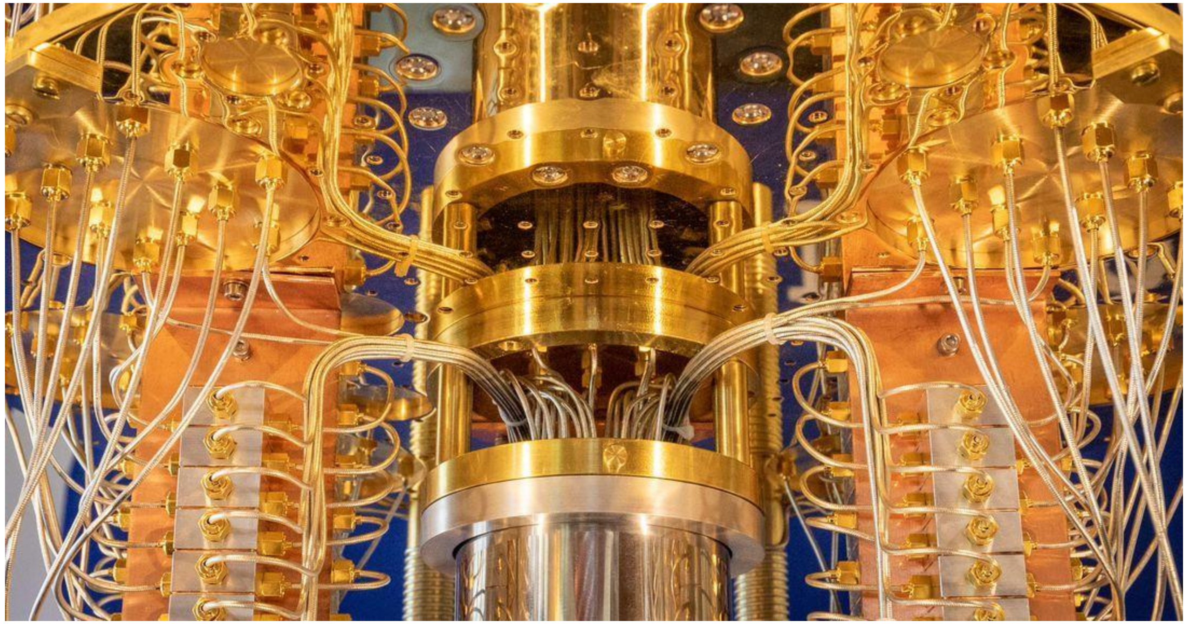
Quantum strategy of KEK



Shoji ASAI (KEK)

Insight through Accelerators.

KEK

Grand view

QUP plays important role
core of new Quantum Business of KEK:

International Collaboration

Synergy based on "Quantum"

Private Companies

Application
Sensor
Q-Connection

Q-Sensor
Basic Science

academic-
industrial
Collab. office

Mat.Lab

PP Lab

Quantum
Material

Accl. /Workshop
Labs

ASPIRE

Study Q Material
(Various Quantum
beams prove spin/state)
Sensor@ 300K
Application

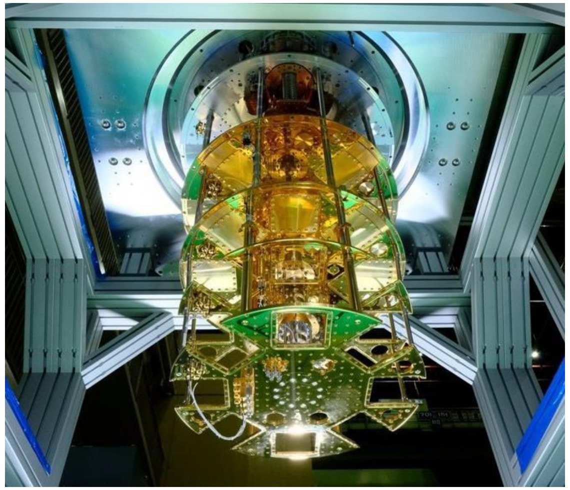
CryoCMOS
interface RF tech.
SC Cavity $Q>10^{11}$
Magnet

Sensor for Basic Science
Gravity
Q-Connection
Dark Matter detection

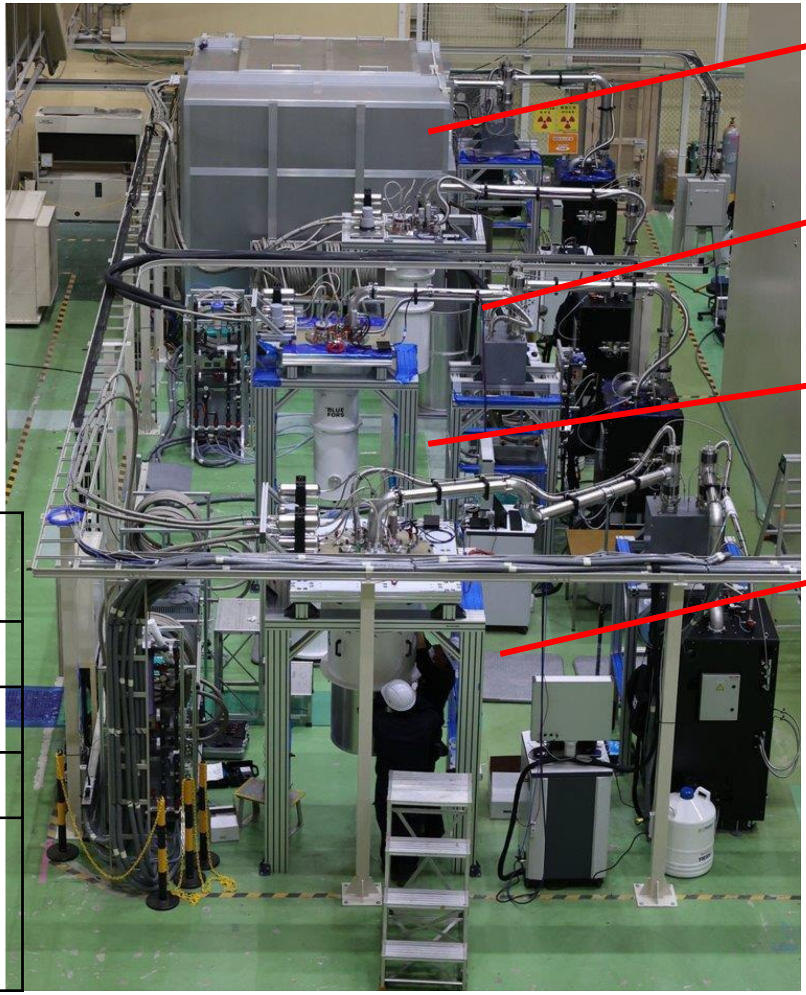
1) Cryogenic Facility

4 Cryogenic machines are ready.
4 Cryo will be usded at Tsukuba

Cryo-Facility @Fuji Hall (B4)



^{3}He-^{4}He dilution cooler BlueFors XLD/LD400	
Base temp.	<10mK
Cooling power	500μW @0.1K
Cables	DC/RF
Available options	Anti vibration stage He. battery Optical window etc…



DR4 (XLD400)

DR3 (LD400)

DR2 (LD400)

DR1 (XLD400)
(Kamioka-DM) -> Move to Kamioka

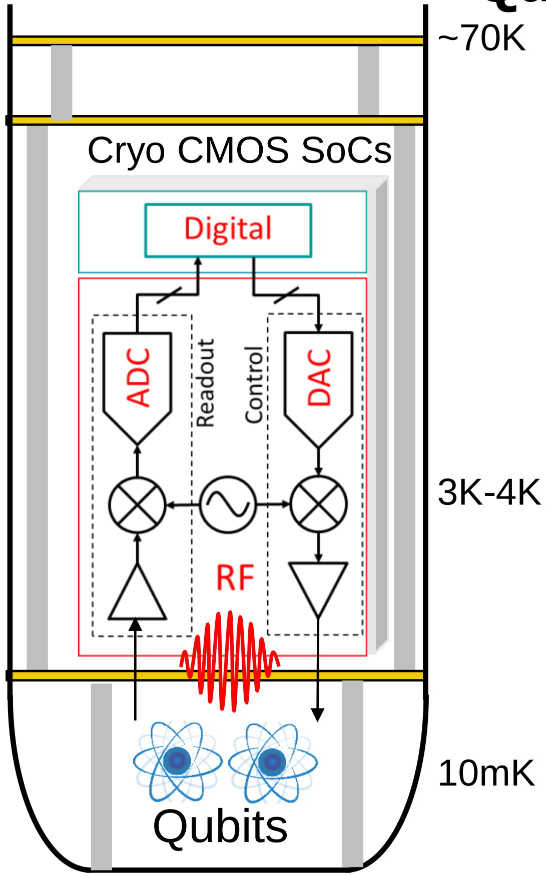
DR0 (Oxford Triton)

+

DR5 (SD250)

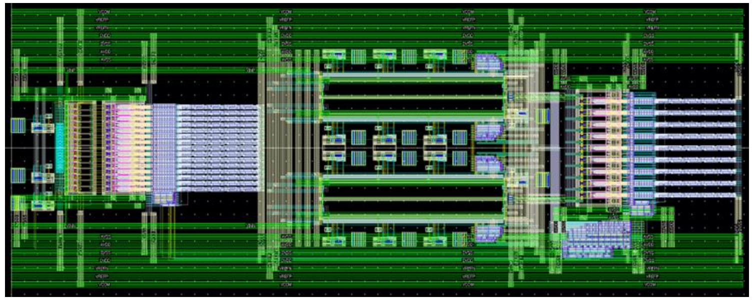
2) Cryogenic CMOS ASICs for Quantum operation/ Q-Computing

Subject Goal: Implementing ASICs operating at a cryogenic temperature to control Qubits.

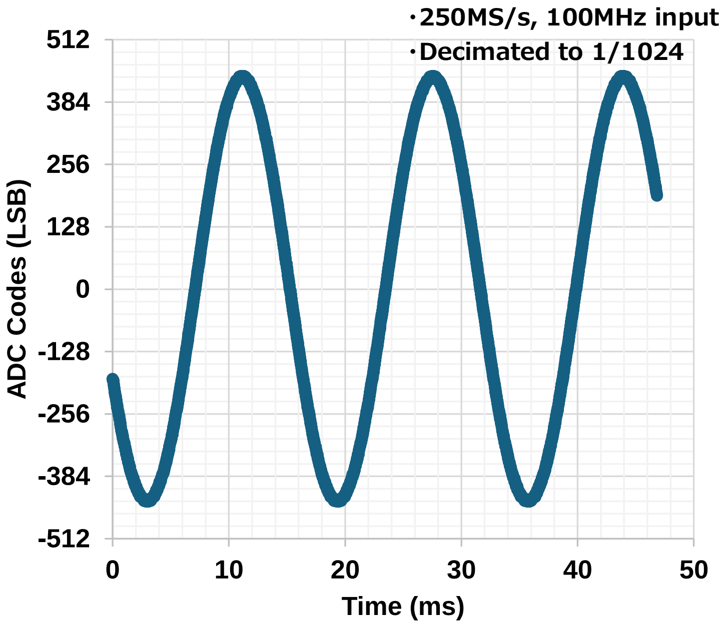


Cryogenic CMOS ASIC for Qubit control

- ✓ Highly integrated
- ✓ Low power
- ✓ Less heat inflow



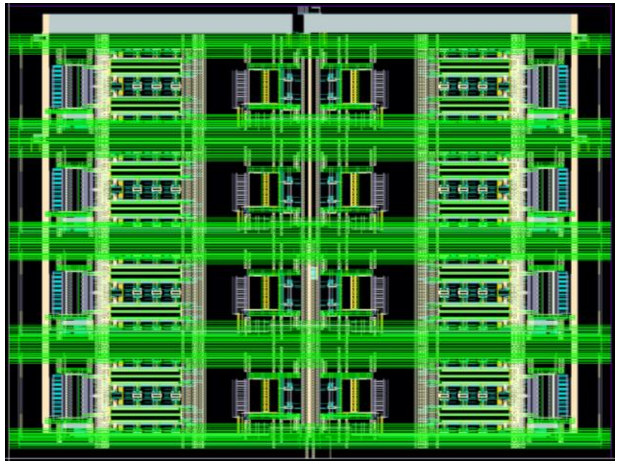
10bit Cryogenic ADC Layout (22nm CMOS)



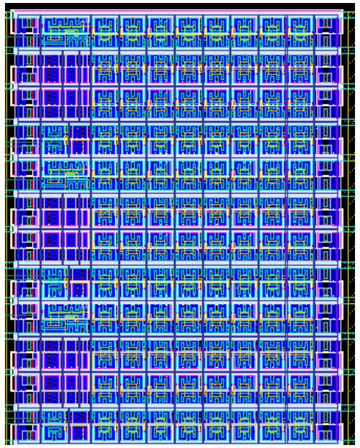
Sine wave input test of ADC @4.2K

Large N Qbit & complicated operation Becomes possible

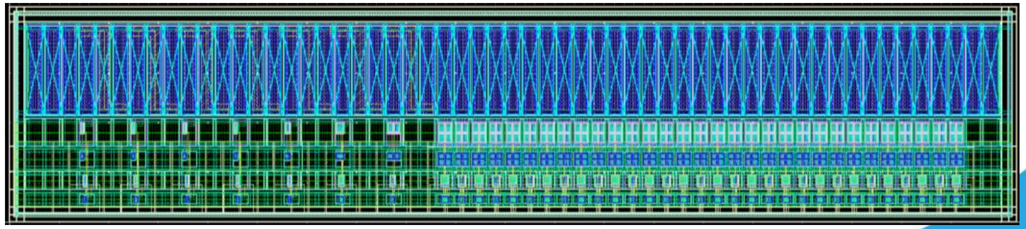
The 1s
properly operated in cryogenic environment.
Various element circuits with further improved performance are under development.



10bit 2GS/s ADC



Oscillator



12bit 2GS/s DAC

3）Superconductive Cavity

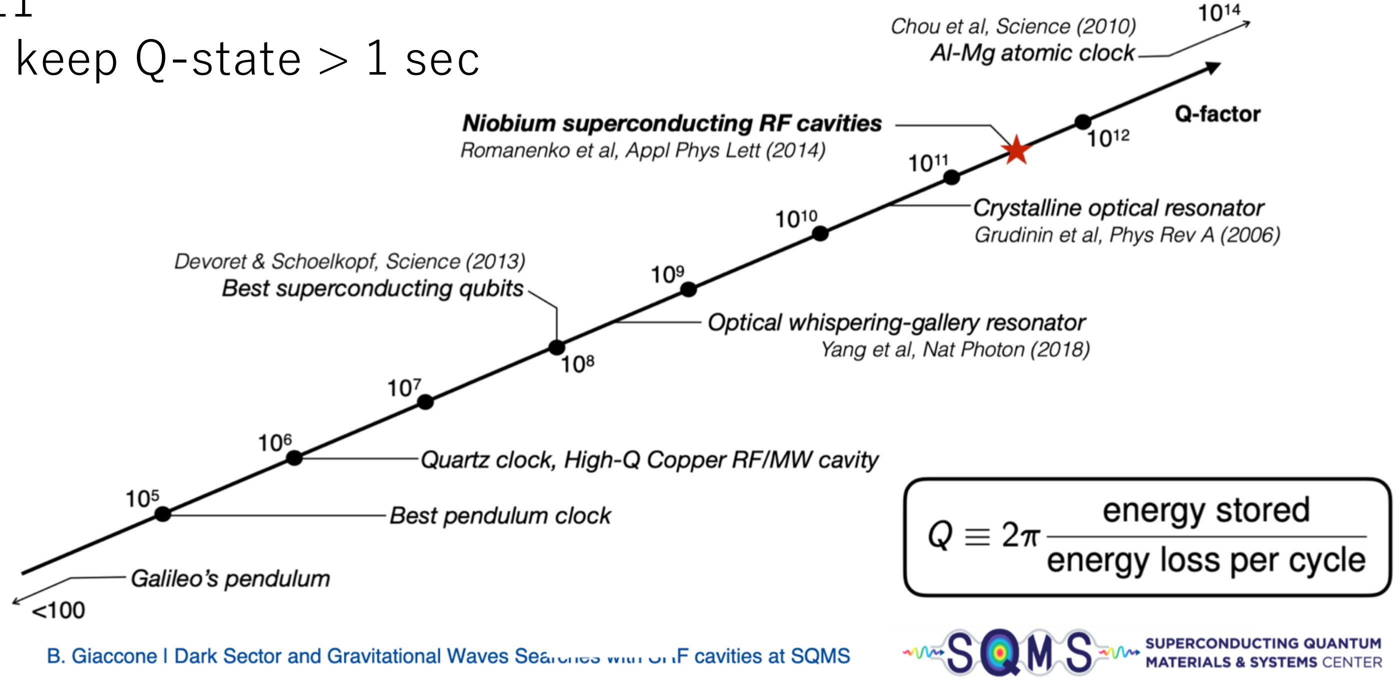
KEK has advantage on SRF cavity.

1.3GHz RF cavity for ILC

Why SRF cavities for quantum sensing?

SRF cavities are the most efficient engineered oscillators

Q>10^11
We can keep Q-state > 1 sec



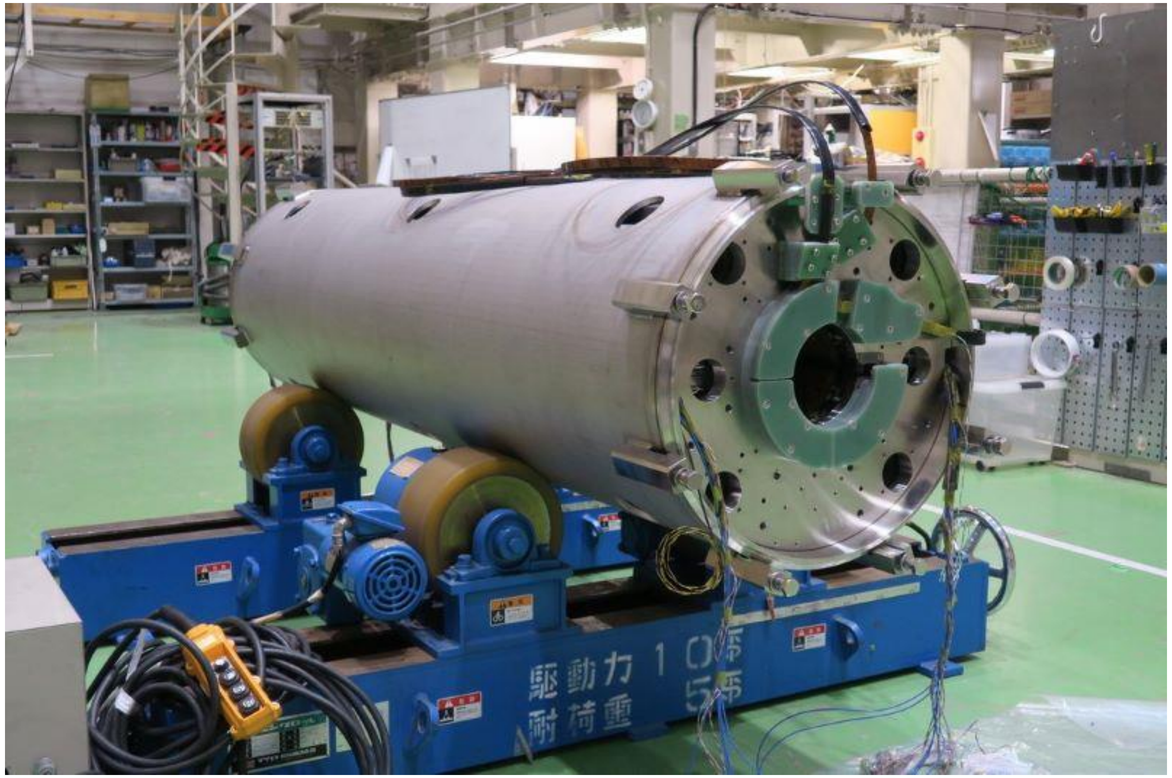
Gravity wave detection

10－100KH z

4) Magnet

Cryogenic Engineering Lab

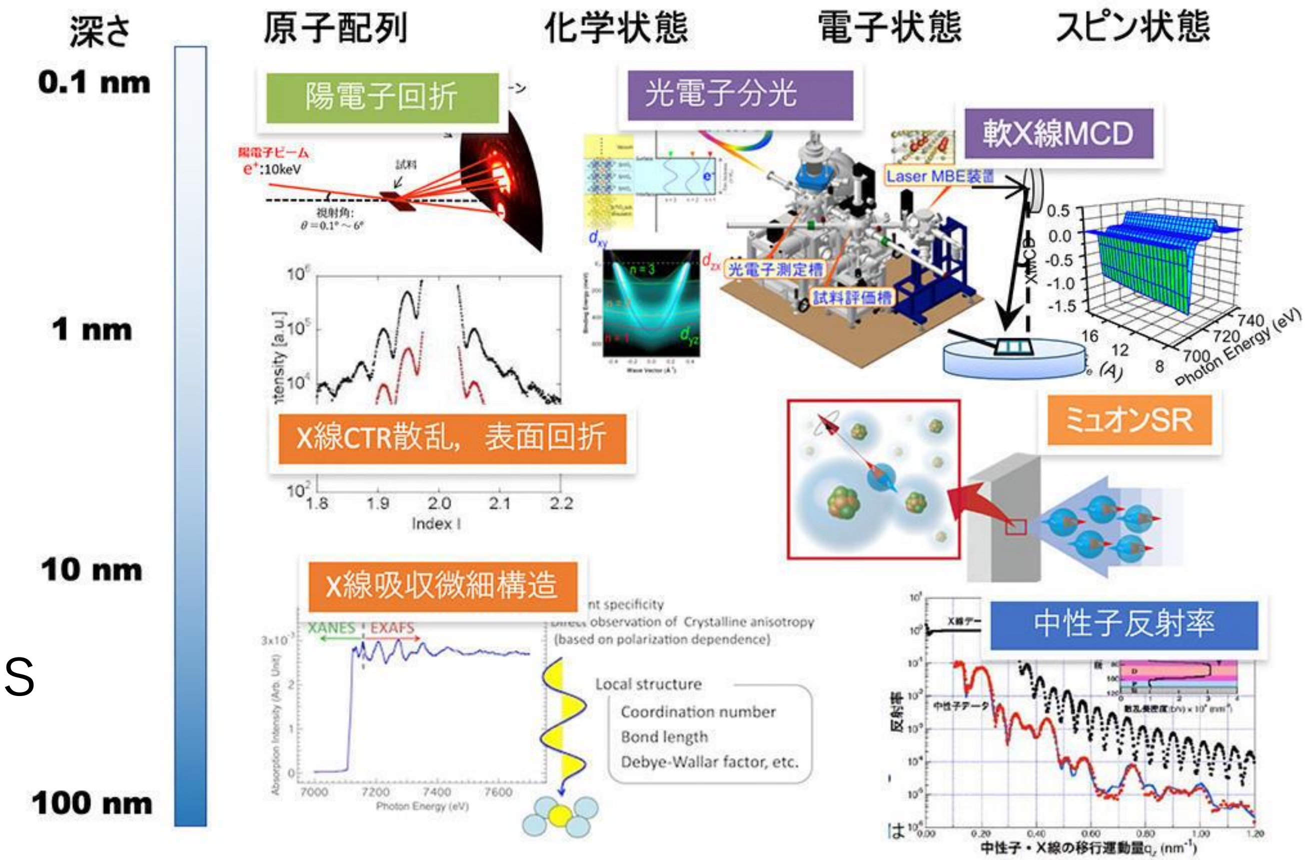
Strong / precision Magnet filed is important element:
Magnet / superconducting Magnet



5）Develop Quantum material

Q-Material

Atomic arrangement　Chemical　Electron state　Spin state



マルチプローブによるマルチスケール，マルチ視点観察

NIMS
AIST
Univ.s
Private Companies

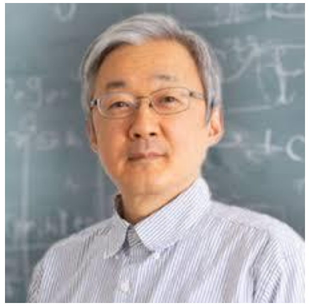
We have
5 quantum beam
to study

Slow Positron
Soft X
Hard X
Muon
Neutron

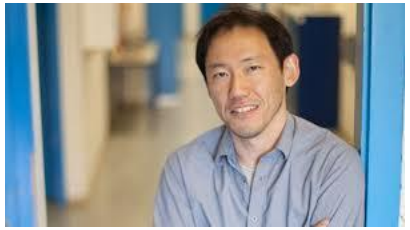
6）Theory Group

Riken

iTHEM.S



KEK
Theory



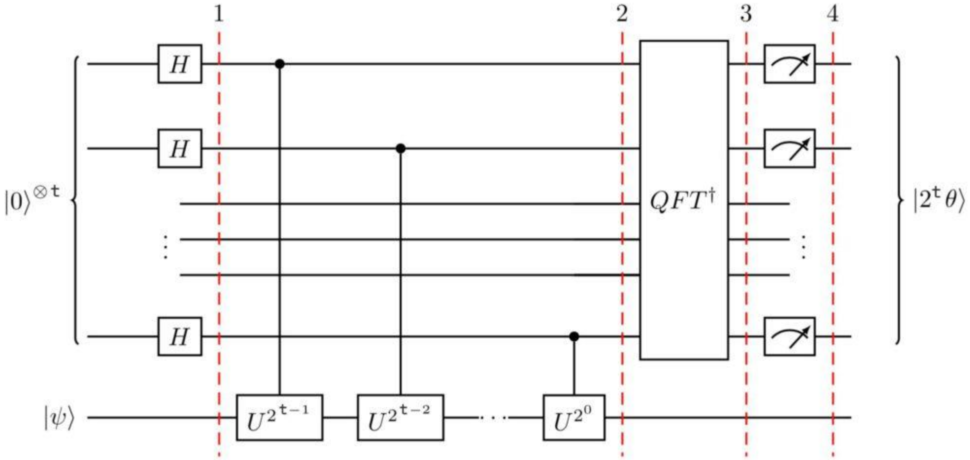
U-Tokyo
Aspire

David Awschalom

UTokyo

ASPIRE

Q Algorithm



International / domestic
collaboration

Private Companies

Insight through Accelerators.

KEK

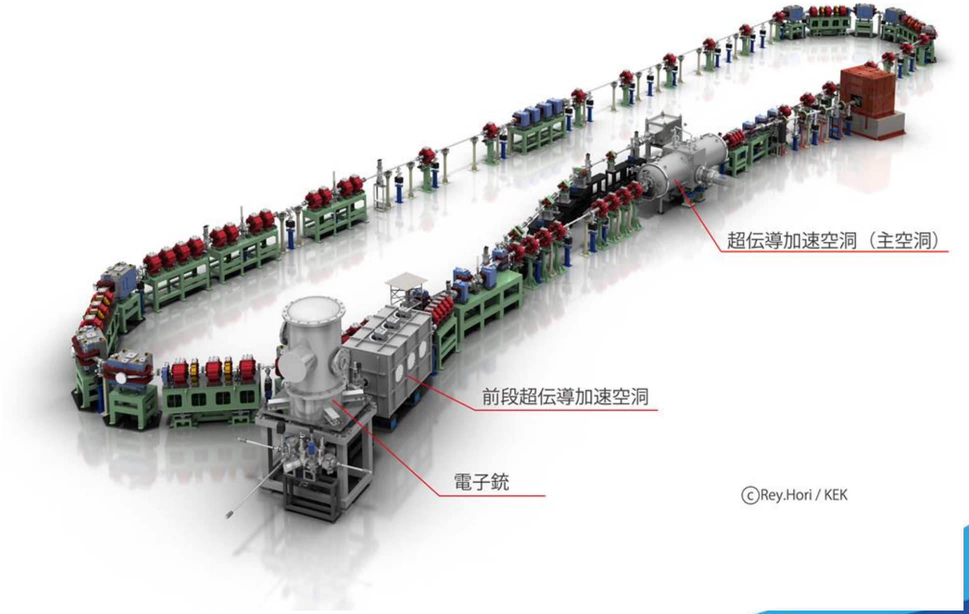
KEK at the end of 21st century

Waterside?（Tokai?）Just image!!!

Compact Accl.

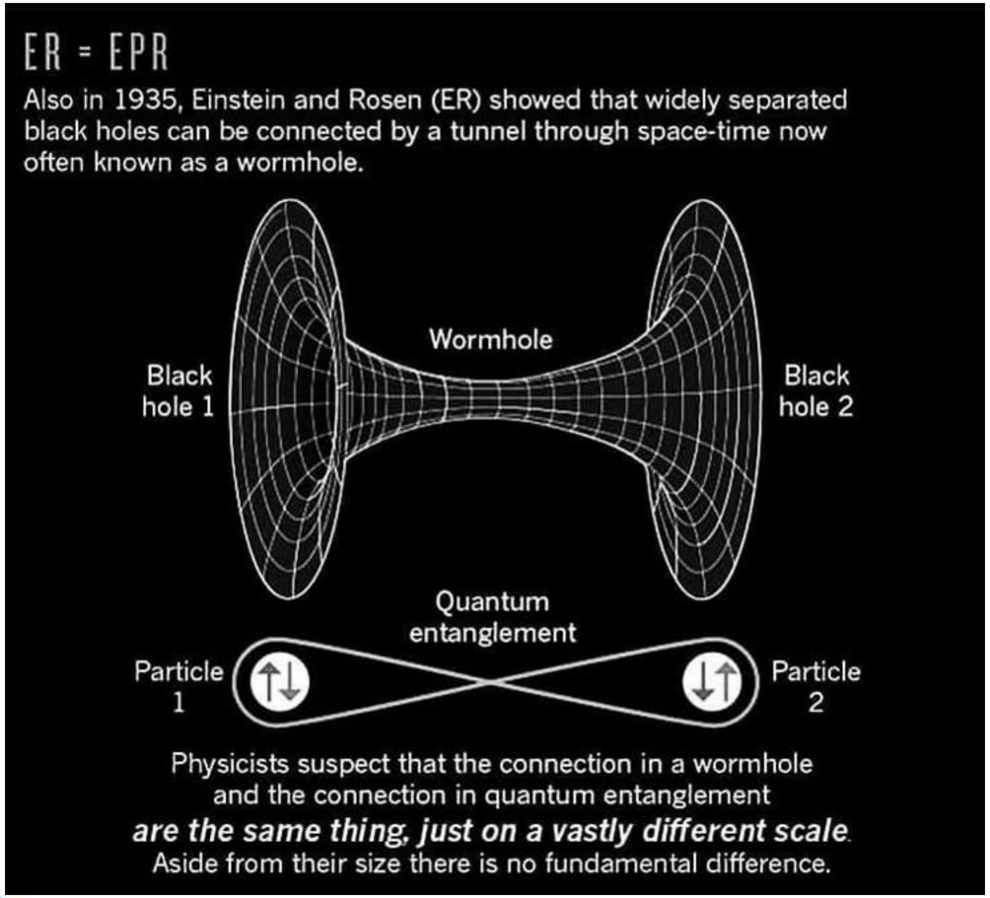
Energy Recover　(small Power consumption)

Future DG not need to take care of electric price.



GOAL at the end of 21st century

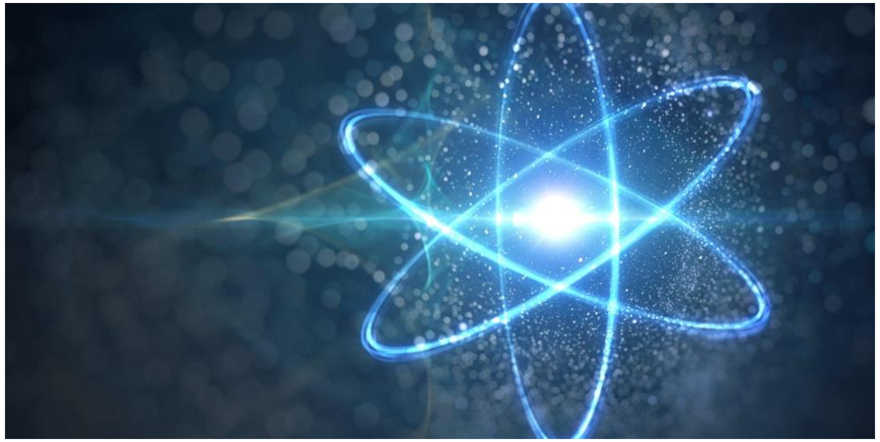
Understand:
Entanglement
in context of space-time?

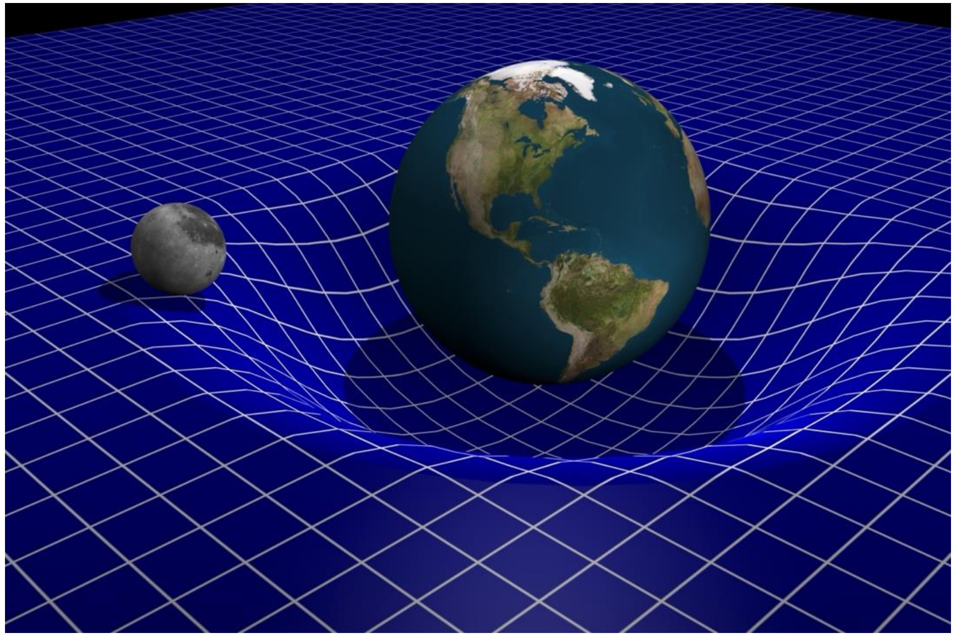


Quantum

Unify

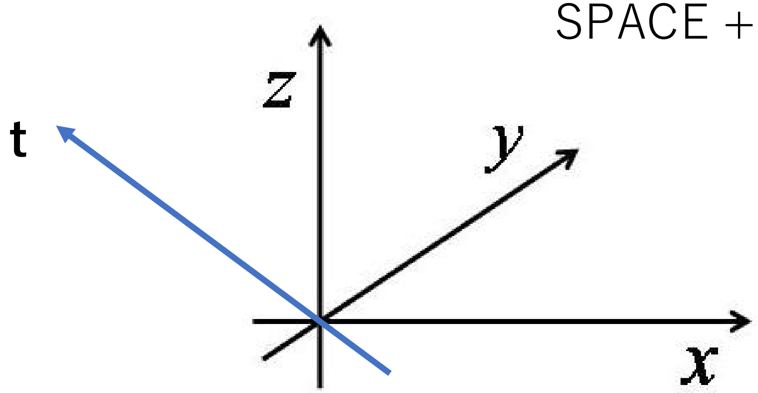
Gravity



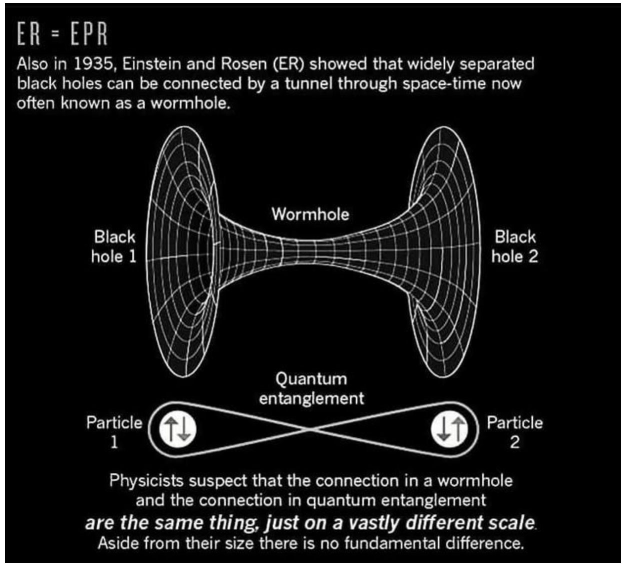


4-dimension

SPACE + TIME + SPIN +(Extra-dim)



Space should be
extended.



$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

1)$R_{\mu\nu}$

A: Exactly same between Boson and Fermion equivalence principle @ Elementary?
(Examined at Atomic level but not Elementary)

B: Constant ? Unique? (double metric or function of scale) EP at small scale

C: EP for Entangle / non-Entangle

D: Particle vs Anti-Particle EP? CP violation
Phase shift?

E： Continue? Violation of Lorentz invariance (Planck scale level?)

$E^2 = P^2 + m^2 + E^2 \Sigma\, \eta\ (E/m_{planck})$

Insight through Accelerators.
KEK

$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

2) Λ

$\Lambda_{\text{observed}} = (10^{-3}\ \text{eV})^4$

$\Lambda_{\text{Higgs}} = (10^{12}\ \text{eV})^4$ 10^{60}

$\Lambda_{\text{GUT}} = (10^{25}\ \text{eV})^4$ 10^{112}

A: Vacuum Field feels the R?

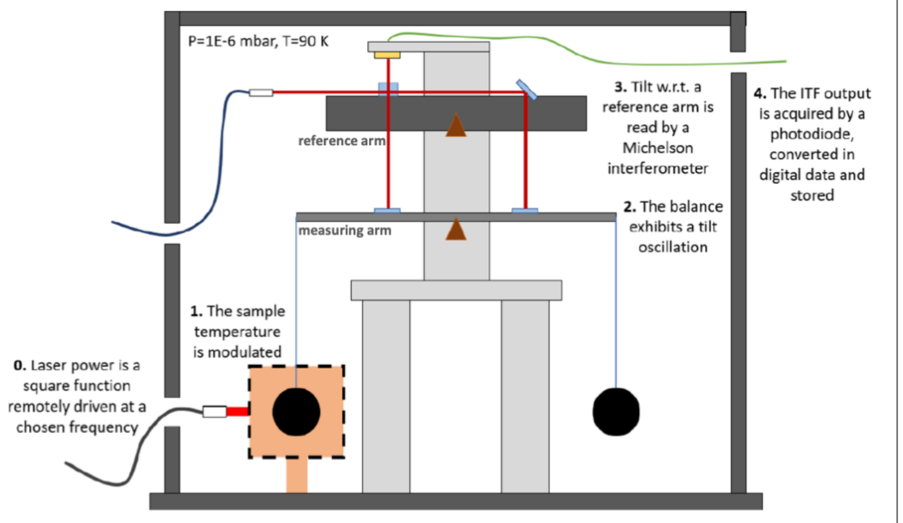
B: EP / R function as the distance / energy scale (1B)

Vacuum field contribute to T?

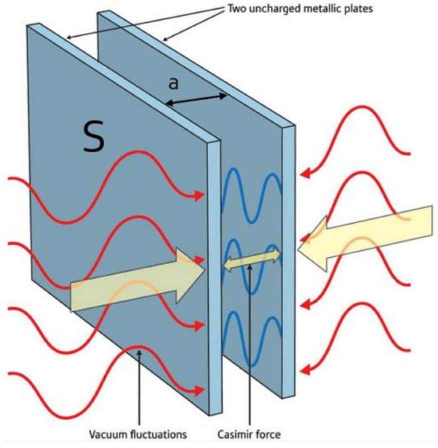
Macro vs Micro where is boundary?

Archimedes Experiment

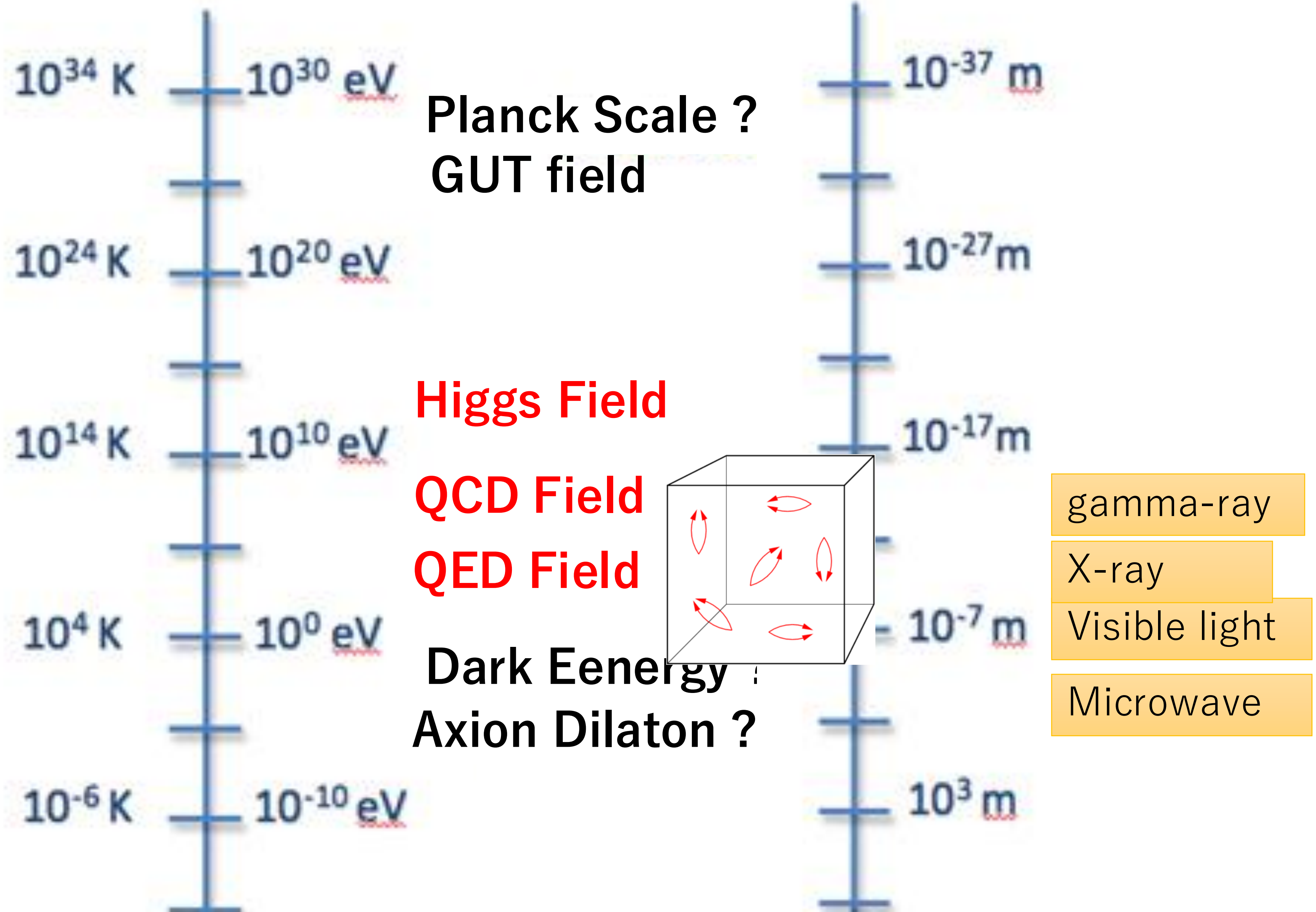
Torsion balance



courtesy of Dr Luciano Errico



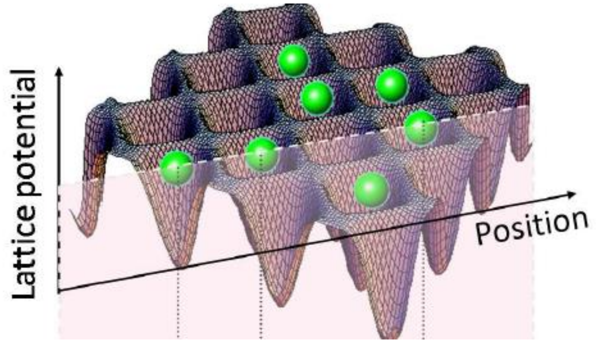
Various fields are hidden in our vacuum



$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

What makes R?
energy, mass, Entropy?

3) Energy Momentum tensor T



Light makes R? (T)
Vacuum (field) makes R(T)??
BE state ?

Precision Clock
(Katori 10^{-18})
Nuclear 10^{-19}

Effect is too small
We need "On-Off" measurement

Becomes
Sensor for
Small R

Insight through Accelerators.
KEK

Let’s kick off long adventure with QUP!!!