University of London
Pint of Science, The Water Poet, London
May 18, 2015

Emmy Noether (1882-1935)

Mathematician from Germany

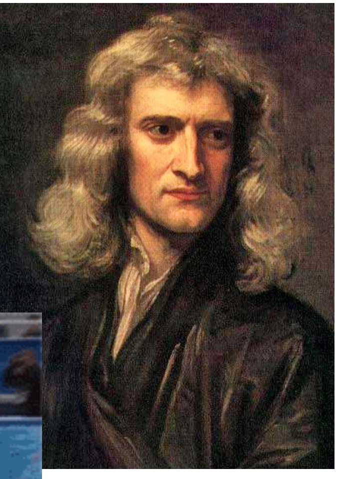
Noether's Theorem
"Every conservation law is a consequence of corresponding symmetry"

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

etc

Conservation of Angular Momentum

Isaac Newton



Rotating object keep rotating

Conservation of angular momentum

Yulia Lipnitskaya (Russia)

Conservation of Angular Momentum

Rotating object keep rotating

Conservation of
angular momentum

Yulia Lipnitskaya (Russia)

Emmy Noether

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

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 is 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

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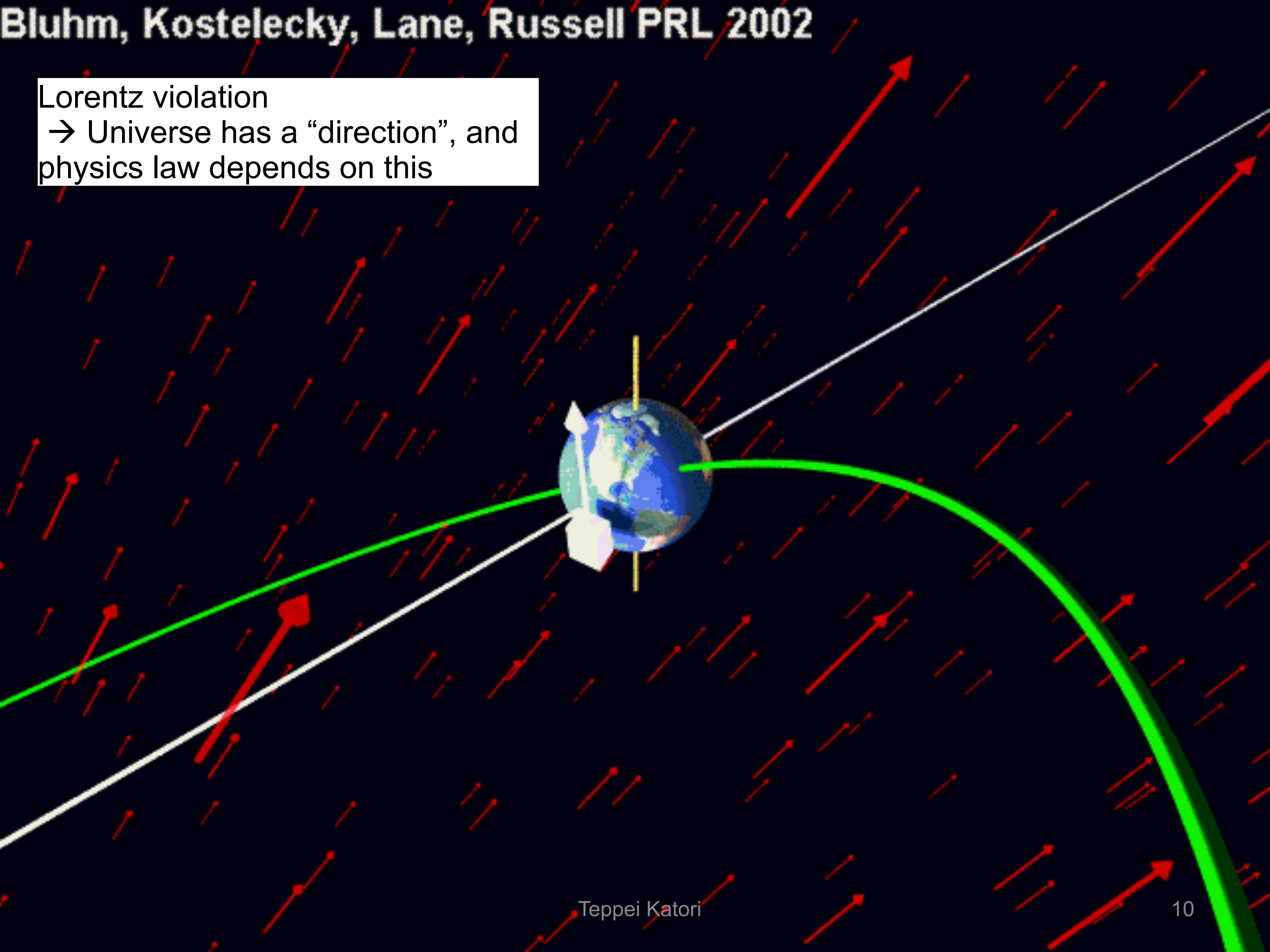


Lorentz violation
→ Universe has a “direction”, and physics law depends on this

The race to defeat Einstein

Most precise something

The race to defeat Einstein

Most precise speed of light measurement

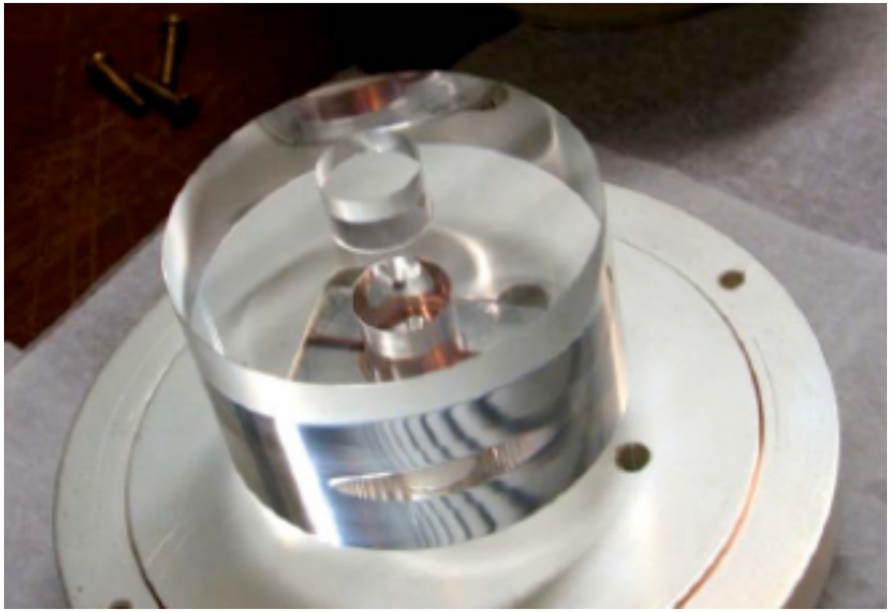
Cryogenic crystal resonator

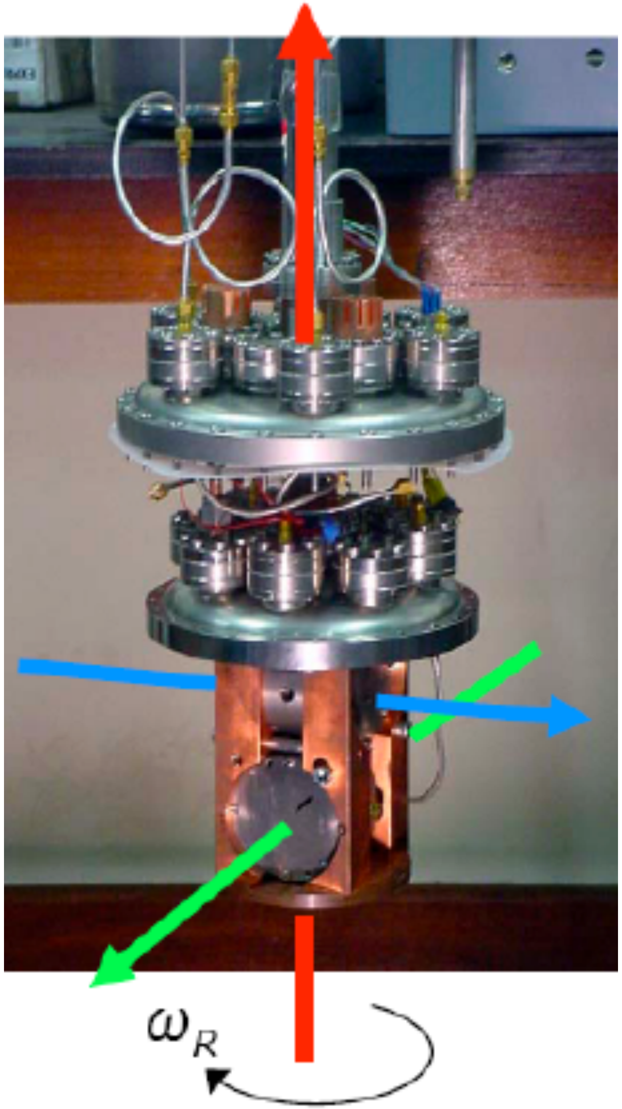
Queen Mary
University of London

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

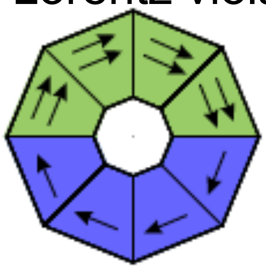
Spin pendulum

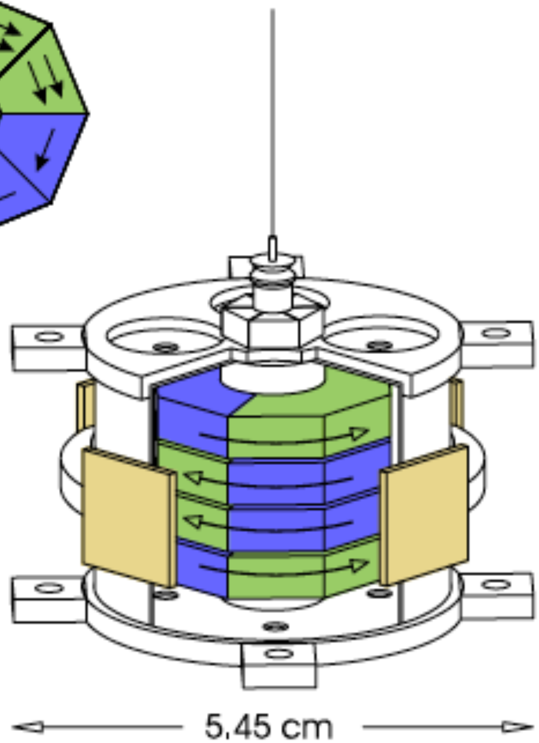
Cryogenic crystal resonator

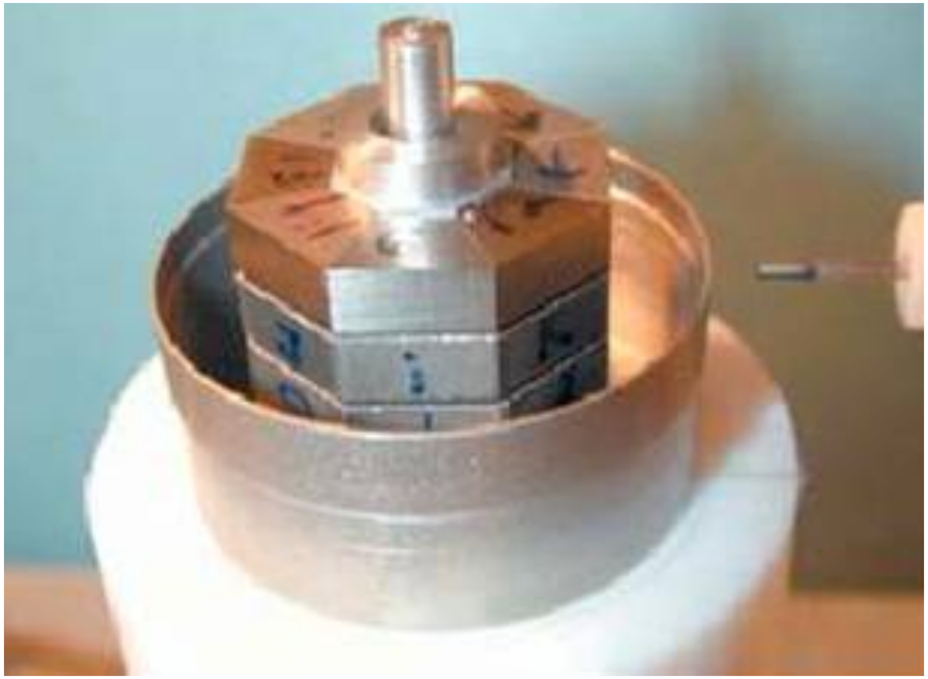
Double Alloy Spin Torsion Pendulum

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

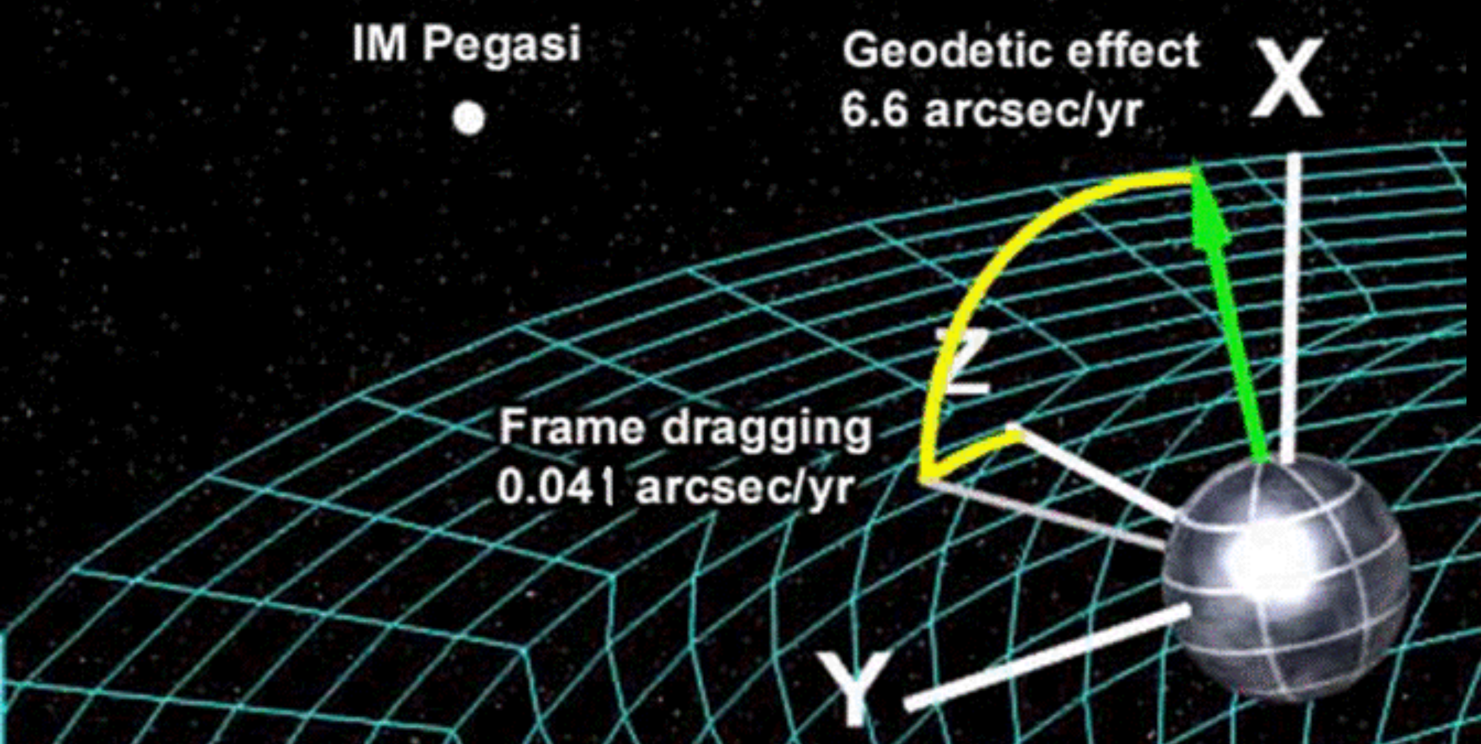
Most precise gyroscope

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

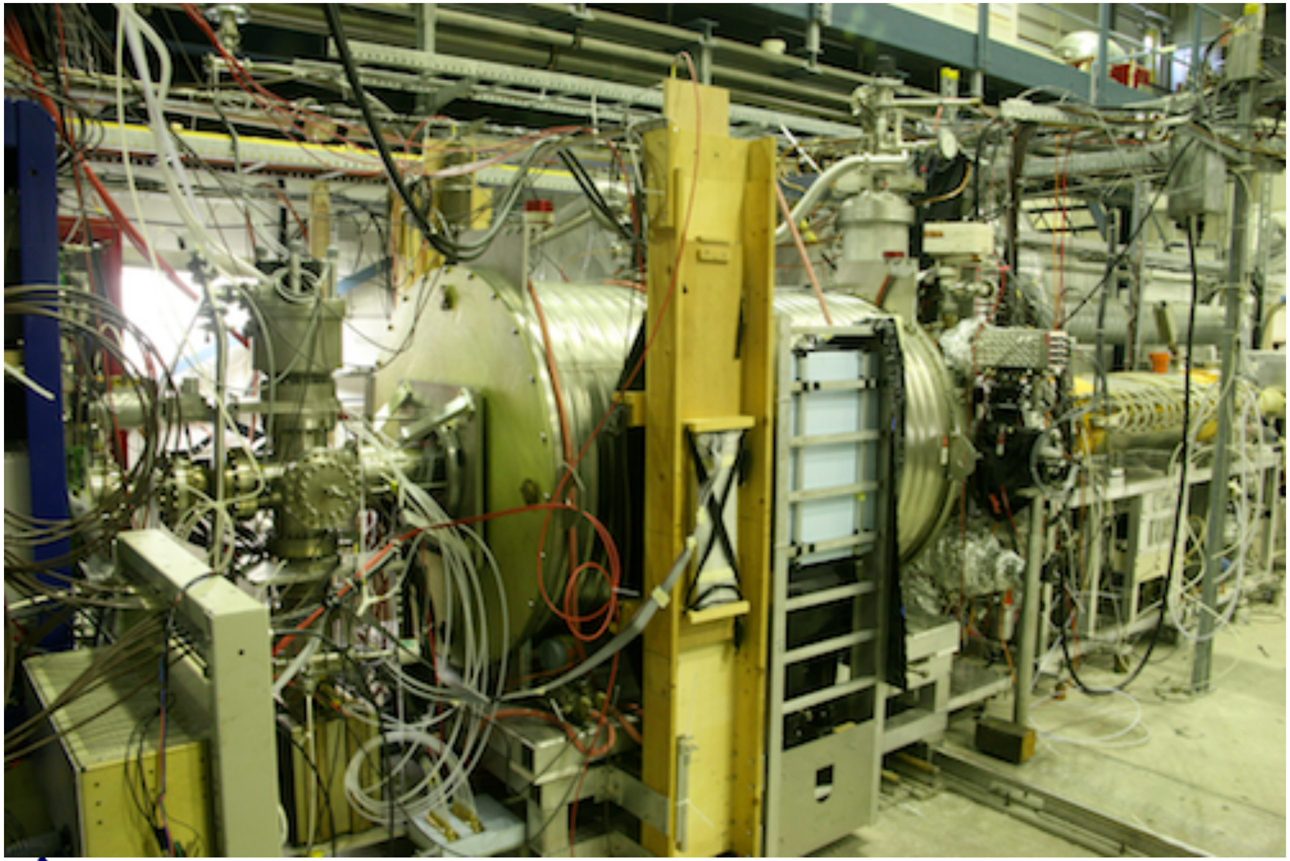
The race to defeat Einstein

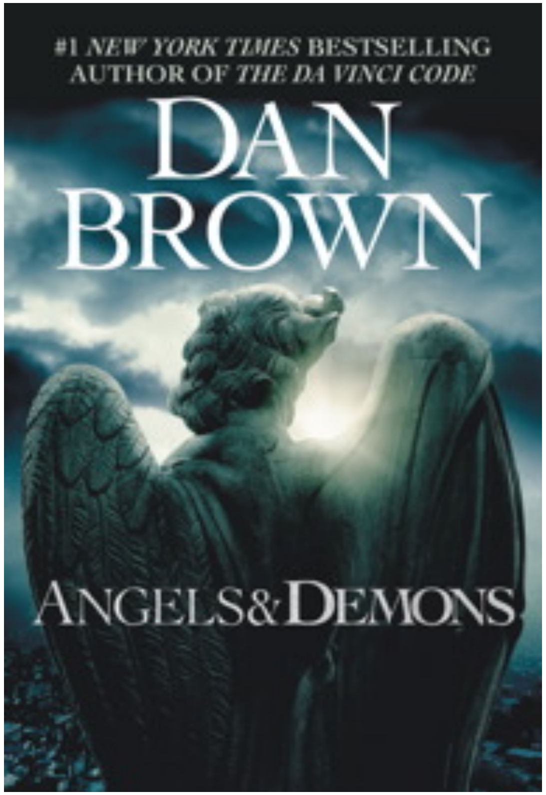
Largest amount of anti-hydrogen

Antiproton decelerator at CERN

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

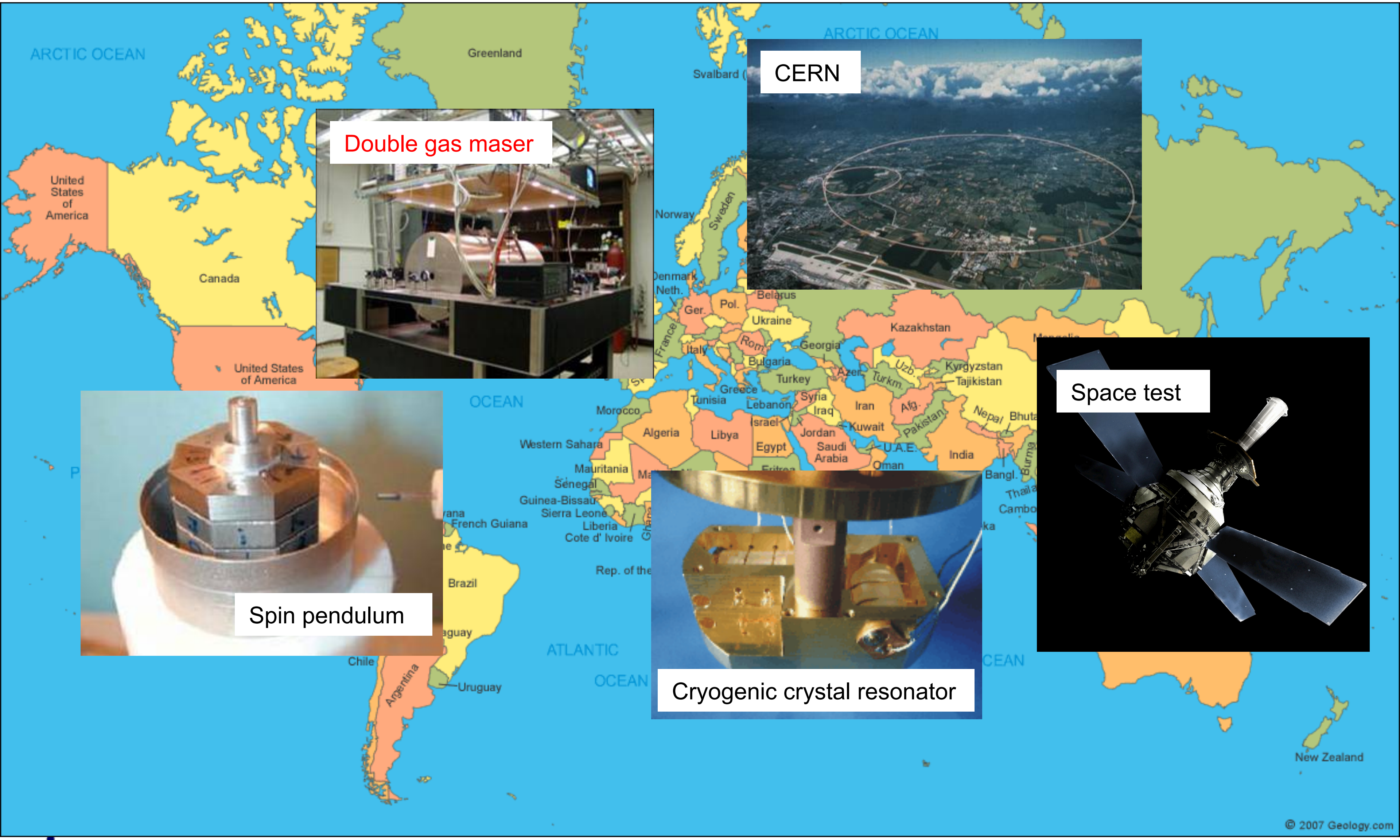
→ Lorentz violation is not discovered





The race to defeat Einstein

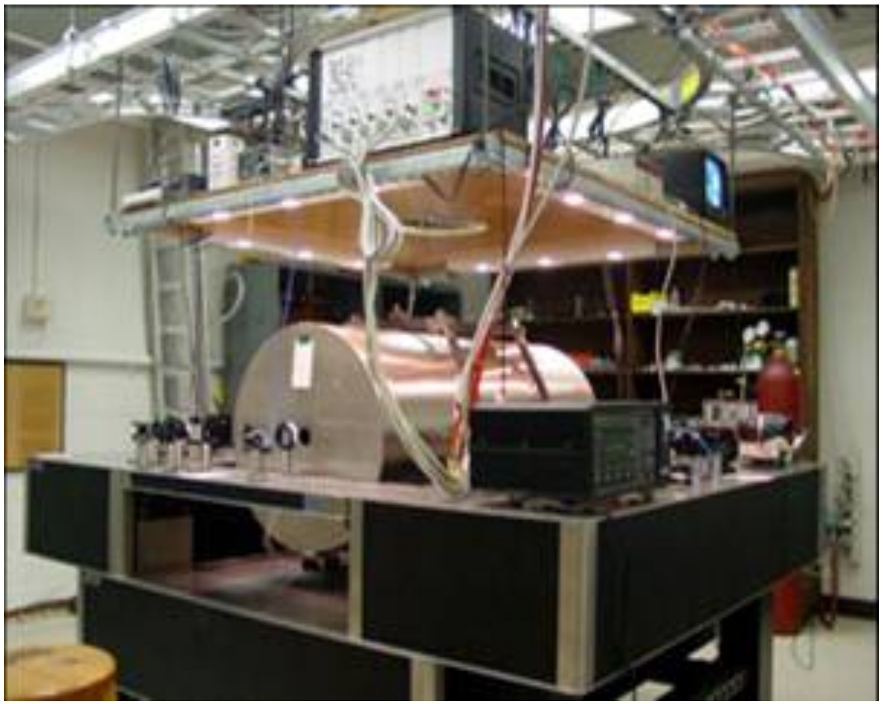
Most precise magnetic field measurement

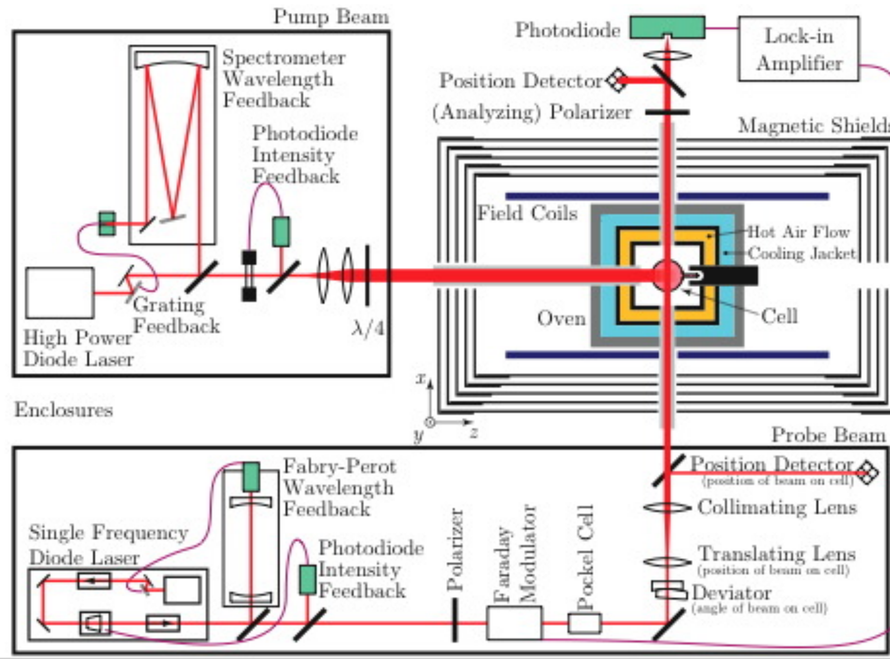


Double Noble Gas Maser

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

→ Lorentz violation is not discovered





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Double Noble Gas Maser

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

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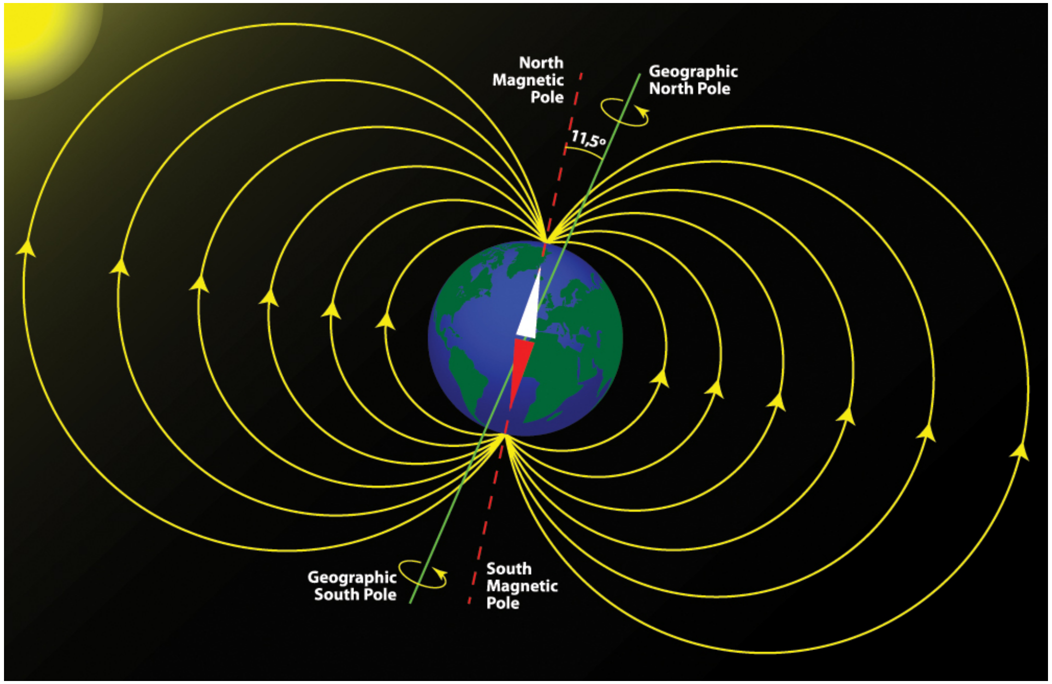
The earth magnetic field gives error. To improve sensitivity, scientists want to repeat the measurement at special location on the earth (special earth magnetic field configuration)

Princeton university group vs. Amherst college group



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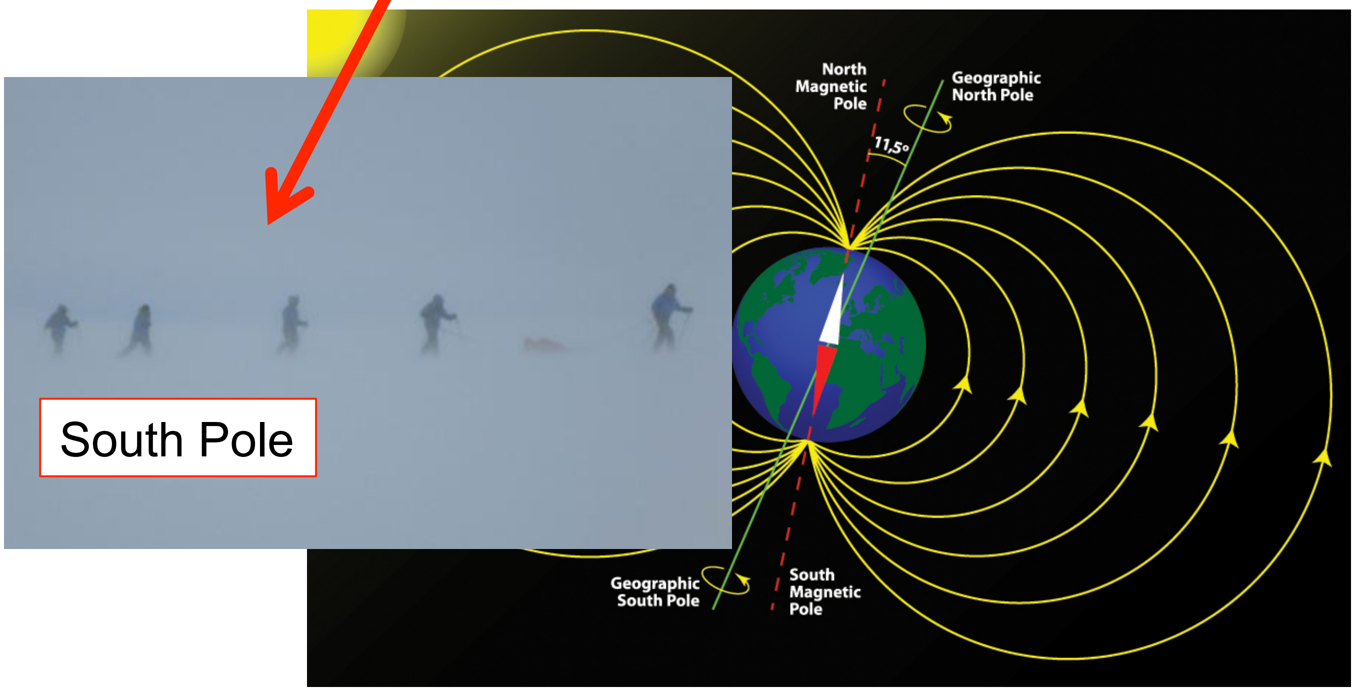

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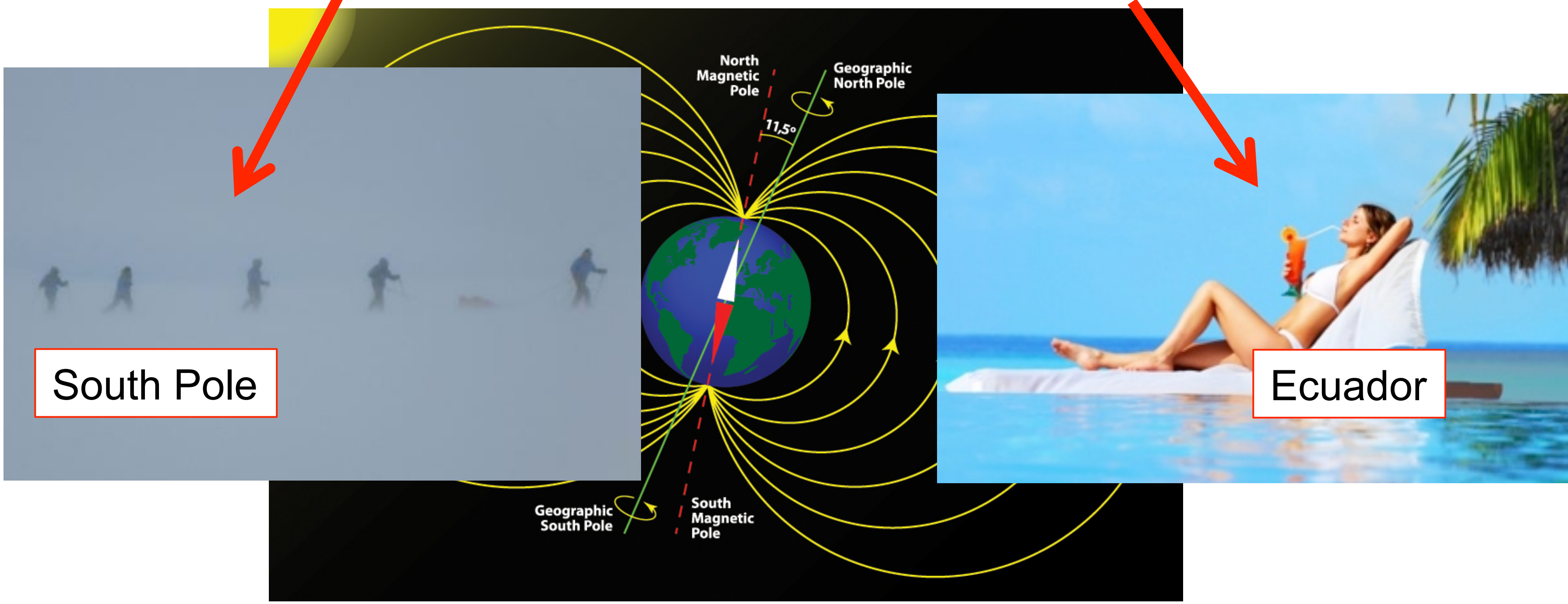

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The race to defeat Einstein

Most precise something

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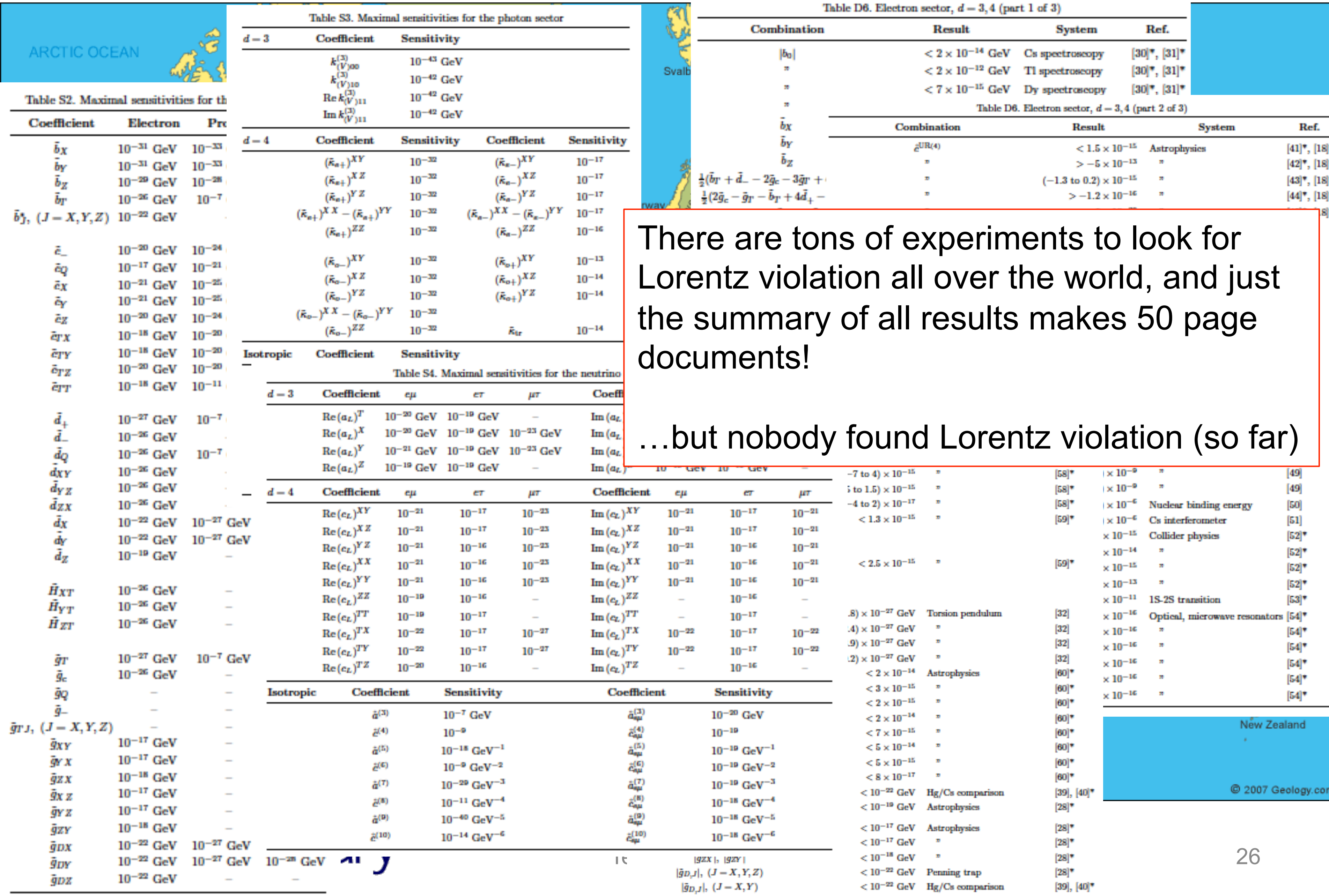
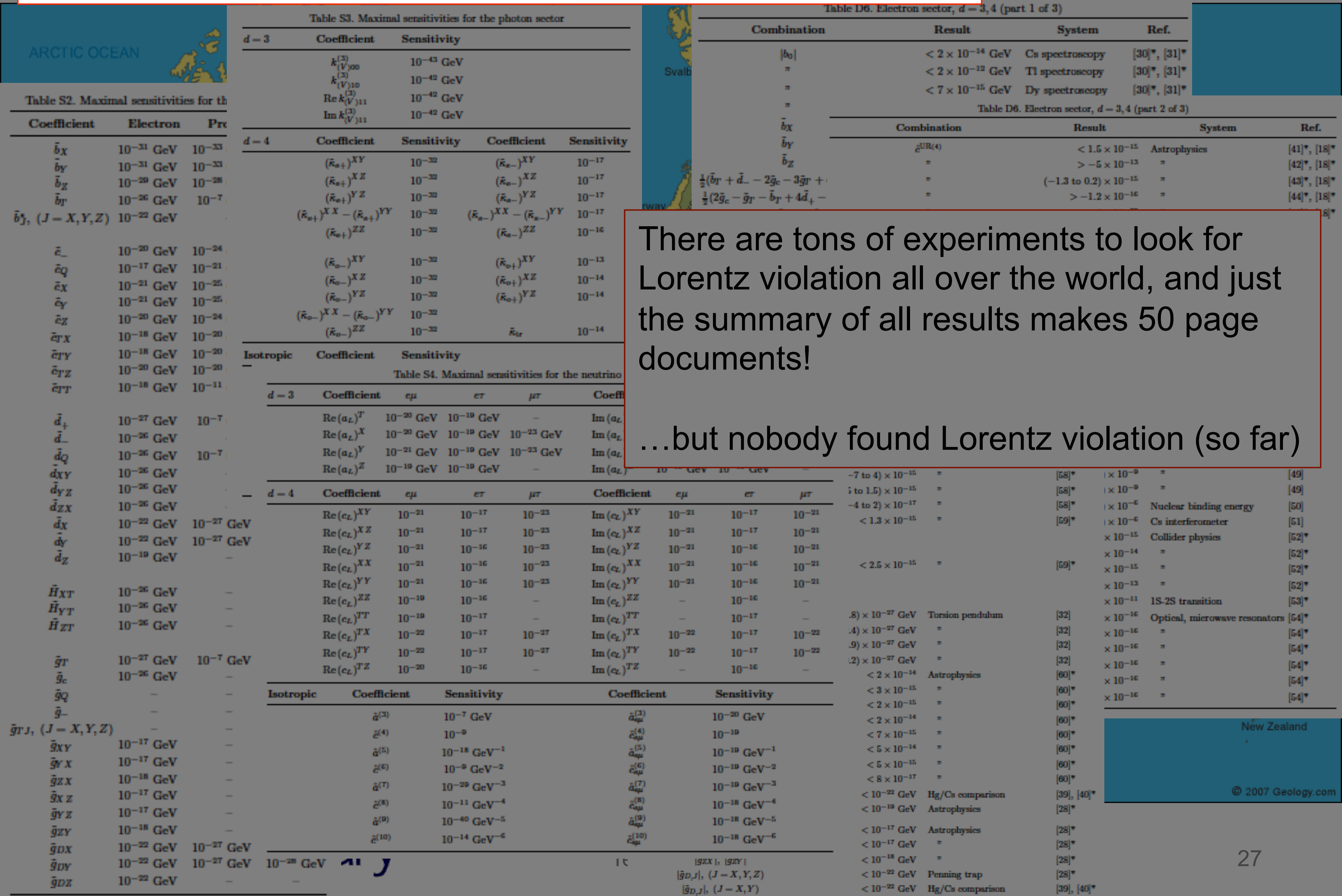


There are tons of experiments to look for Lorentz violation all over the world, and just the summary of all results makes 50 page documents!

…but nobody found Lorentz violation (so far)

So far no experiments find Lorentz violation…

Most precise something



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- Carl Sagan

There are to… Lorentz viola… the summary … documents!

…but nobod… far)

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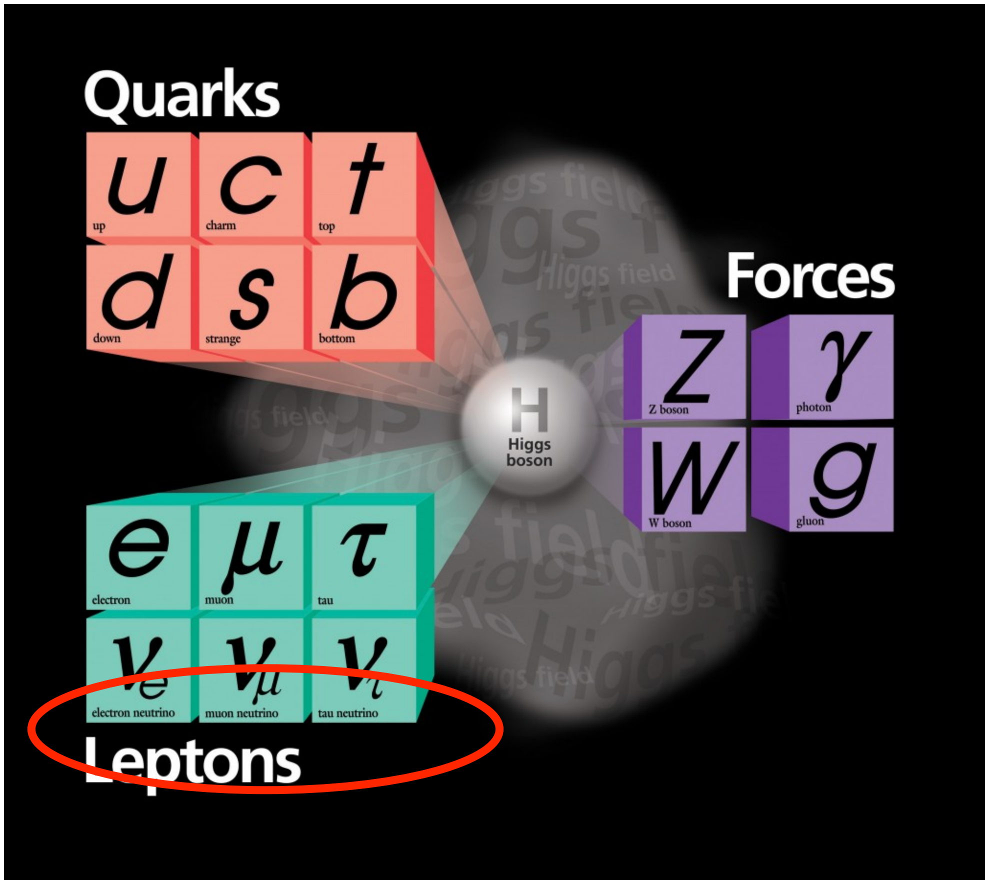
↓

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?

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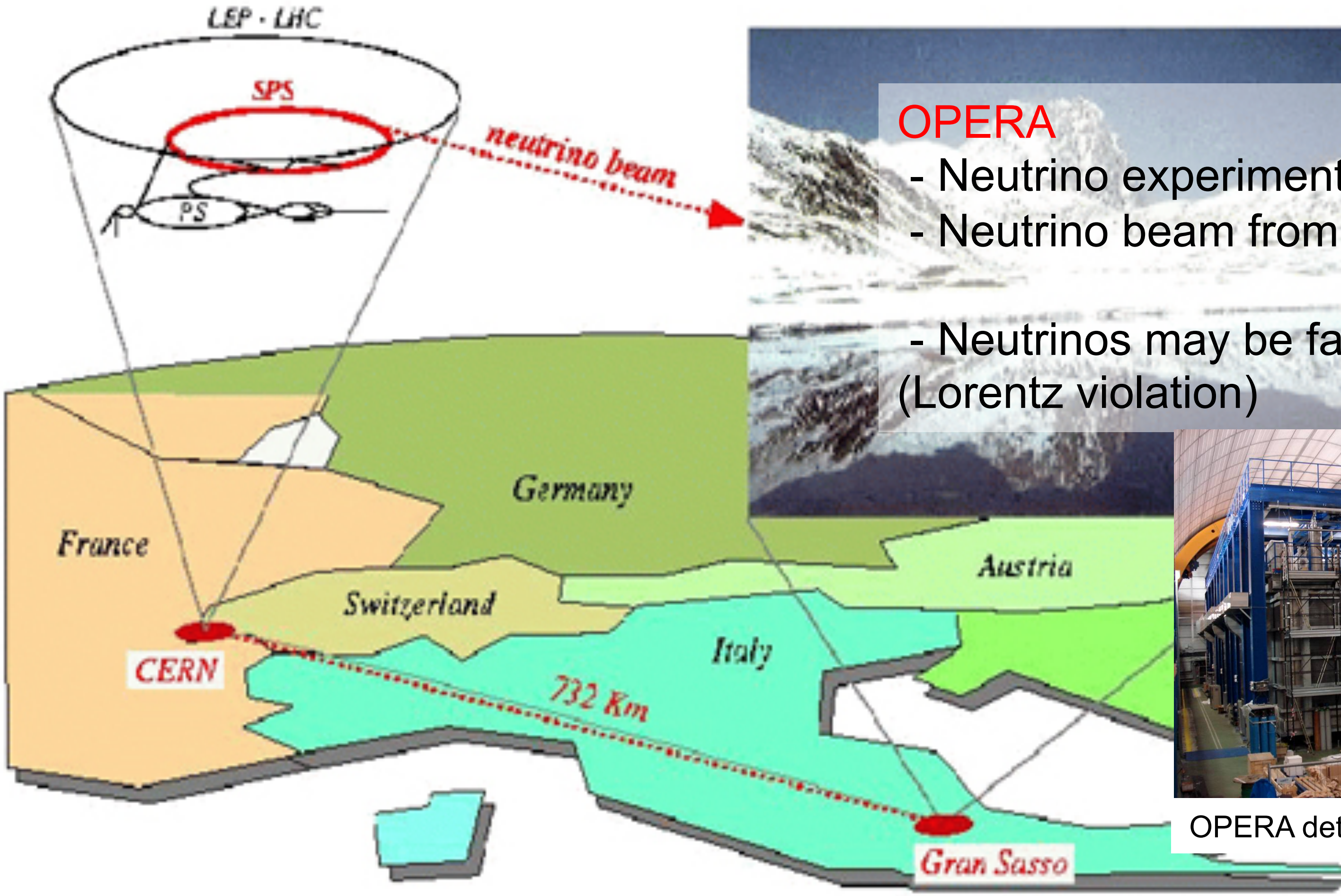

OPERA
- Neutrino experiment at Gran Sasso, Italy
- Neutrino beam from CERN, Switzerland

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

OPERA detector at Gran Sasso

Search of Lorentz Violation

Neutrinos are mysterious particle[...] [...]bout neutrinos
→ Maybe neutrinos have better [...]

Especially, many neutrino data sh[...]

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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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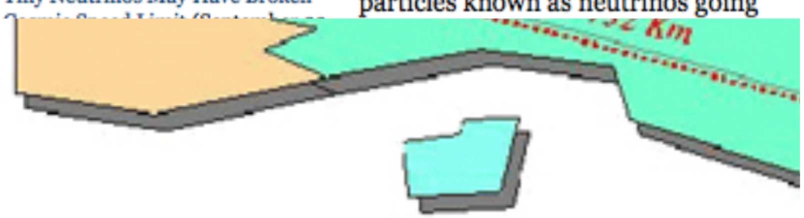
Tiny Neutrinos May Have Broken [...]

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



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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 Violatior

bout neutrinos

The Washington Post — Make us your start page

POSTOPINIONS

Posted at 01:23 PM ET, 02/23/2012

Faster-than-light neutrinos aren't?

By Alexandra Petri

You can return to your homes. There is nothing more to see.

It turns out those faster-than-light neutrinos at Europe's CERN lab

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By

The New York Times — **Science**

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Two Technical Problems Leave Neutrinos' Speed in Question

By KENNETH CHANG
Published: February 23, 2012

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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.

theguardian

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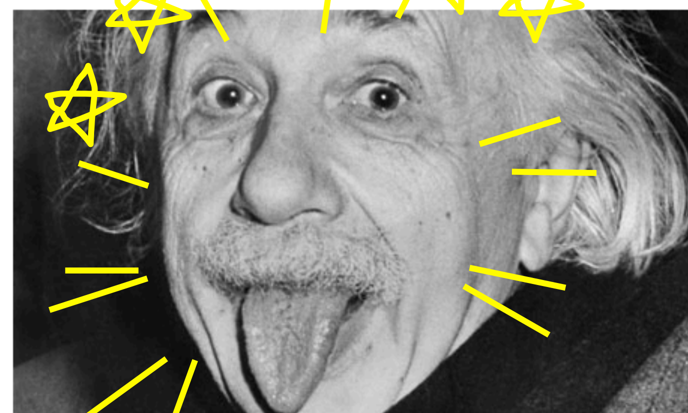
News › Science › Cern

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.

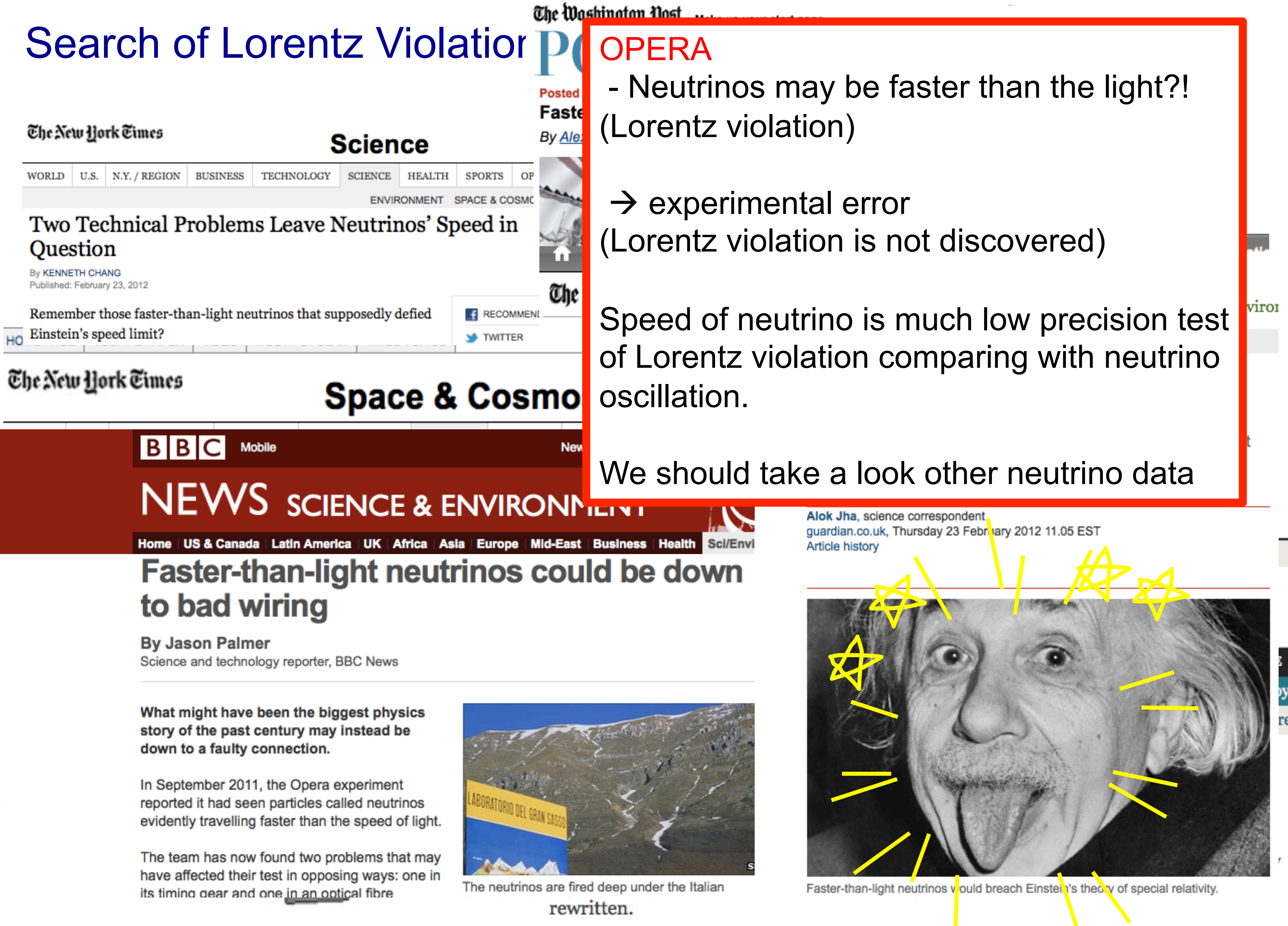
Search of Lorentz Violatior

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

→ experimental error
(Lorentz violation is not discovered)

Speed of neutrino is much low precision test of Lorentz violation comparing with neutrino oscillation.

We should take a look other neutrino data



The New York Times — Science

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LABORATORIO DEL GRAN SASSO

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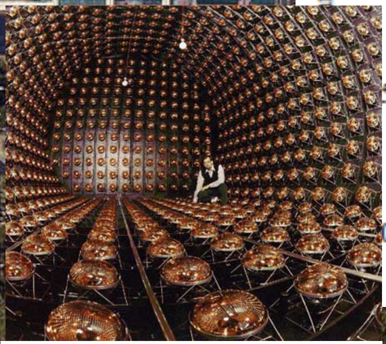
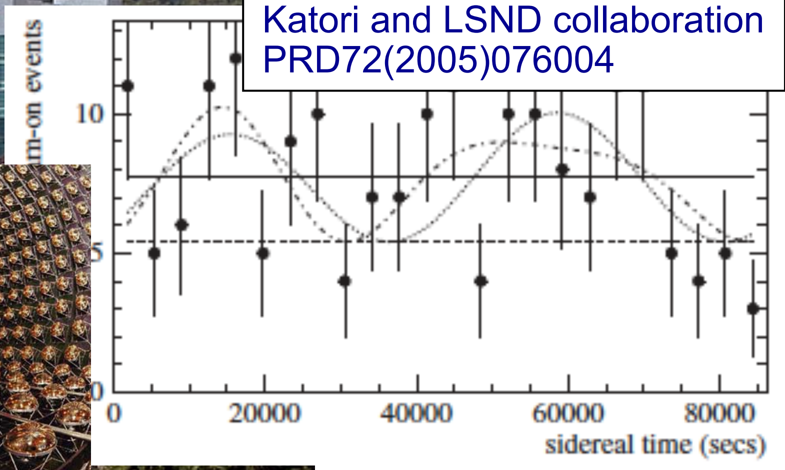
Neutrinos are mysterious particles, and we still don't know much about neutrinos
→ Maybe neutrinos have better chance to find Lorentz violation?

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

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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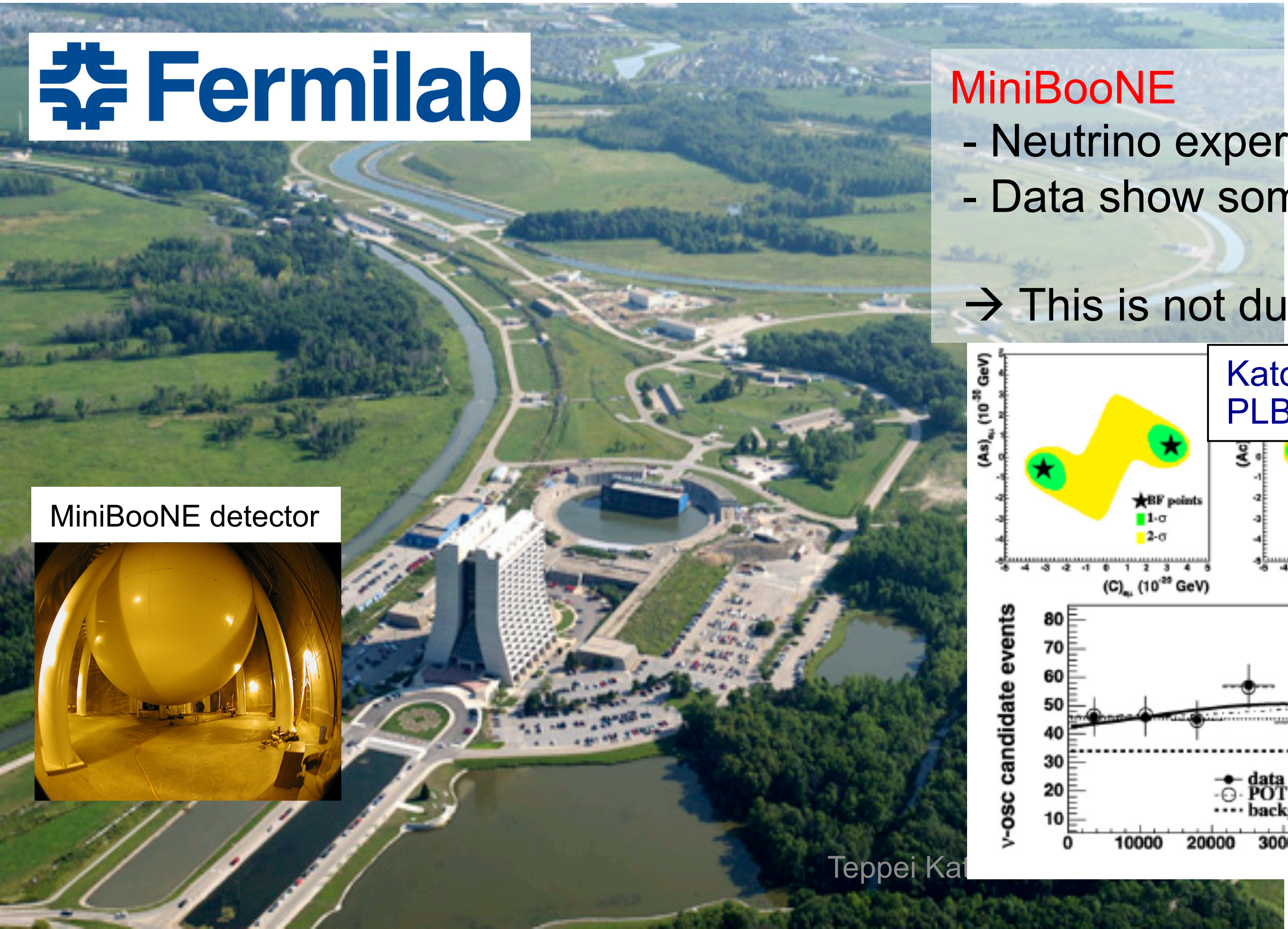

MiniBooNE detector

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

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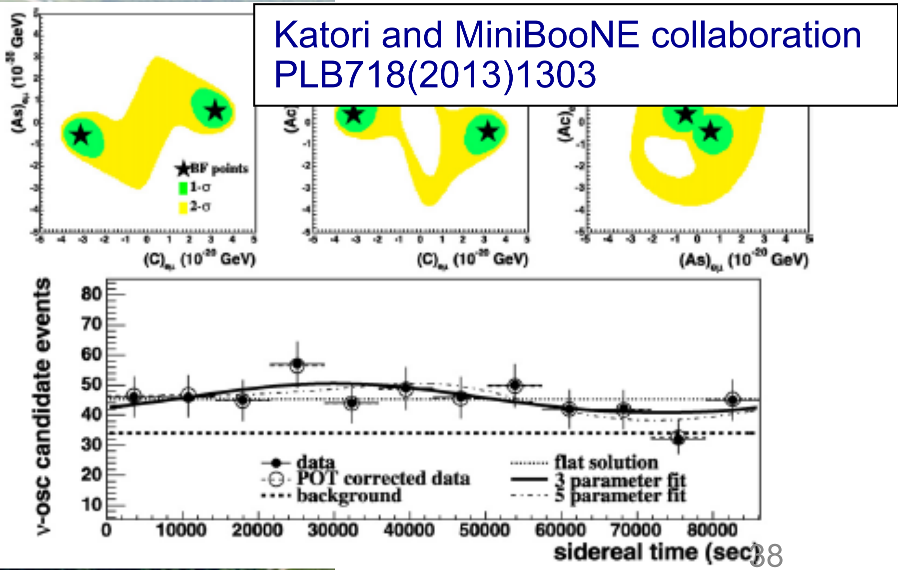

Katori and MiniBooNE collaboration
PLB718(2013)1303

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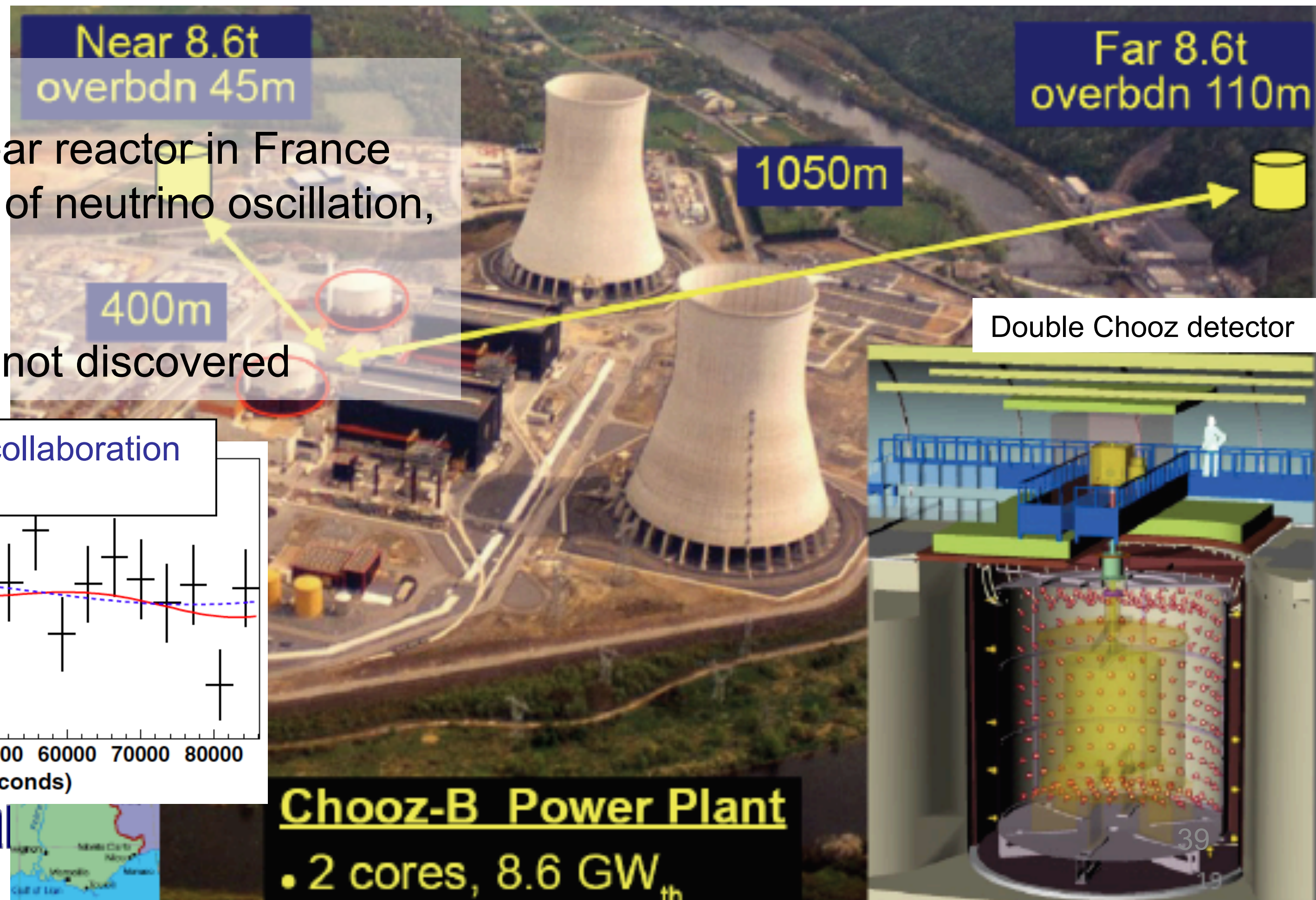


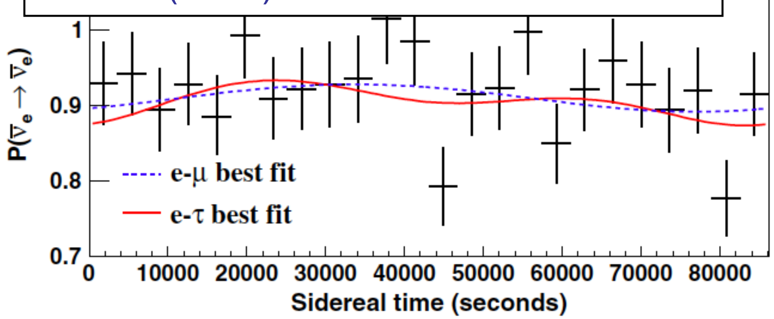
Double Chooz

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

→ Lorentz violation is not discovered

Double Chooz detector

Katori and Double Chooz collaboration
PRD86(2012)112009



Queen Mary University of London

So far, no neutrino experiments find Lorentz violation…

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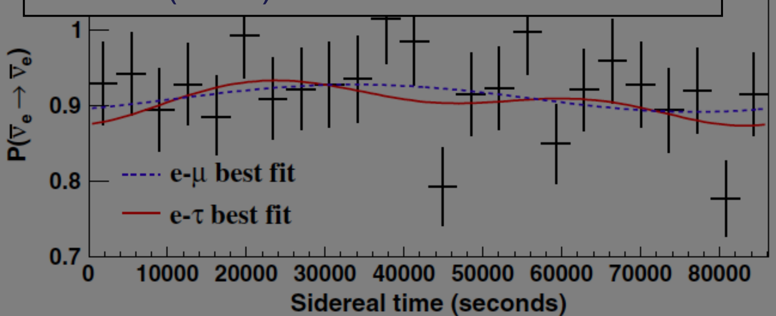
PRD86(2012)112009



University of London

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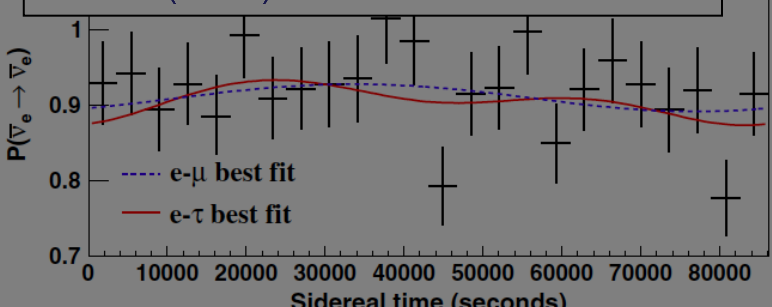
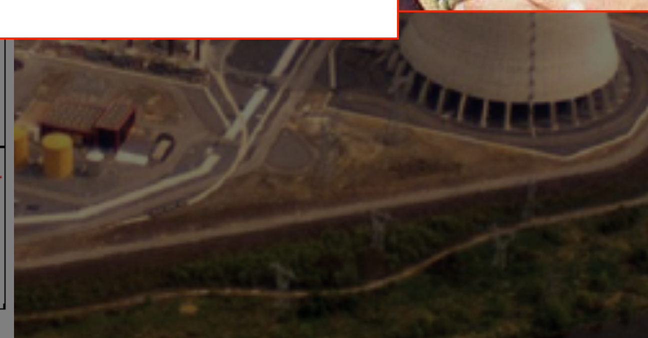
"Extraordinary discovery requires extraordinary evidence"
- Carl Sagan

↓

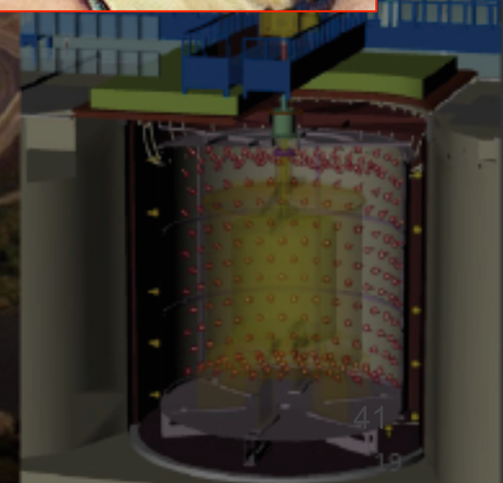
"Extraordinary discovery requires extraordinary particles"
- Teppei

…may be this is not extraordinary enough?





Chooz-B Power Plant
- 2 cores, 8.6 GW_{th}



University of London

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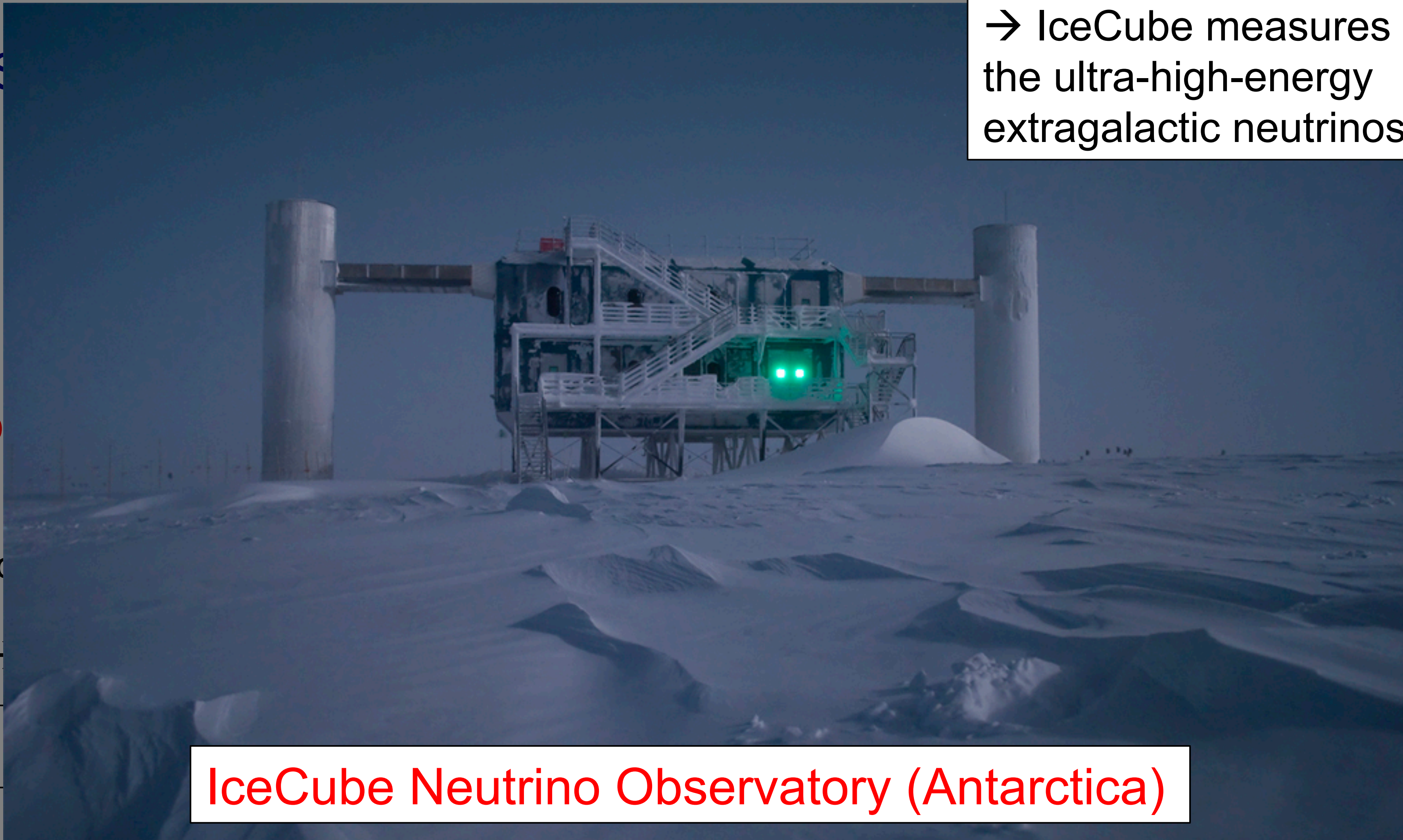
"Extraordinary discovery requires extraordinary particles with the extraordinary energy and extraordinary propagation distance"
- Teppei

→ IceCube measures the ultra-high-energy extragalactic neutrinos



IceCube Neutrino Observatory (Antarctica)

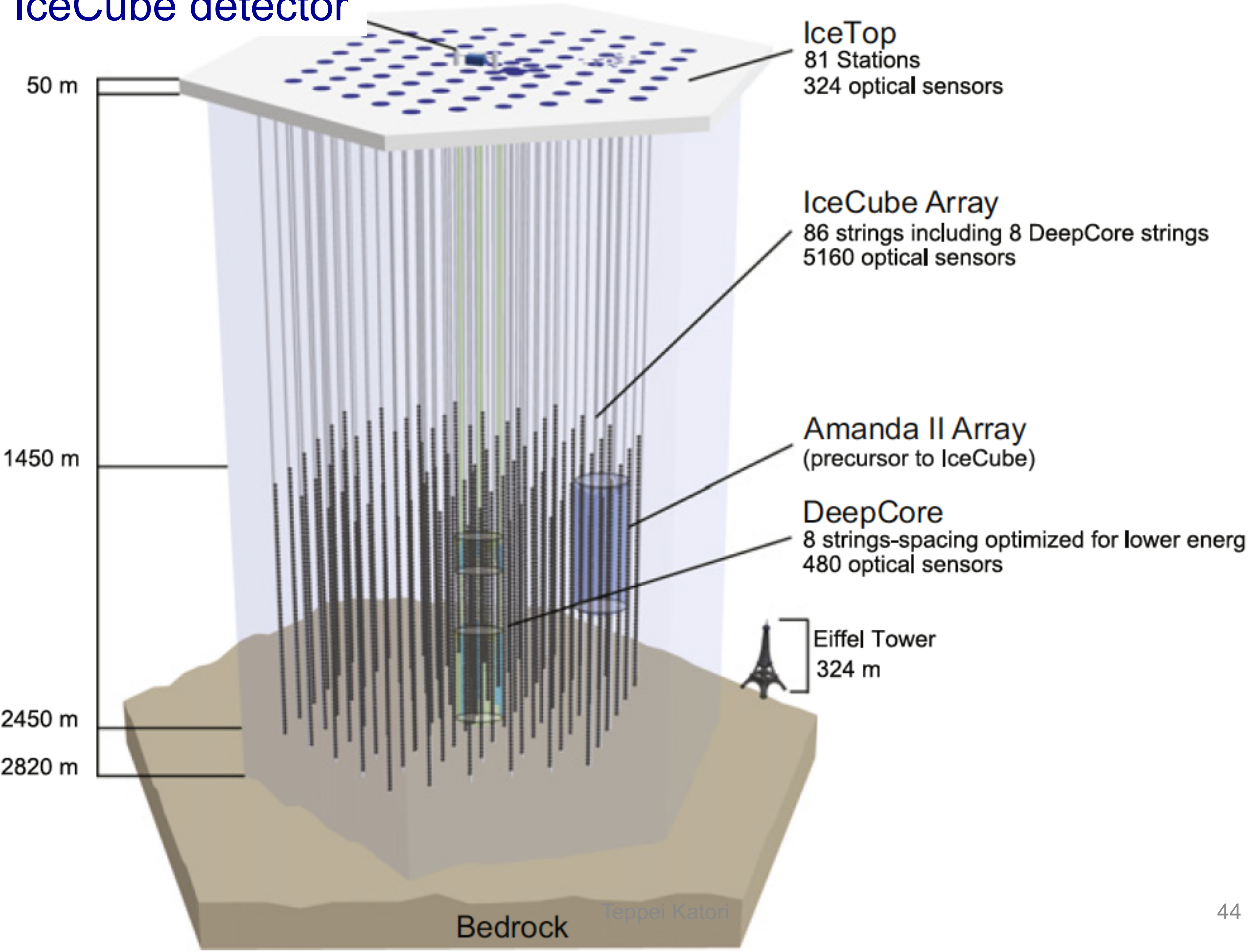
"Extraordinary discovery requires extraordinary particles with the extraordinary energy and extraordinary propagation distance"

- Teppei

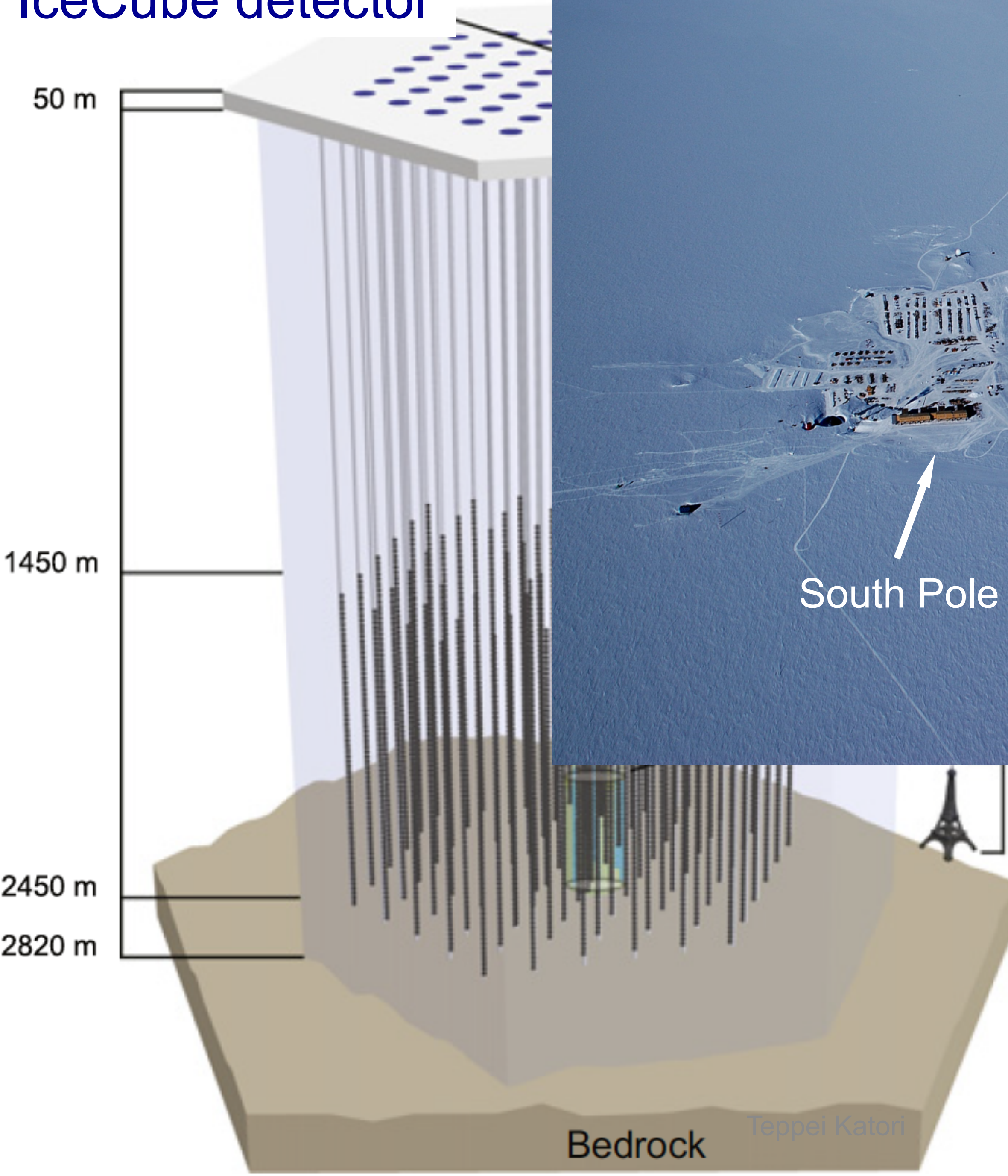
University of London

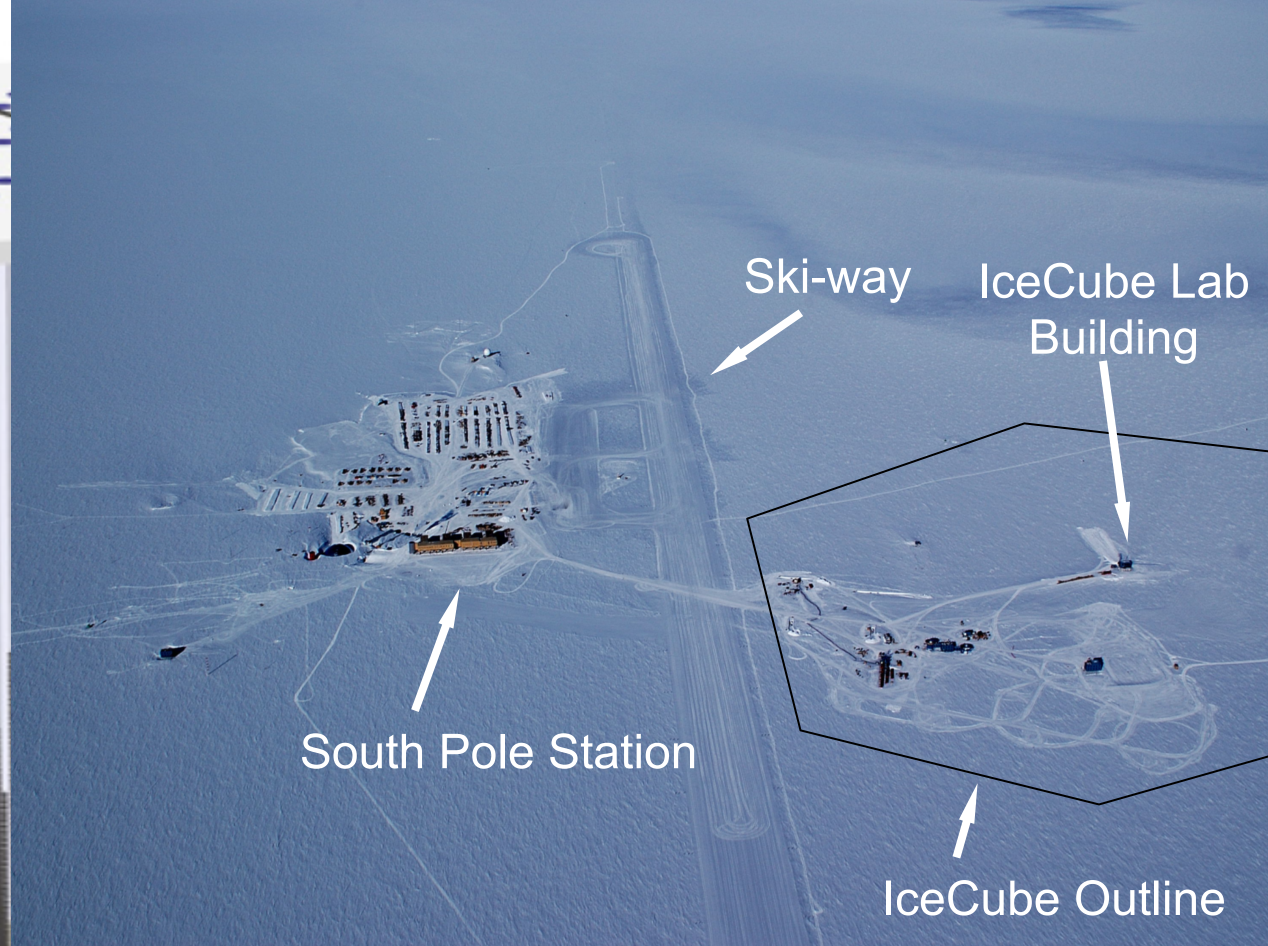
• 2 cores, 8.6 GW_{th}

IceCube detector

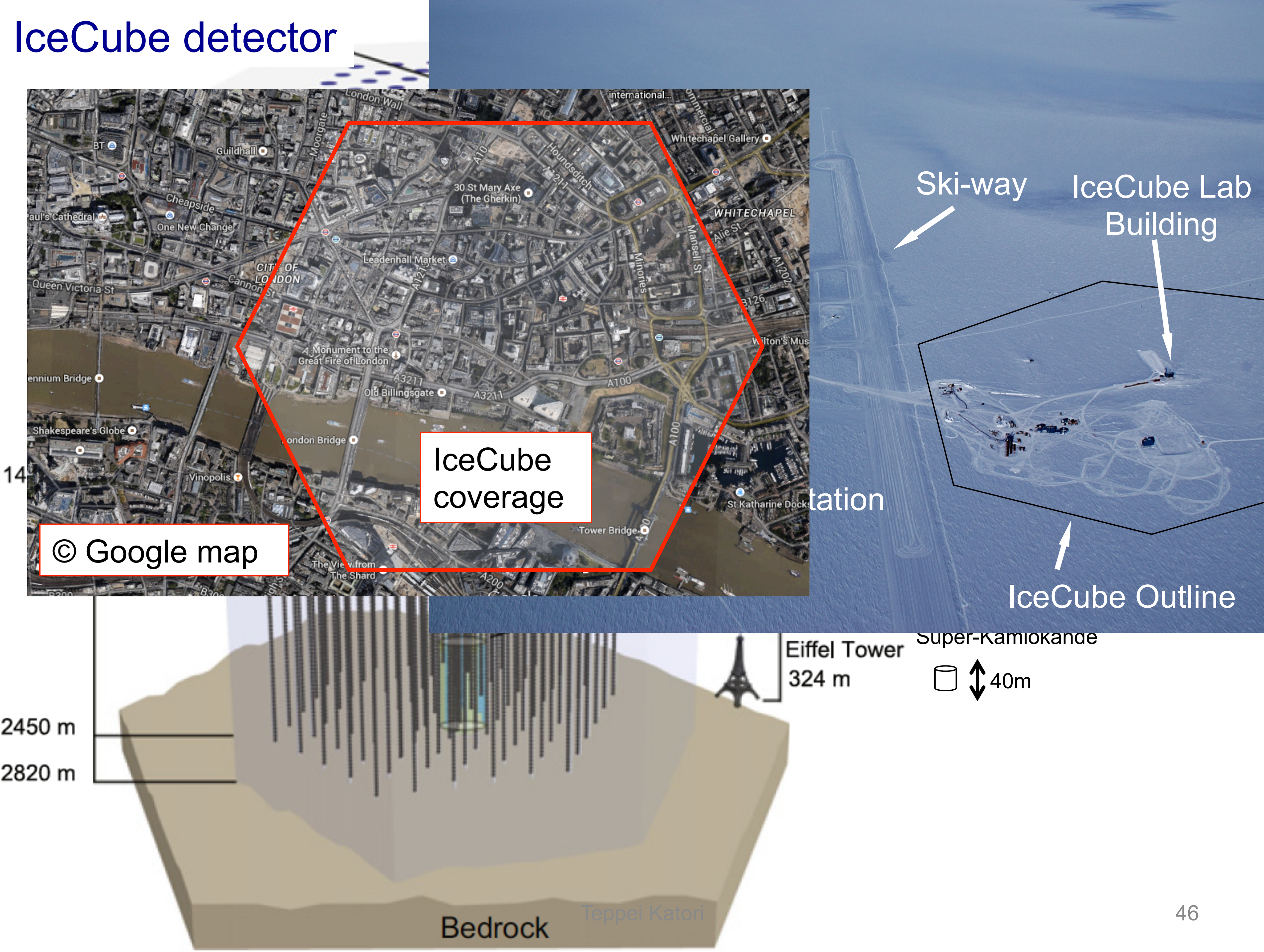


IceCube detector

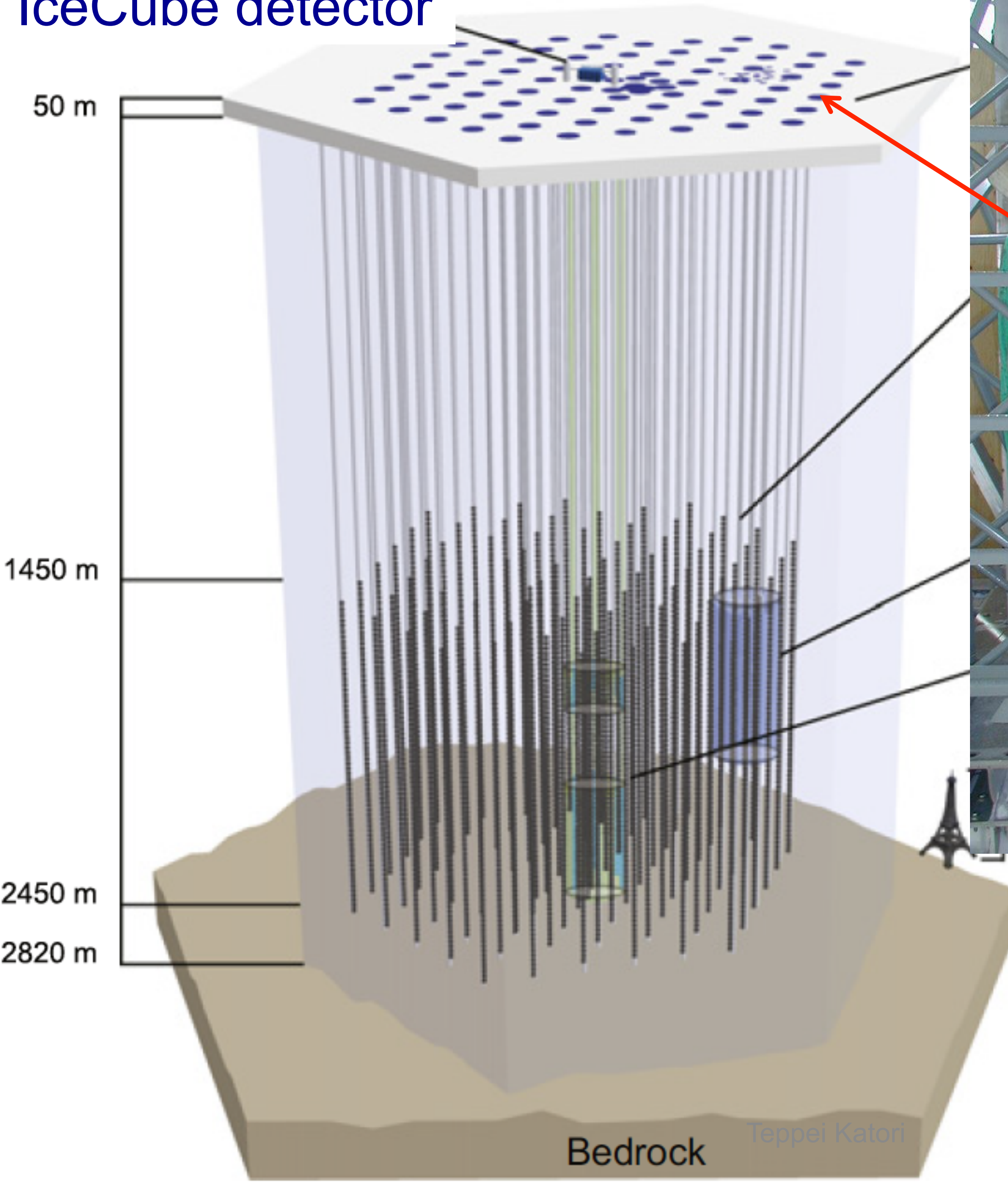




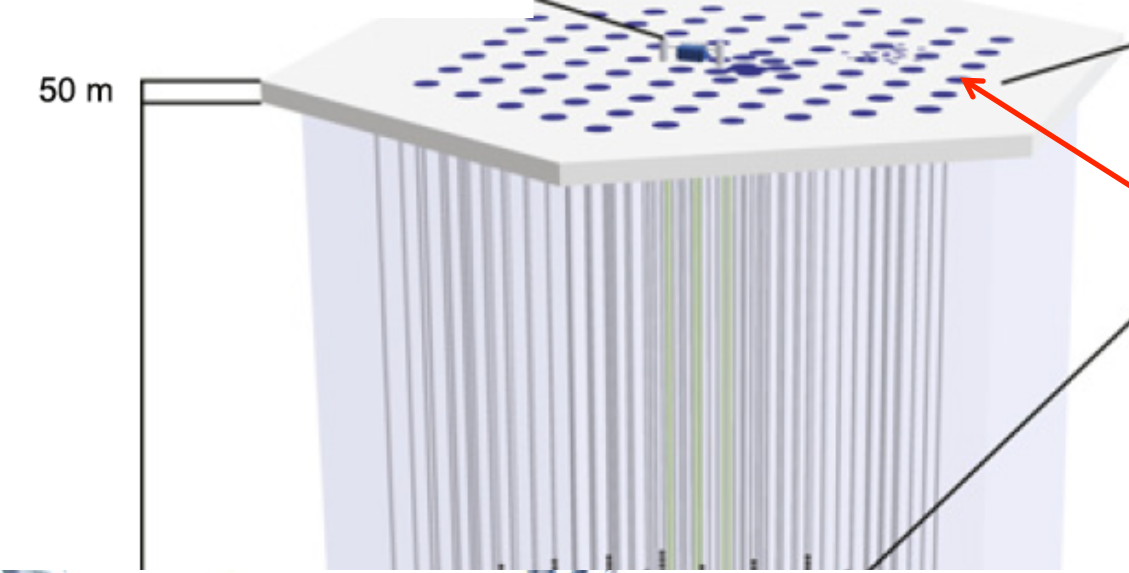
IceCube detector

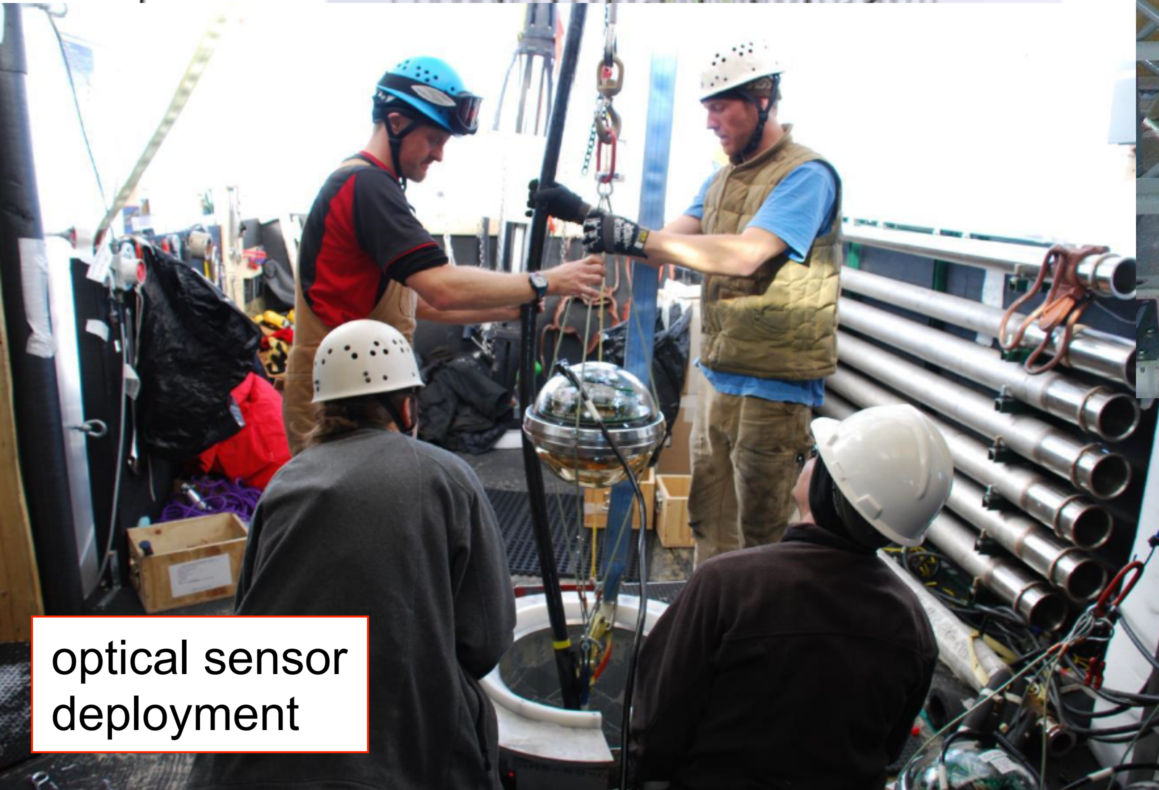


IceCube detector

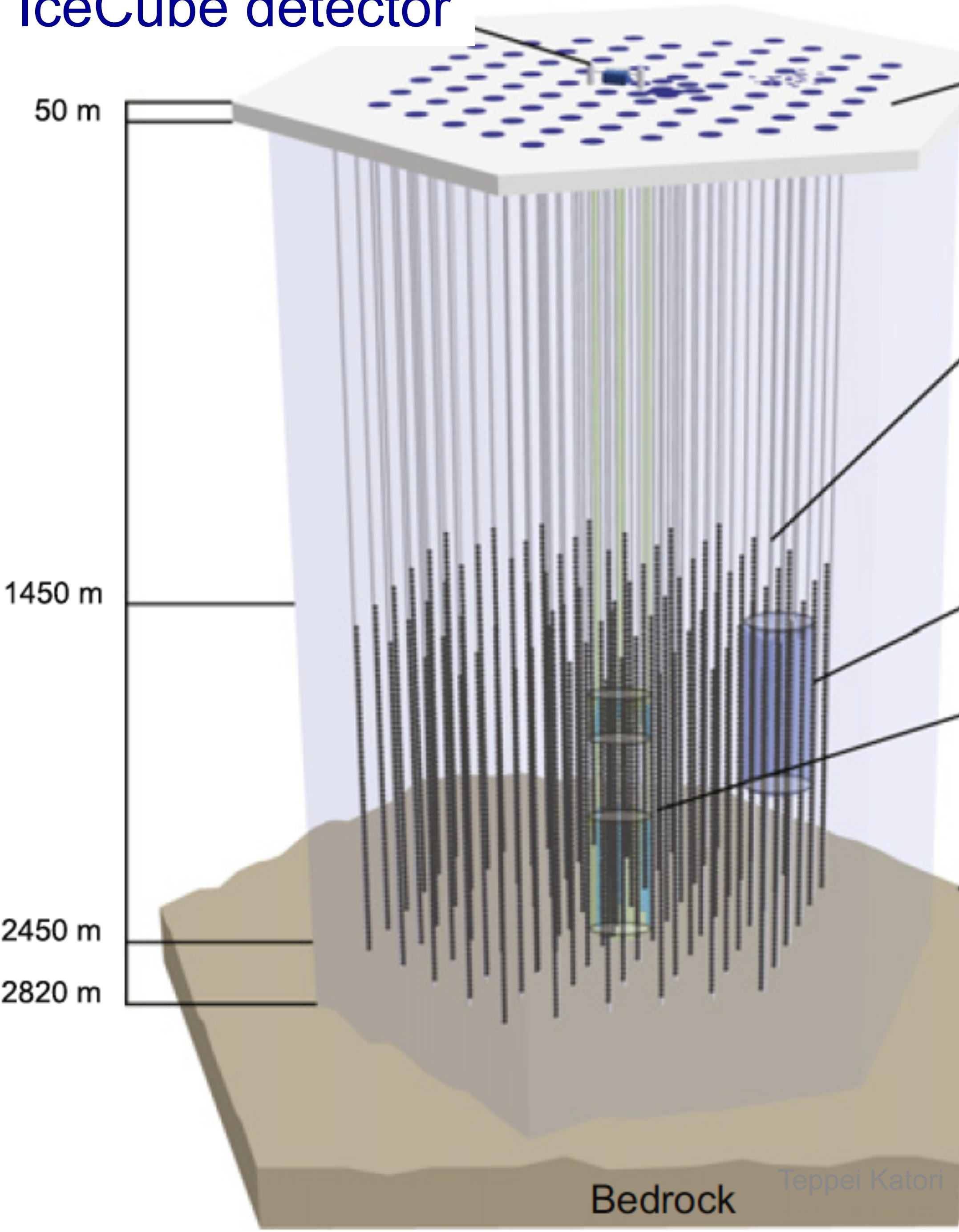


IceCube detector



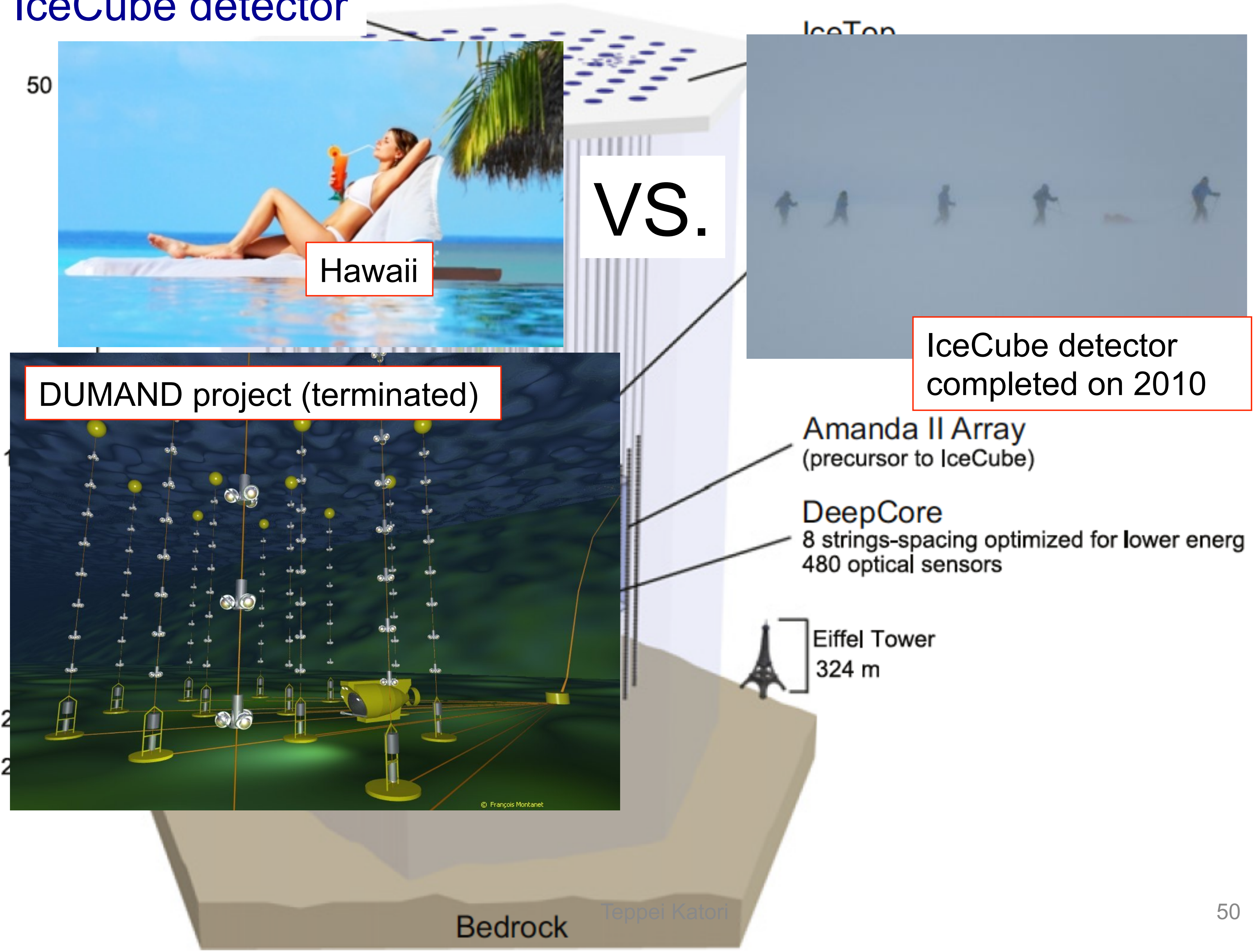


IceCube detector



IceCube detector completed on 2010

IceCube detector

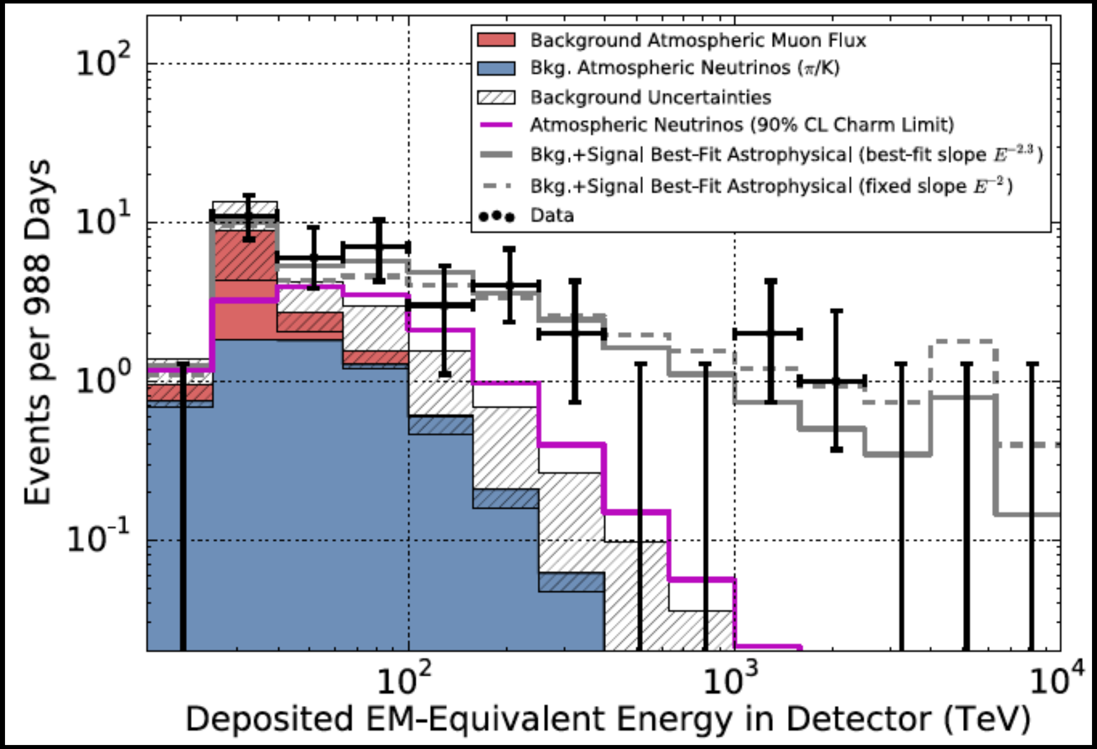


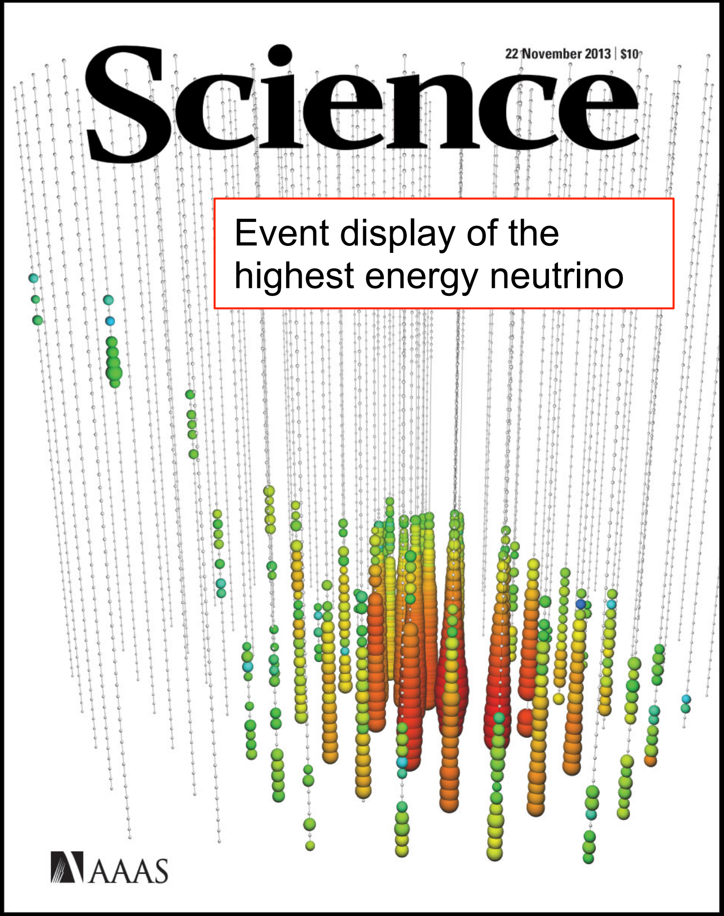
Discovery of Ultra-High-Energy Astrophysical Neutrinos

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

We need more ultra-high-energy neutrinos to test Lorentz violation!

Measured high energy neutrino spectrum

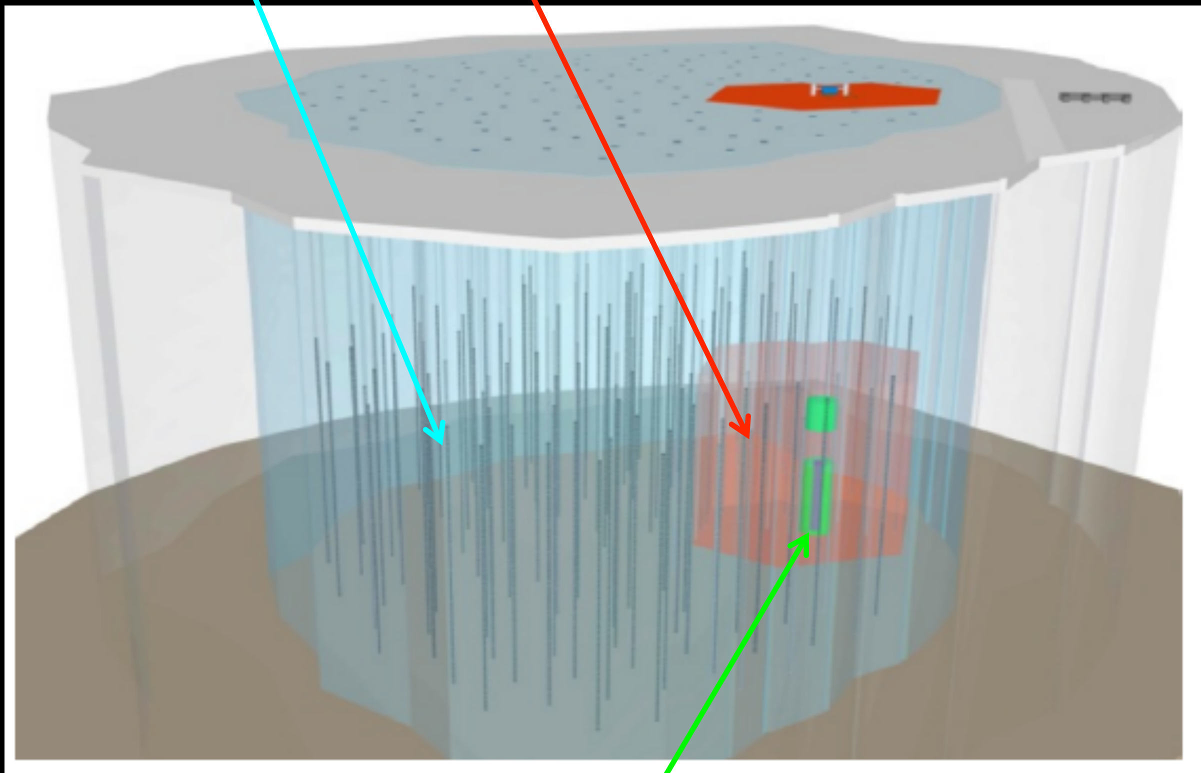




Event display of the highest energy neutrino

IceCube-Gen2 collaboration
arXiv:1412.5106

IceCube-Generation 2 (Gen2)



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

Queen Mary
University of London

IceCube-Generation 2 (Gen2)

IceCube-Gen2 collaboration meeting (May 1, 2015)

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

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PINGU: special region to study low energy neutrino

UK members: Queen Mary
Oxford, Manchester

Queen Mary
University of London

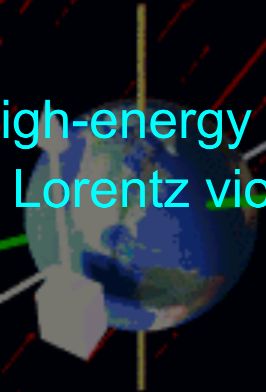
Bluhm, Kostelecky, Lane, Russell PRL 2002

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!