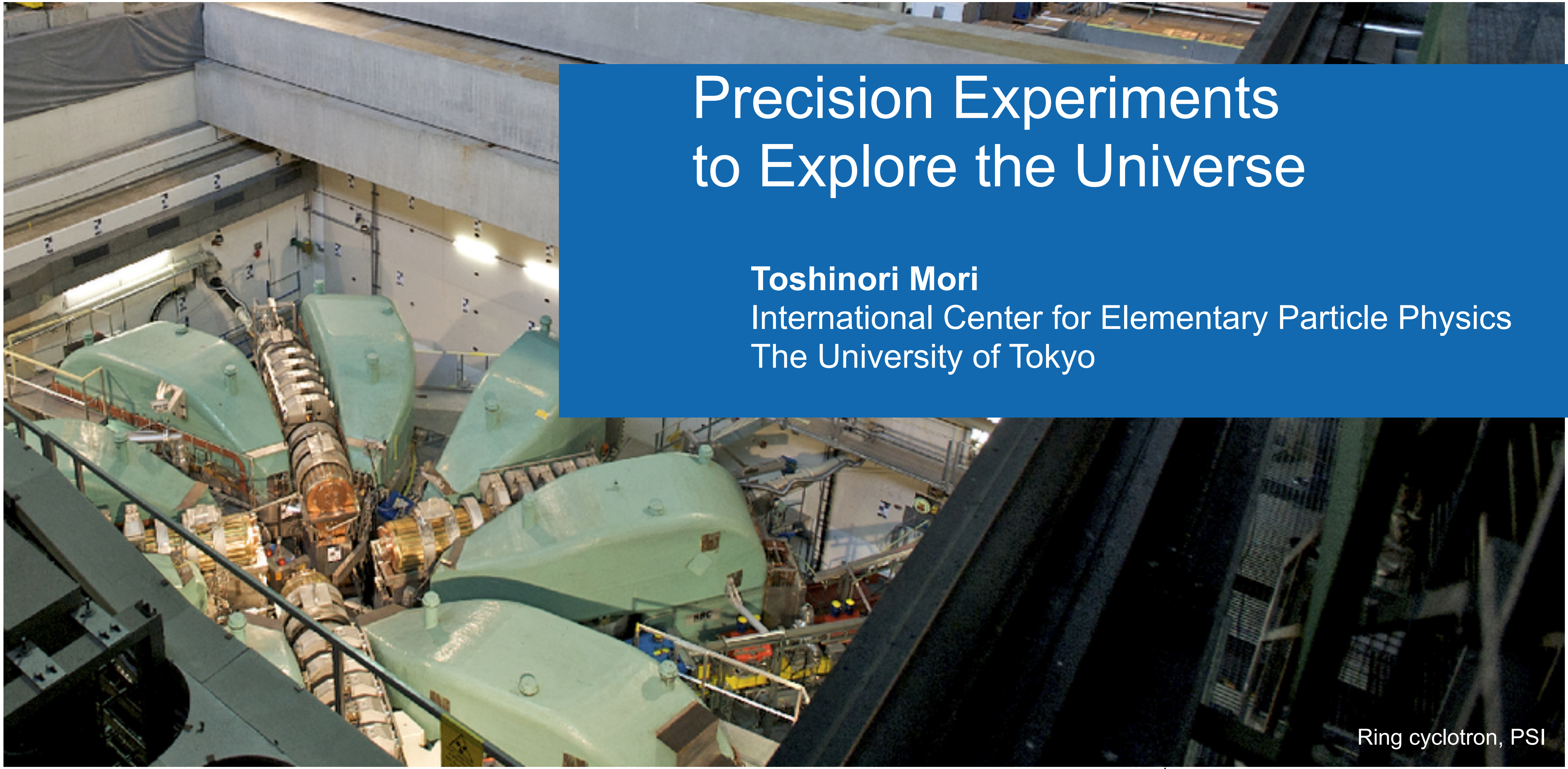
ETH zürich

東京大学 THE UNIVERSITY OF TOKYO

University of Zurich UZH



Precision Experiments to Explore the Universe

Toshinori Mori
International Center for Elementary Particle Physics
The University of Tokyo

Ring cyclotron, PSI

ETH zürich

東京大学
THE UNIVERSITY OF TOKYO

Kirch

ETH zürich

Ootani Sakemi Mibe Mori

東京大学
THE UNIVERSITY OF TOKYO

Kirch

ETH zürich

PAUL SCHERRER INSTITUT PSI

Ootani Sakemi Mibe Mori

東京大学 THE UNIVERSITY OF TOKYO

RIKEN

KEK

Kirch

ETH zürich

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Kirch Ootani Mori

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東京大学 THE UNIVERSITY OF TOKYO

RIKEN

Sakemi

KEK

Mibe

Kirch

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PSI

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東京大学
THE UNIVERSITY OF TOKYO

RIKEN

Sakemi

KEK

Mibe

How do we explore the Universe?

How do we explore the Universe?

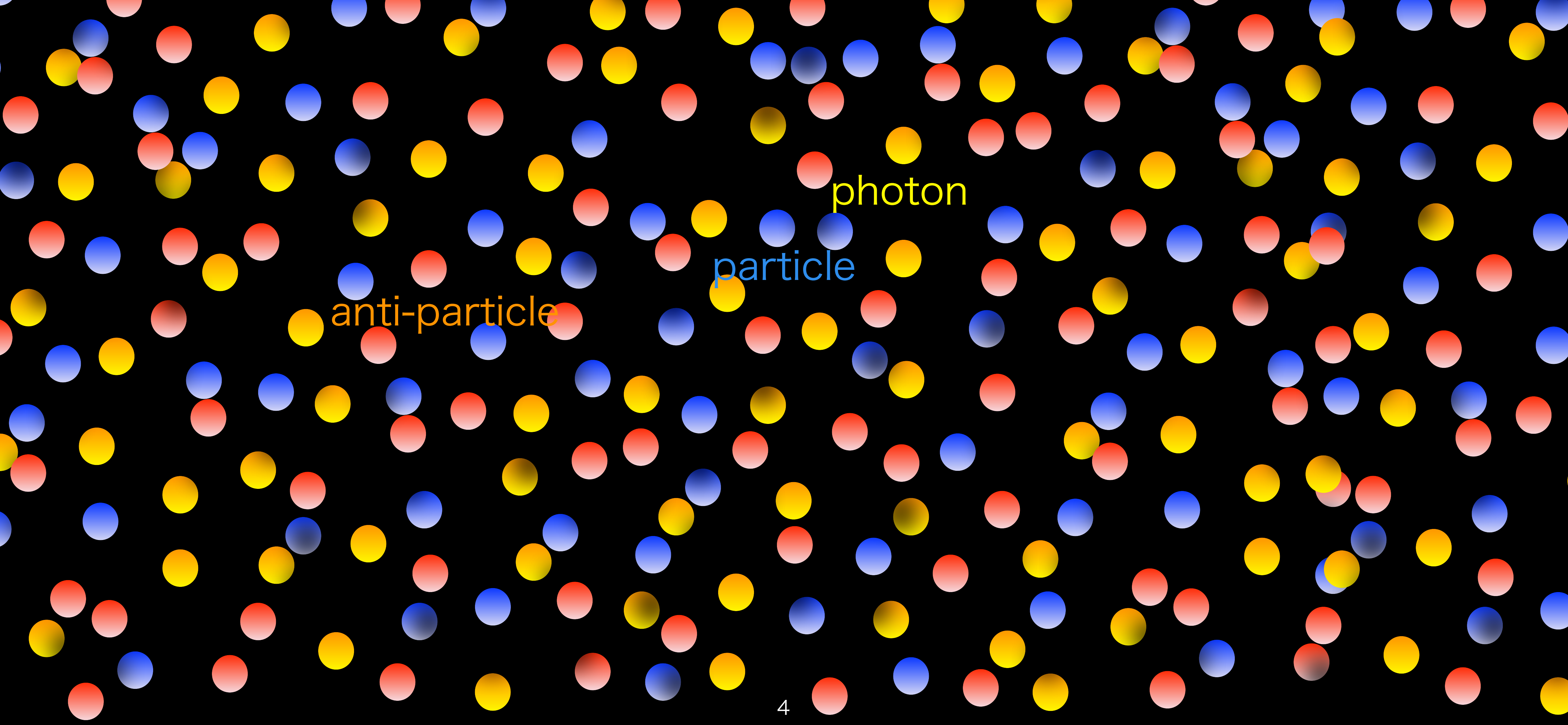
BIG BANG!!

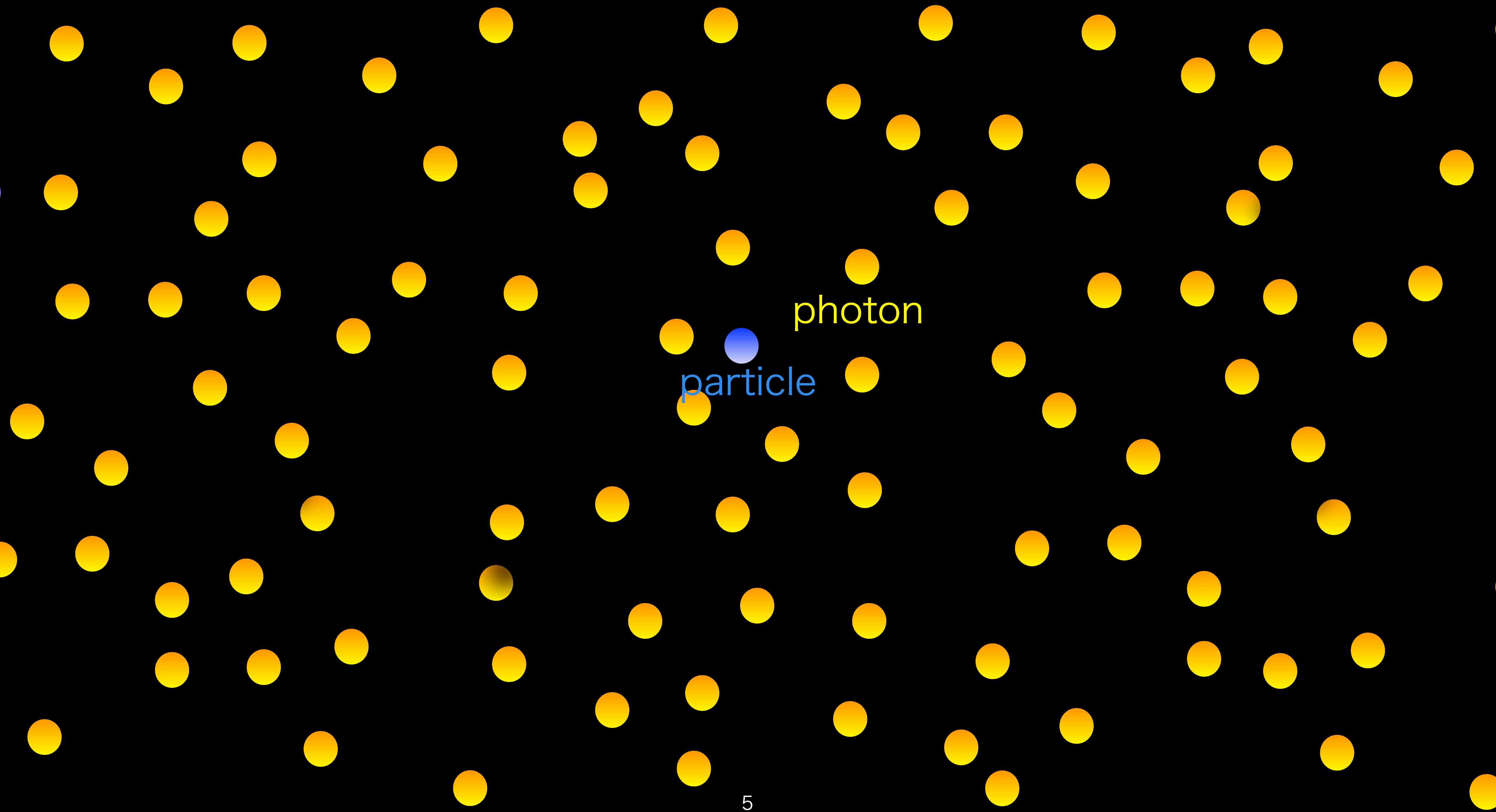
How do we explore the Universe?

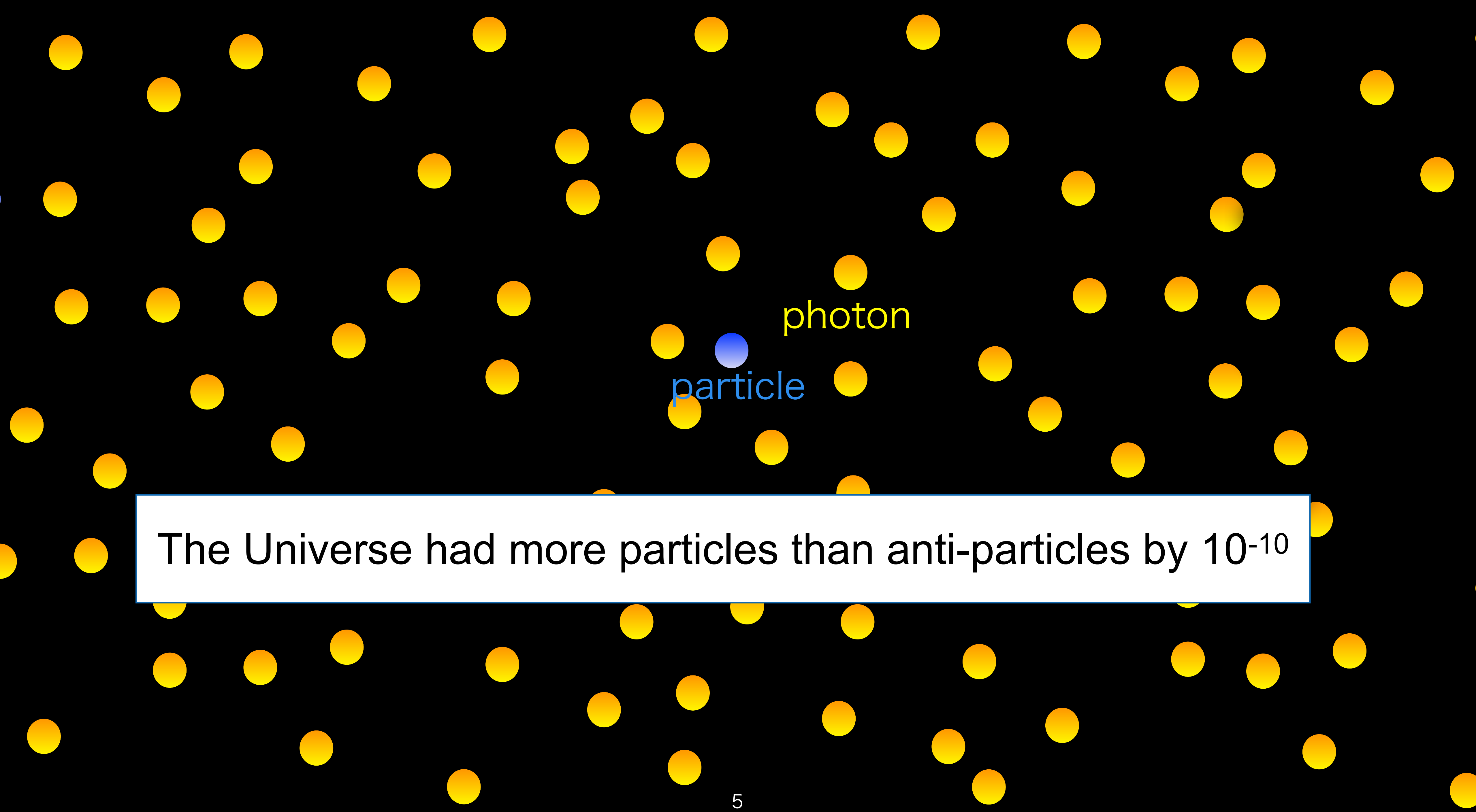
BIG BANG!!

The Universe started as a hot, dense soup of ENERGY.

BIG BANG created particles, anti-particles, and photons

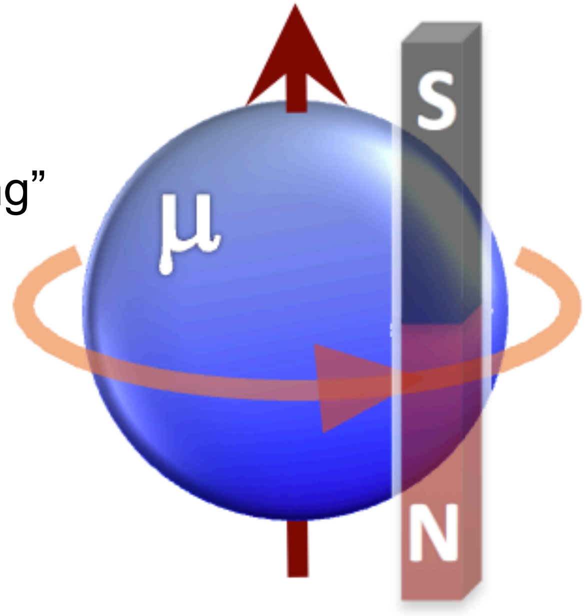


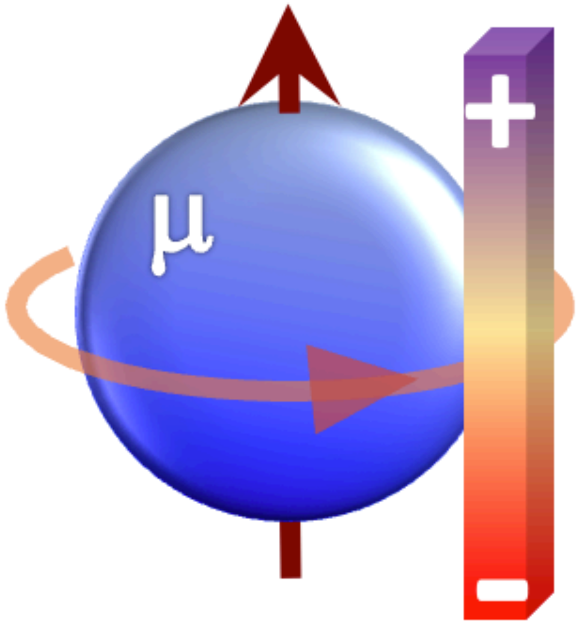

photon
particle


photon
particle
The Universe had more particles than anti-particles by 10^{-10}

The laws of Nature must be a little different for particles and anti-particles

A particle is “rotating”

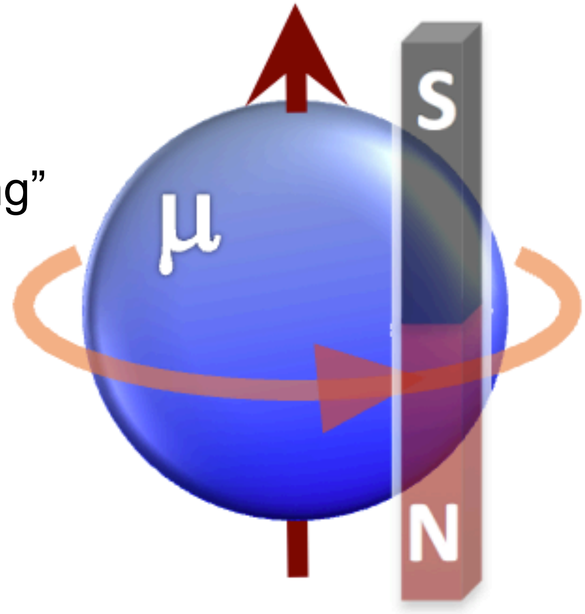




A charged particle is a “magnet”
i.e. it has magnetic dipole moment

The laws of Nature must be a little different for particles and anti-particles

A particle is “rotating”



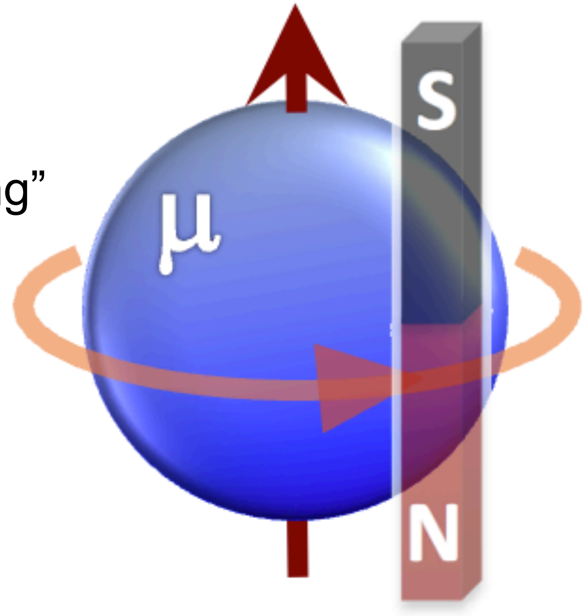
A charged particle is a “magnet”
i.e. it has magnetic dipole moment

The Nature Law is symmetric about time direction.

A charged particle cannot have **electric dipole moment**

The laws of Nature must be a little different for particles and anti-particles

A particle is “rotating”



The Nature Law is symmetric about time direction.

↓

The Nature Law is symmetric about particle & anti-particle.

A charged particle is a “magnet”
i.e. it has magnetic dipole moment

A charged particle cannot have
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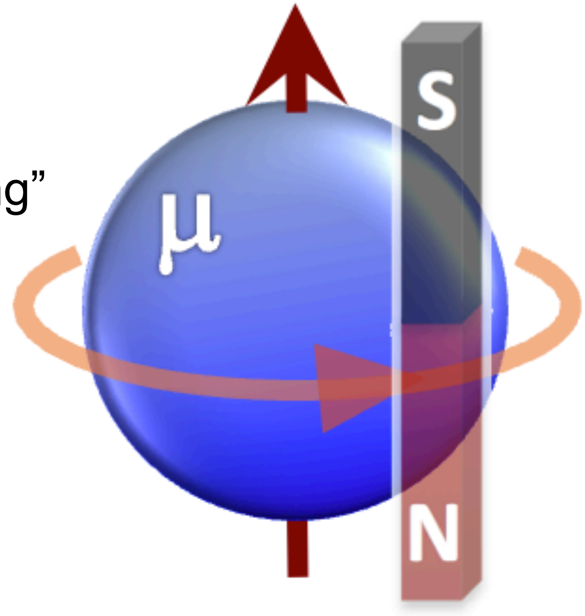
The laws of Nature must be a little different for particles and anti-particles

A particle is "rotating"



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↓

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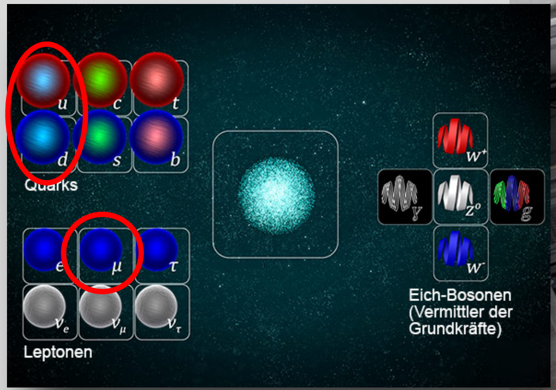
EDM

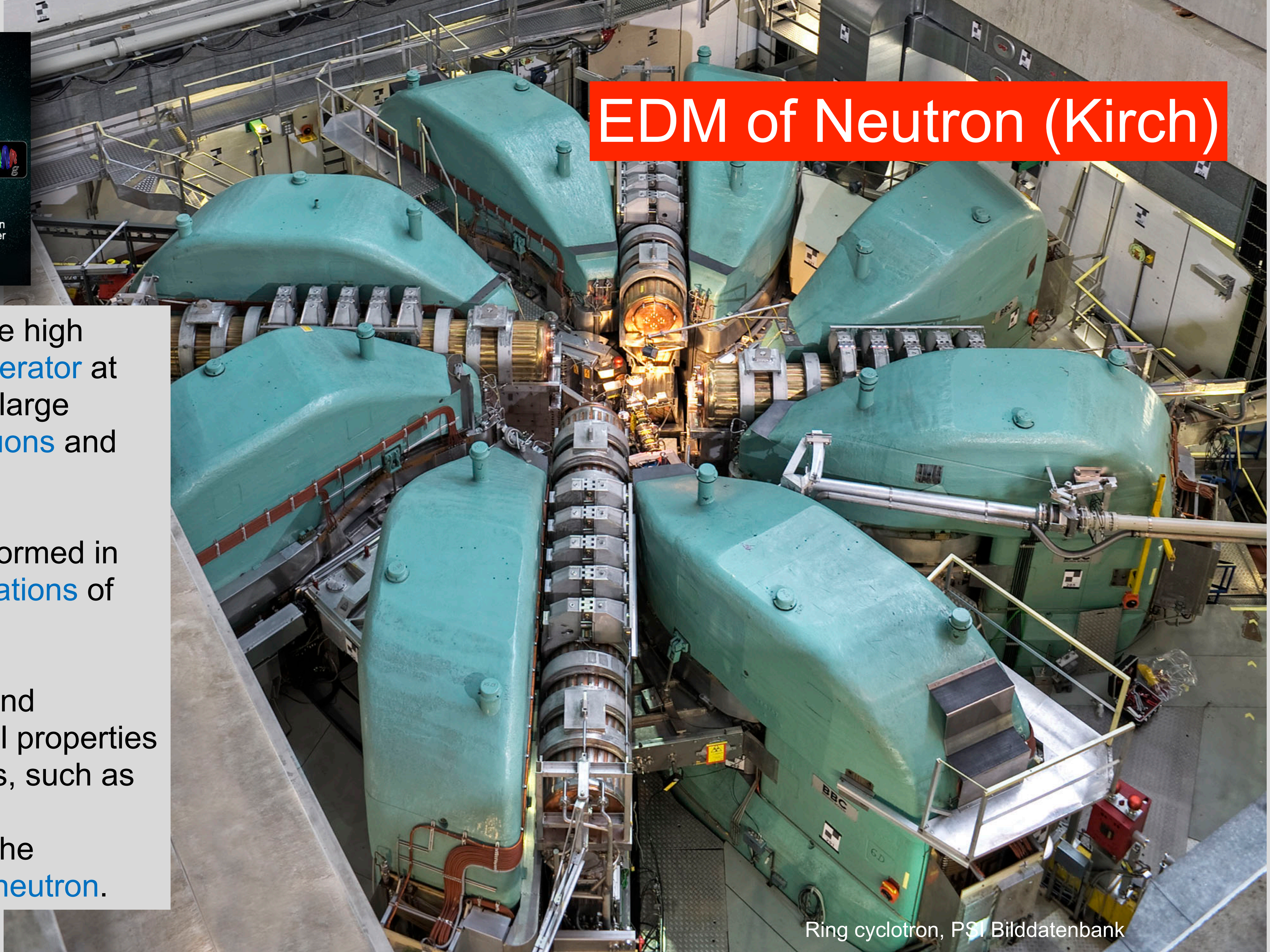
EDM of Neutron (Kirch)



The group is using the high intensity proton accelerator at **PSI**, which produces large amounts of pions, muons and ultracold neutrons.

Experiments are performed in international collaborations of 10-50 people.

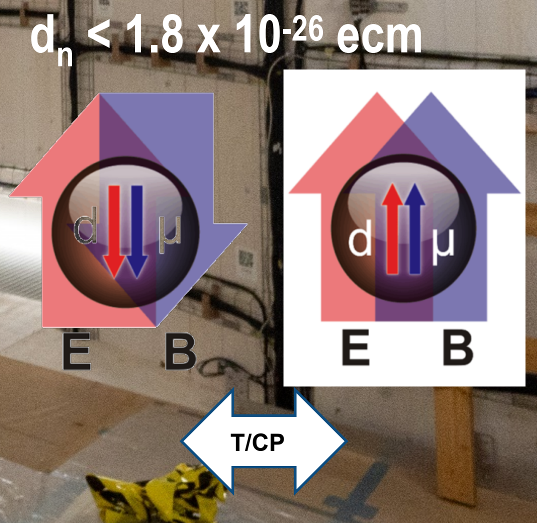
We improve beams and measure fundamental properties of subatomic particles, such as the
size of the proton or the
electric dipole of the neutron.



Ring cyclotron, PSI Bilddatenbank

To find the tiny electric dipole moment of the neutron, a large magnetically silent environment is needed.

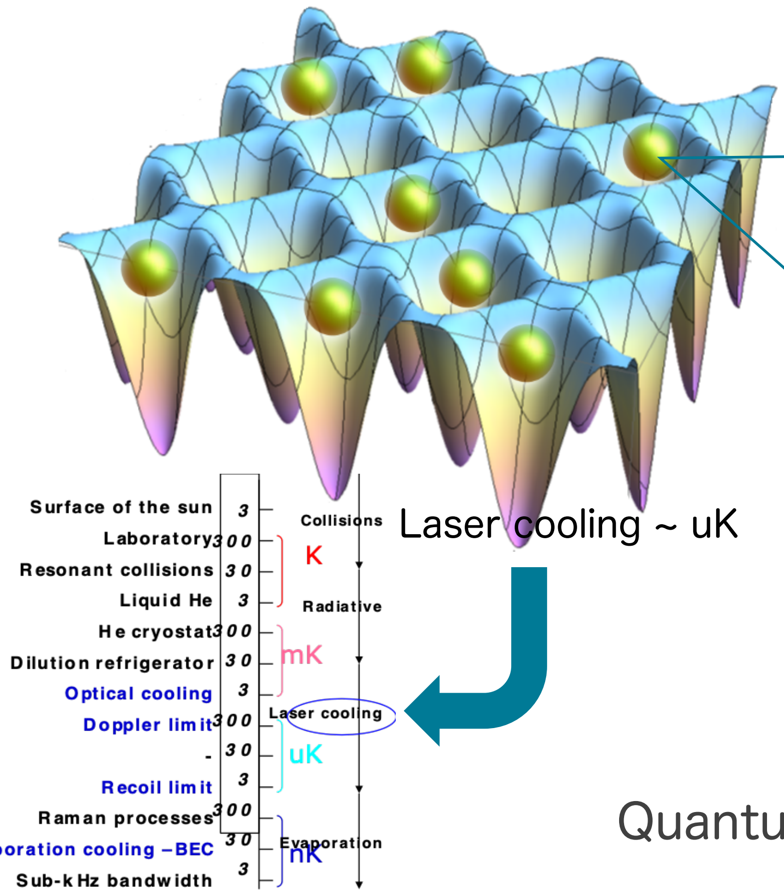
The ETH group built the active magnetic compensation coil system (black cabling) and, together with PSI, the large passively magnetically-shielded room (white cube). n2EDM will improve the sensitivity by more than a factor 10.

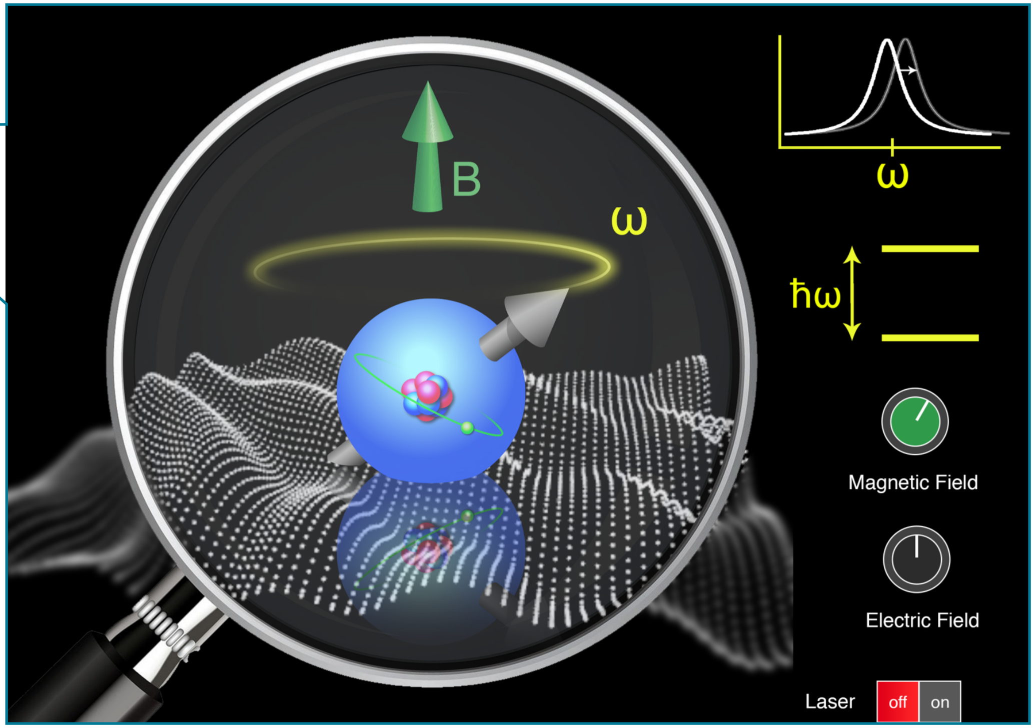


Electric Dipole Moment (EDM) Search

EDM of Electron (Sakemi)

- EDM of the electron ~ understand the fundamental symmetry (CP violation)
- Electron EDM ~ enhanced with the heavy element (Francium ~ × 800) by relativistic effect
- Artificial crystal of the Fr (Optical lattice) = Quantum sensor to measure the EDM with 10^{-30} ecm
- Combine the accelerator (Fr production) and quantum electronics (Fr cooling) techniques





Quantum sensing with cold atoms to search for the new physics

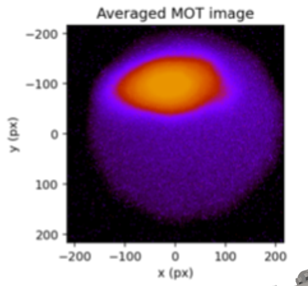
Status of the EDM project at UTokyo/RIKEN

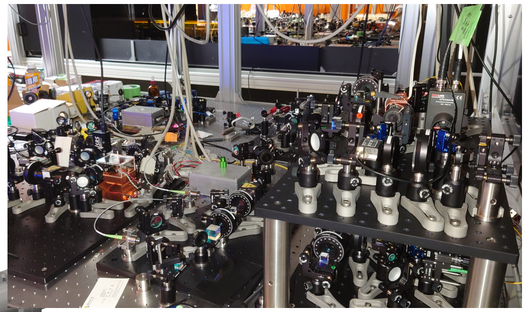
Atomic interferometer with optical lattice for the EDM with 10^{-30} ecm sensitivity

1. Required Fr yield ~ 10^7/s ~realized with new surface ionizer
2. Laser sources for the Fr trapping and co-magnetometer ~Ready
3. Final stage: Optical lattice interferometer ~ under development

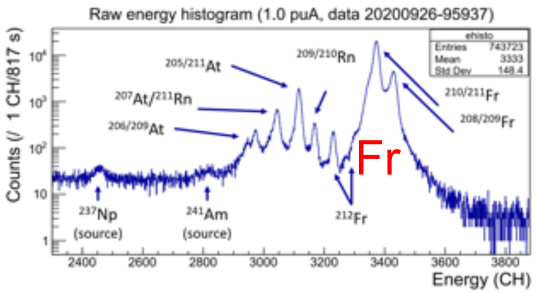
EDM measurement ~ started within 2 years

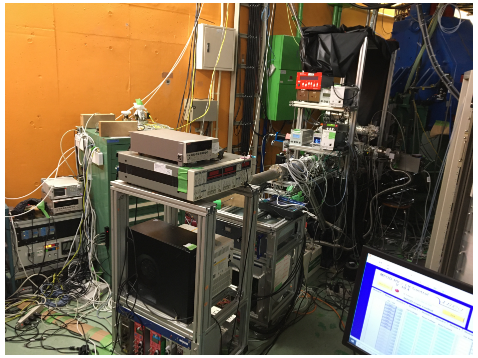
② Laser sources for Fr trap and co-magnetometer

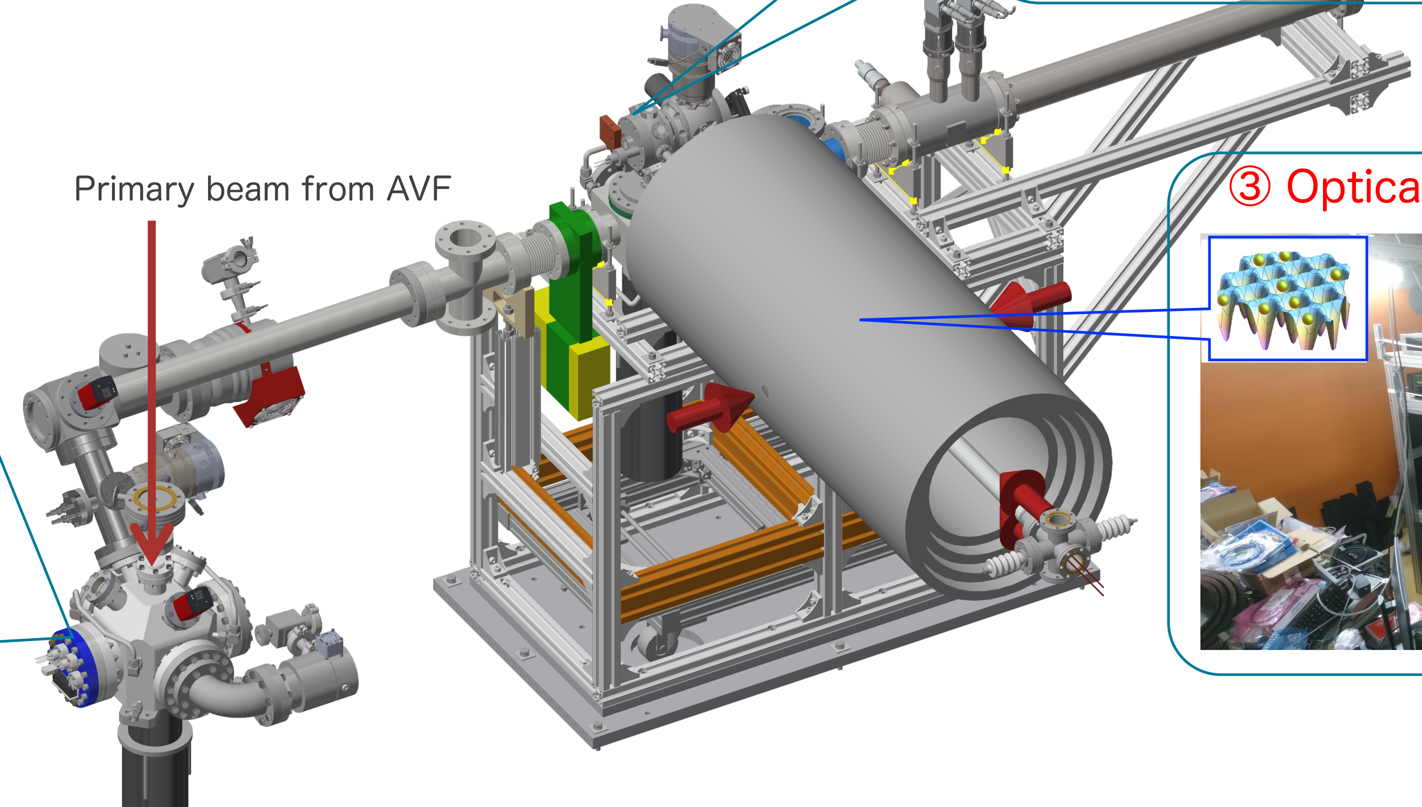




① Fr production ~ 10^7 /s



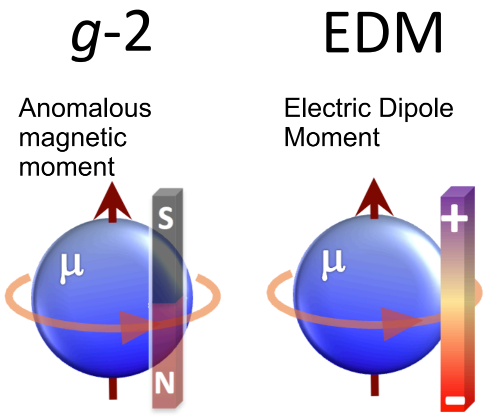


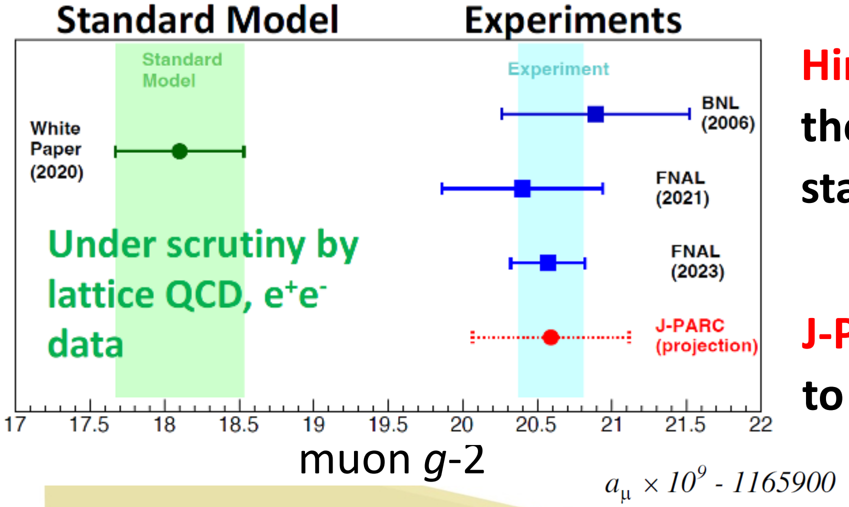


③ Optical lattice interferometer

J-PARC muon *g*-2/EDM experiment

EDM of Muon (Mibe)



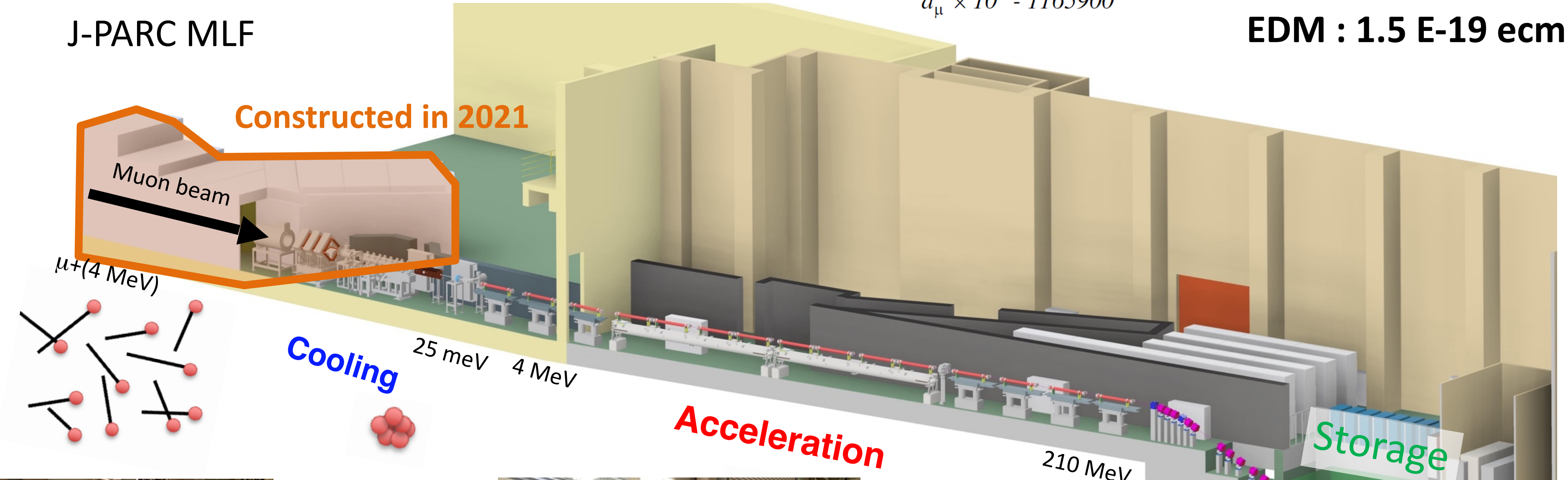


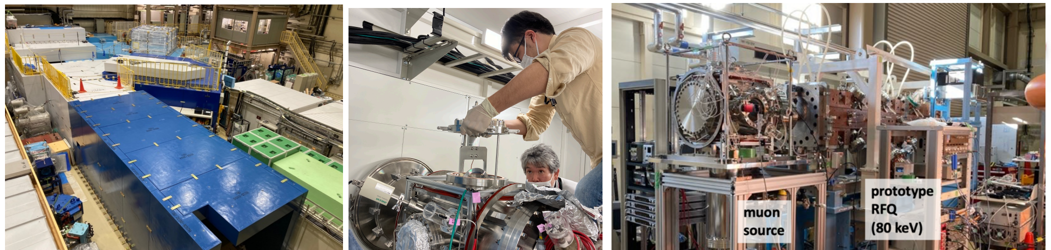
Hint of discrepancy between the experiments and the standard model.

J-PARC is the **only experiment** to check FNAL/BNL results.

***g*-2 : 450 ppb**

EDM : 1.5 E-19 ecm

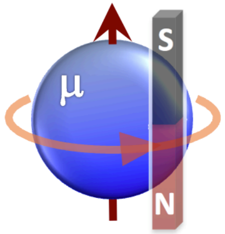


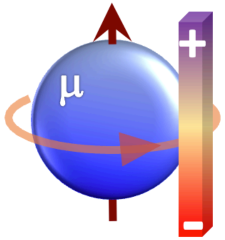


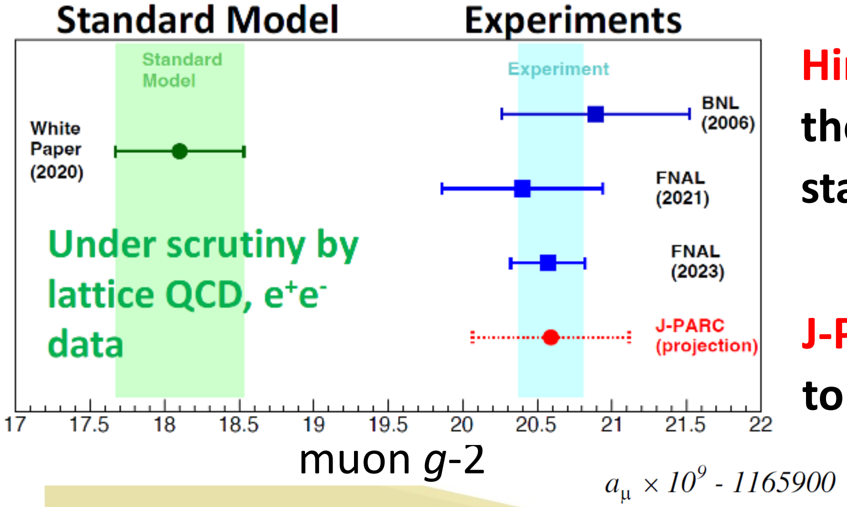
Aiming for data taking from 2028

J-PARC muon *g*-2/EDM experiment

EDM of Muon (Mibe)







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***g*-2 : 450 ppb**

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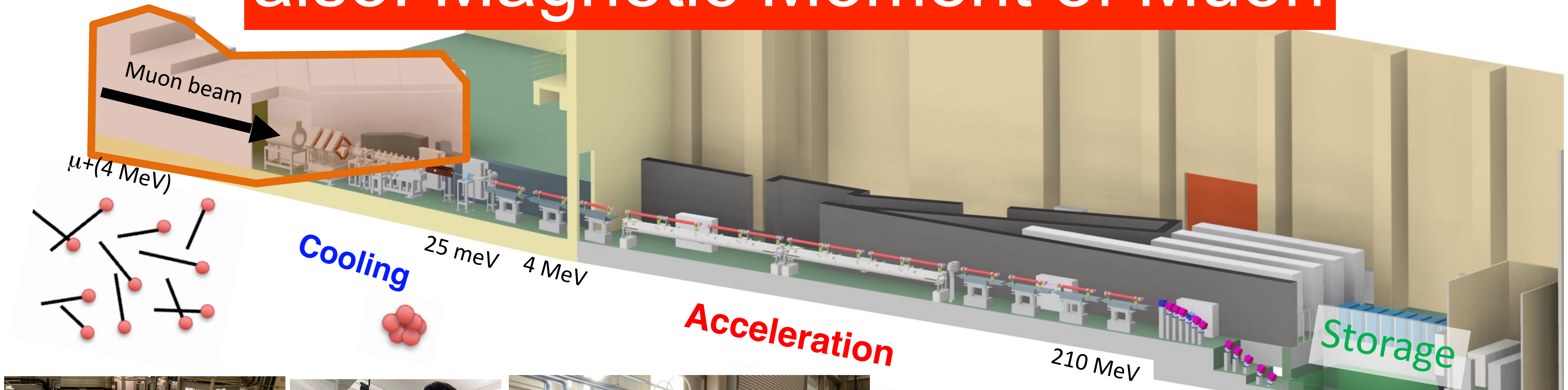
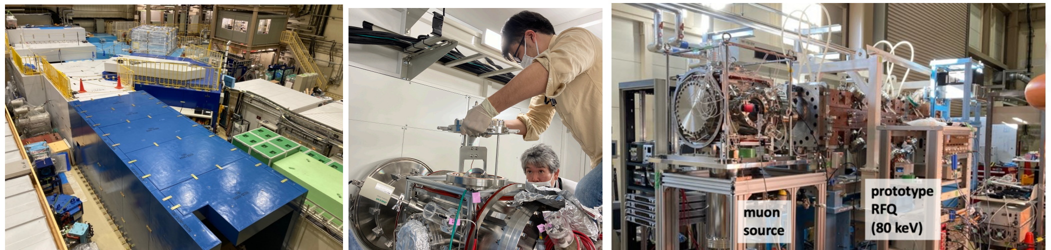
J-PARC MLF

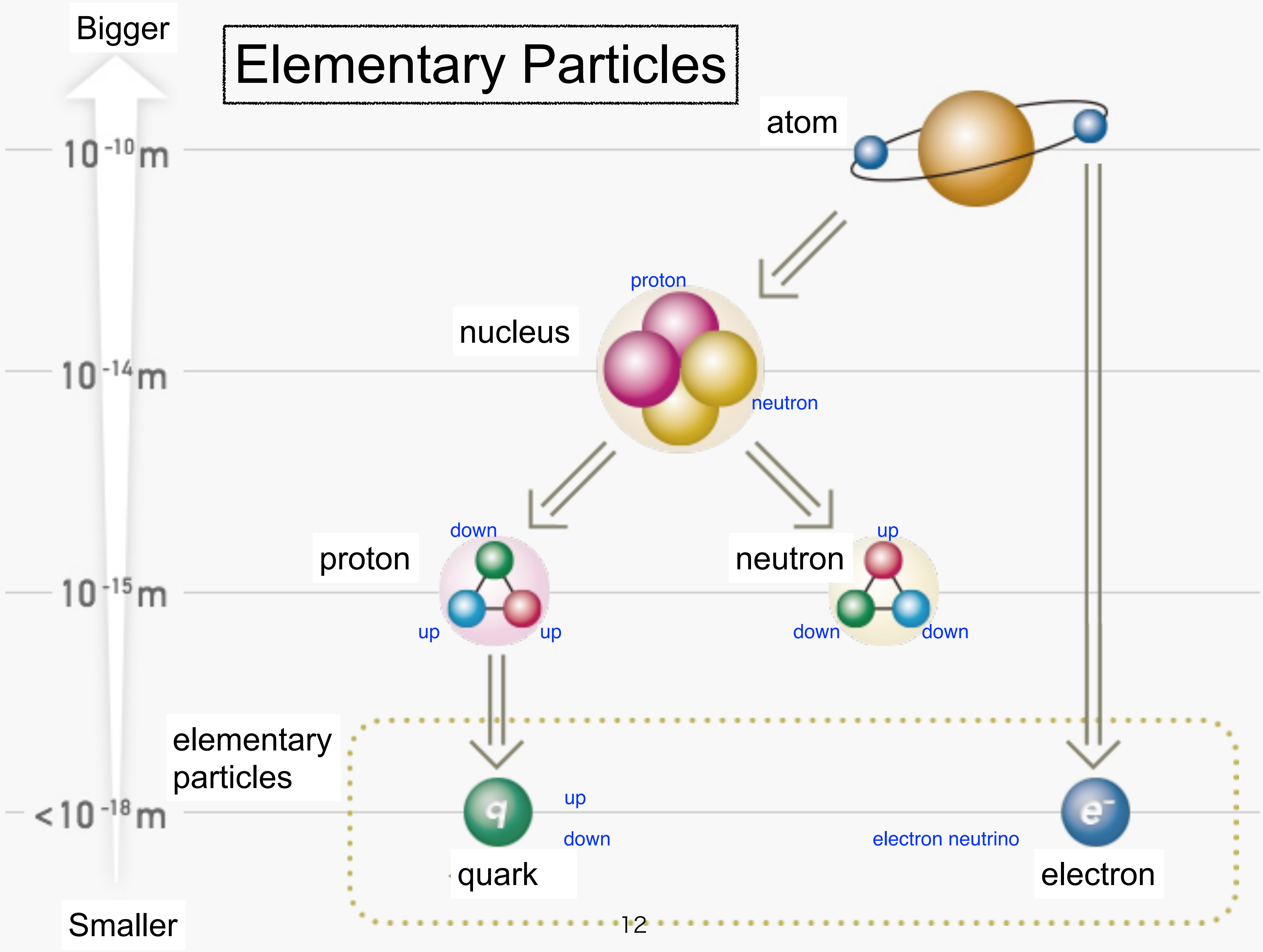
also: Magnetic Moment of Muon

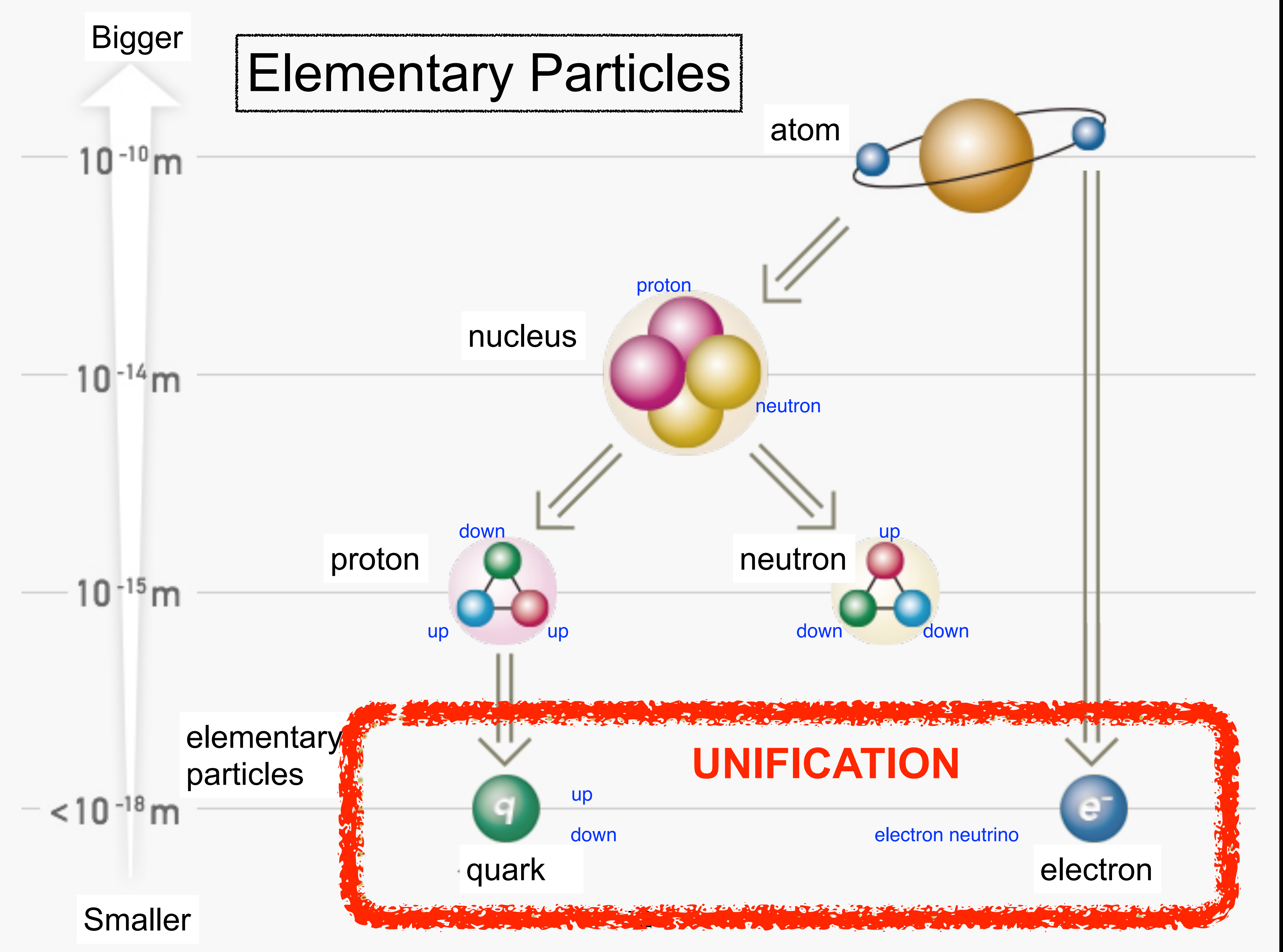




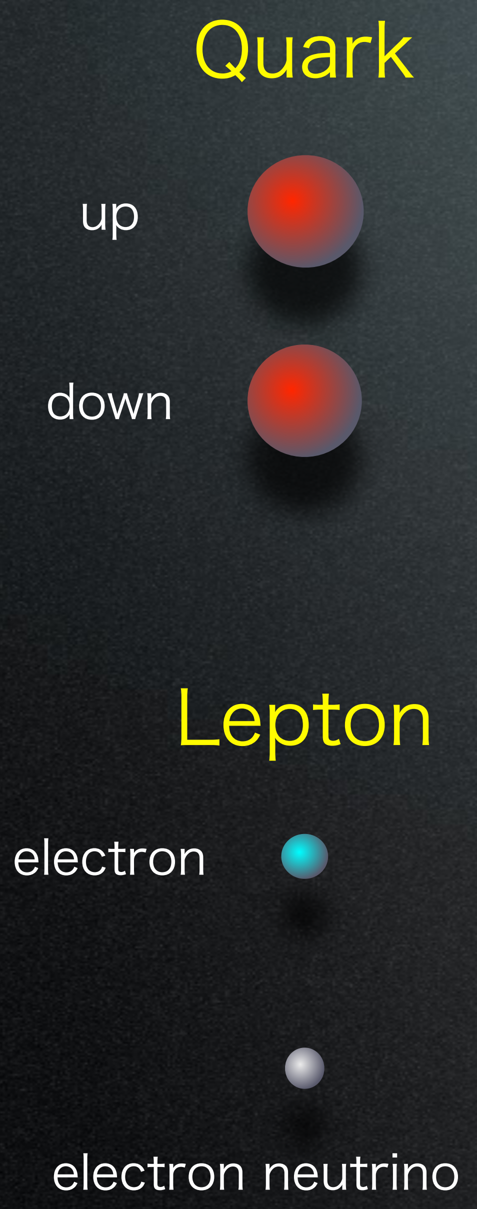
Aiming for data taking from 2028

Elementary Particles




Bigger
Elementary Particles
atom
10^{-10}m
proton
nucleus
10^{-14}m
neutron
down
proton
up
neutron
10^{-15}m
up
up
down
down
elementary particles
UNIFICATION
$<10^{-18}$m
up
down
electron neutrino
quark
electron
Smaller

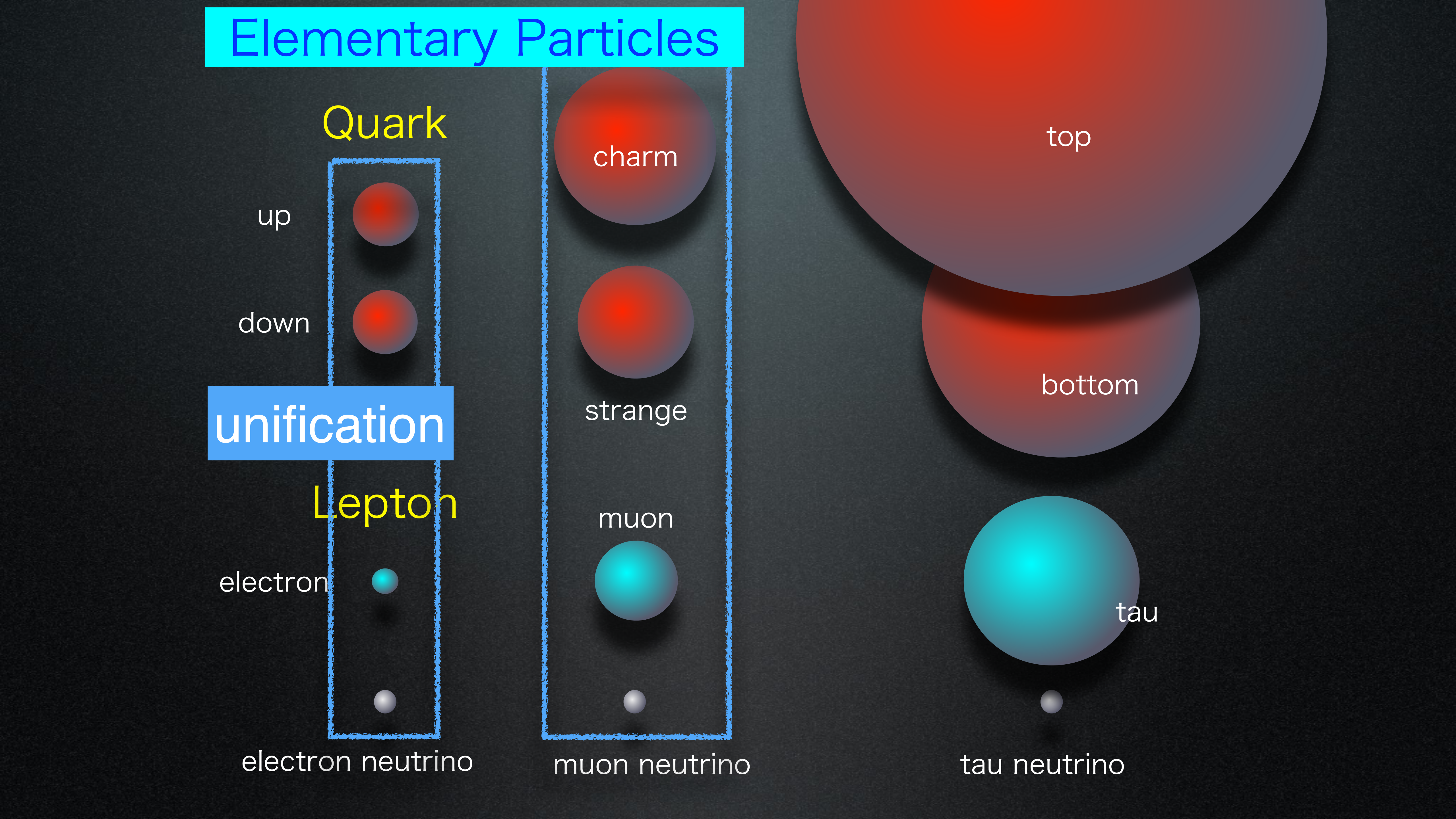
Elementary Particles

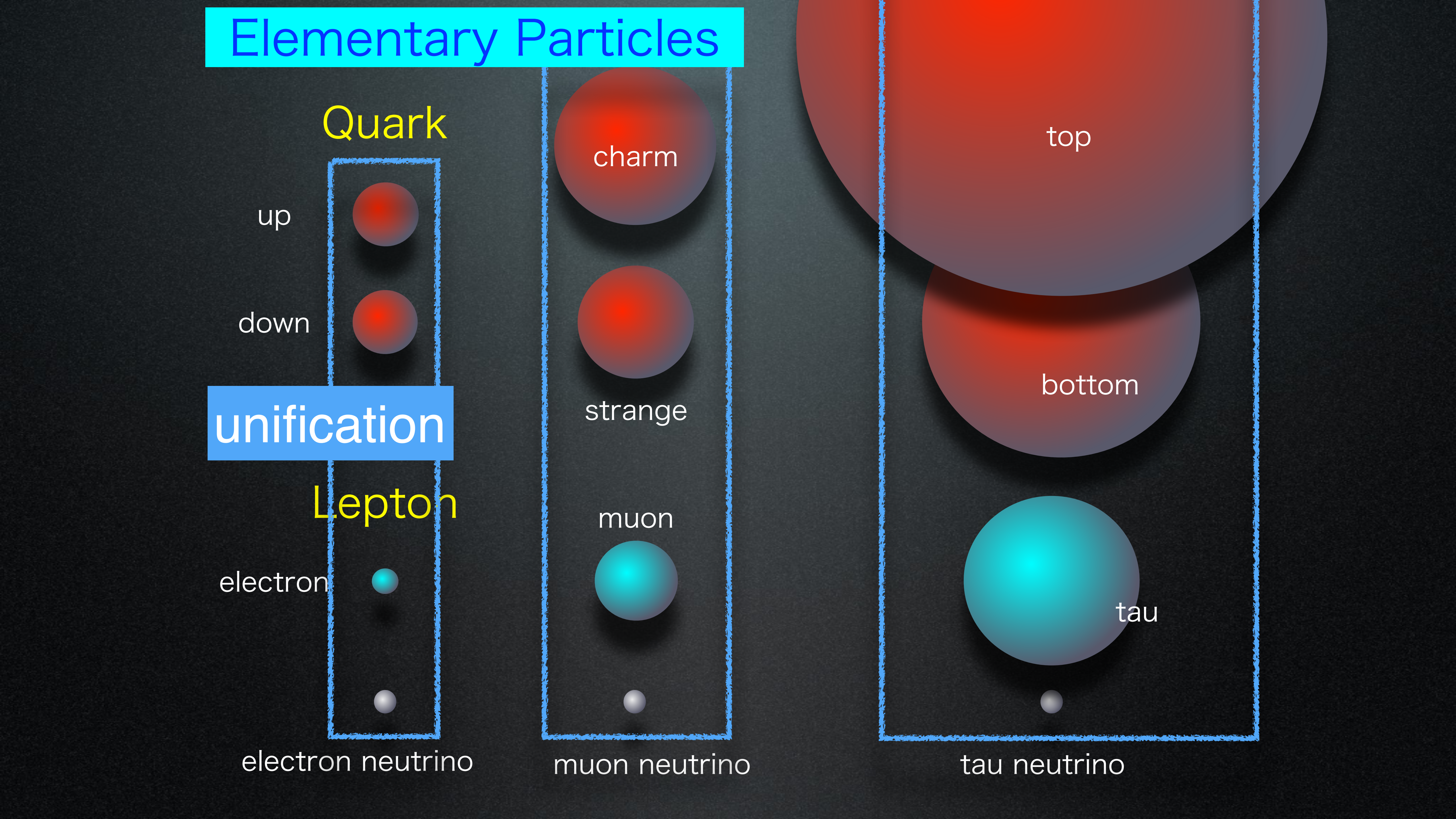


Elementary Particles

Elementary Particles

Elementary Particles


Elementary Particles
Quark
up
down
charm
strange
top
bottom
unification
Lepton
electron
muon
tau
electron neutrino
muon neutrino
tau neutrino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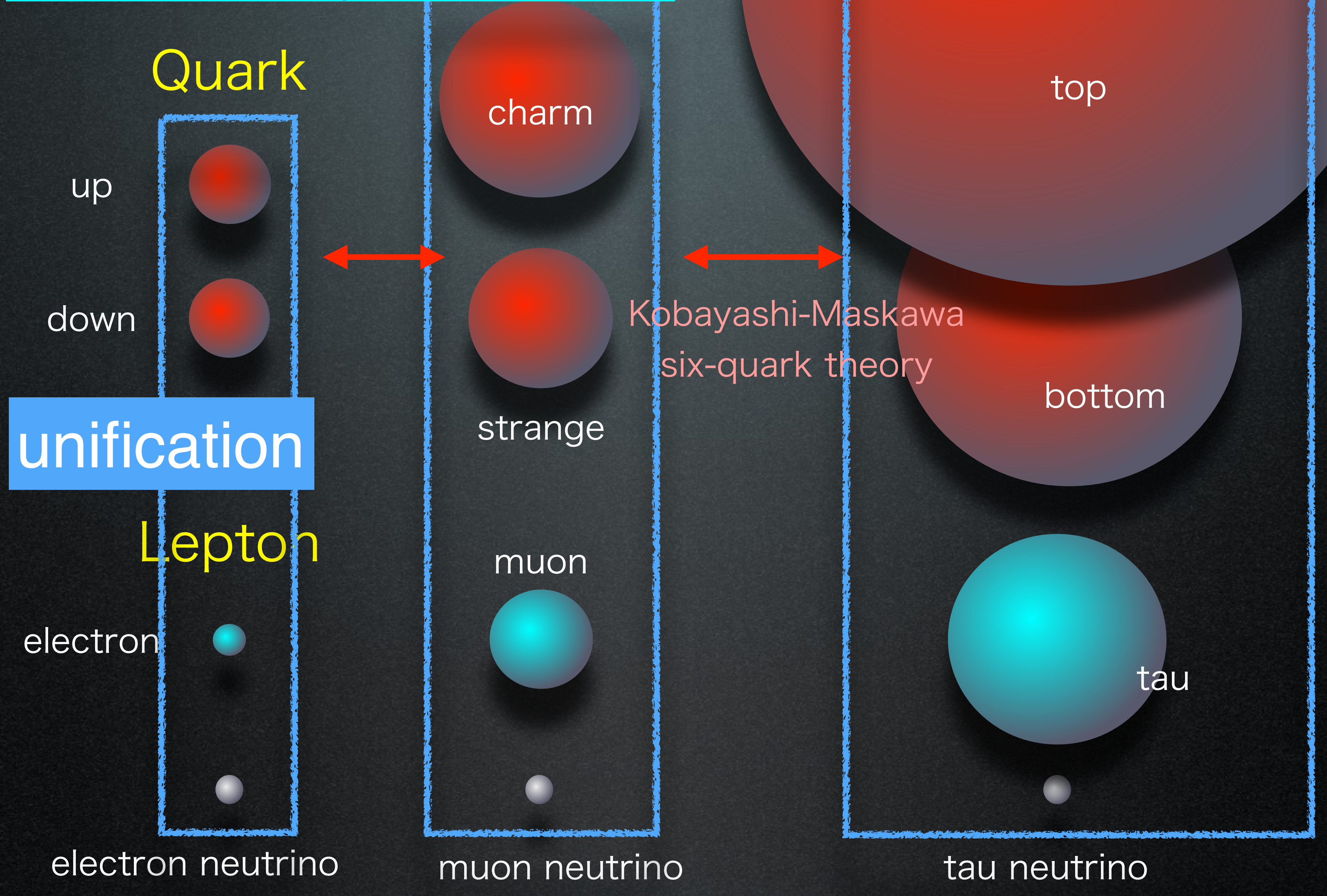
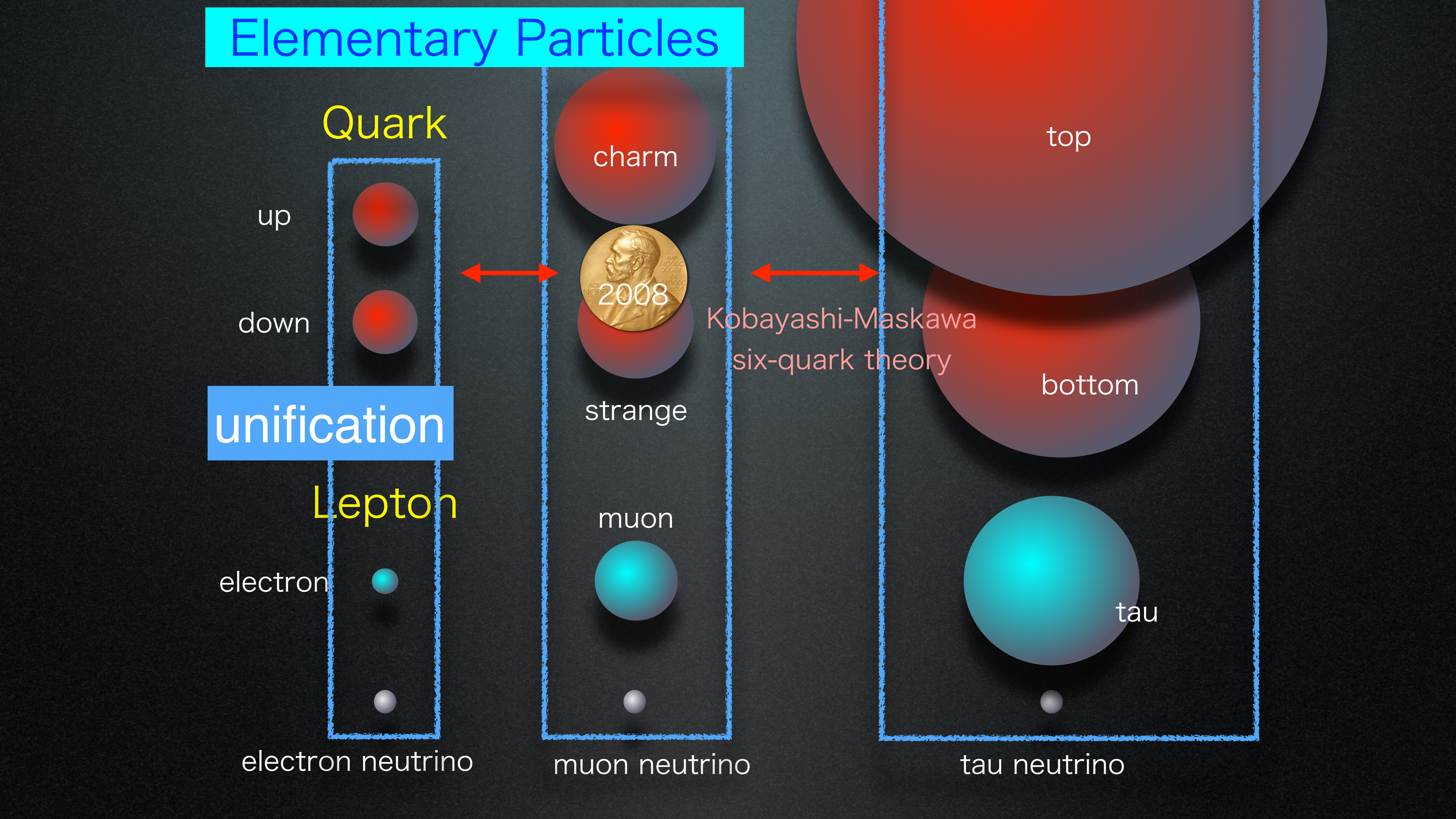
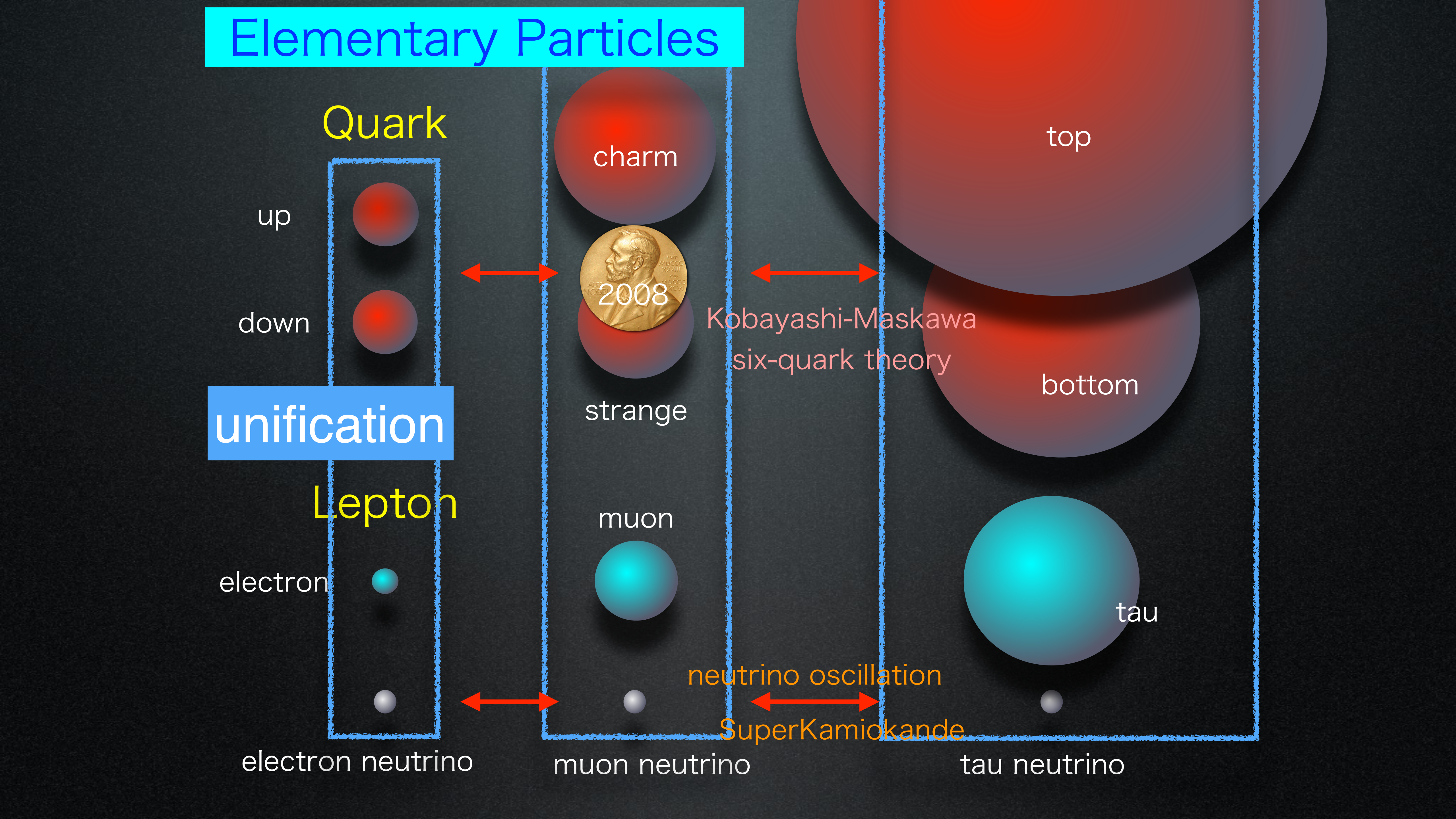
Elementary Particles




Elementary Particles
Quark
up
down
charm
2008
strange
top
bottom
Kobayashi-Maskawa
six-quark theory
unification
Lepton
electron
muon
tau
electron neutrino
muon neutrino
tau neutrino


Elementary Particles
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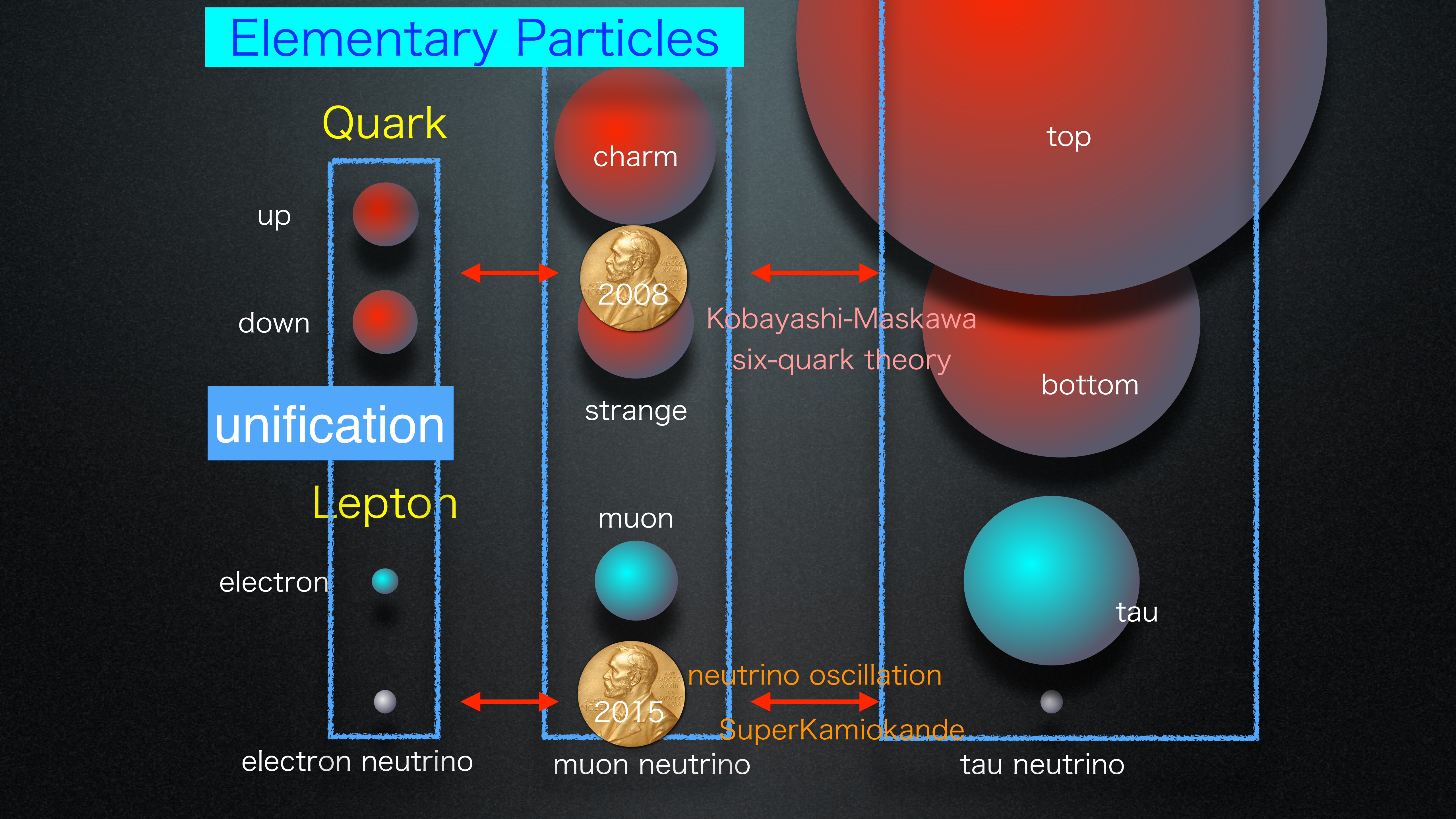
strange
top
bottom
Kobayashi-Maskawa
six-quark theory
unification
Lepton
electron
muon
tau
neutrino oscillation
SuperKamiokande
electron neutrino
muon neutrino
tau neutrino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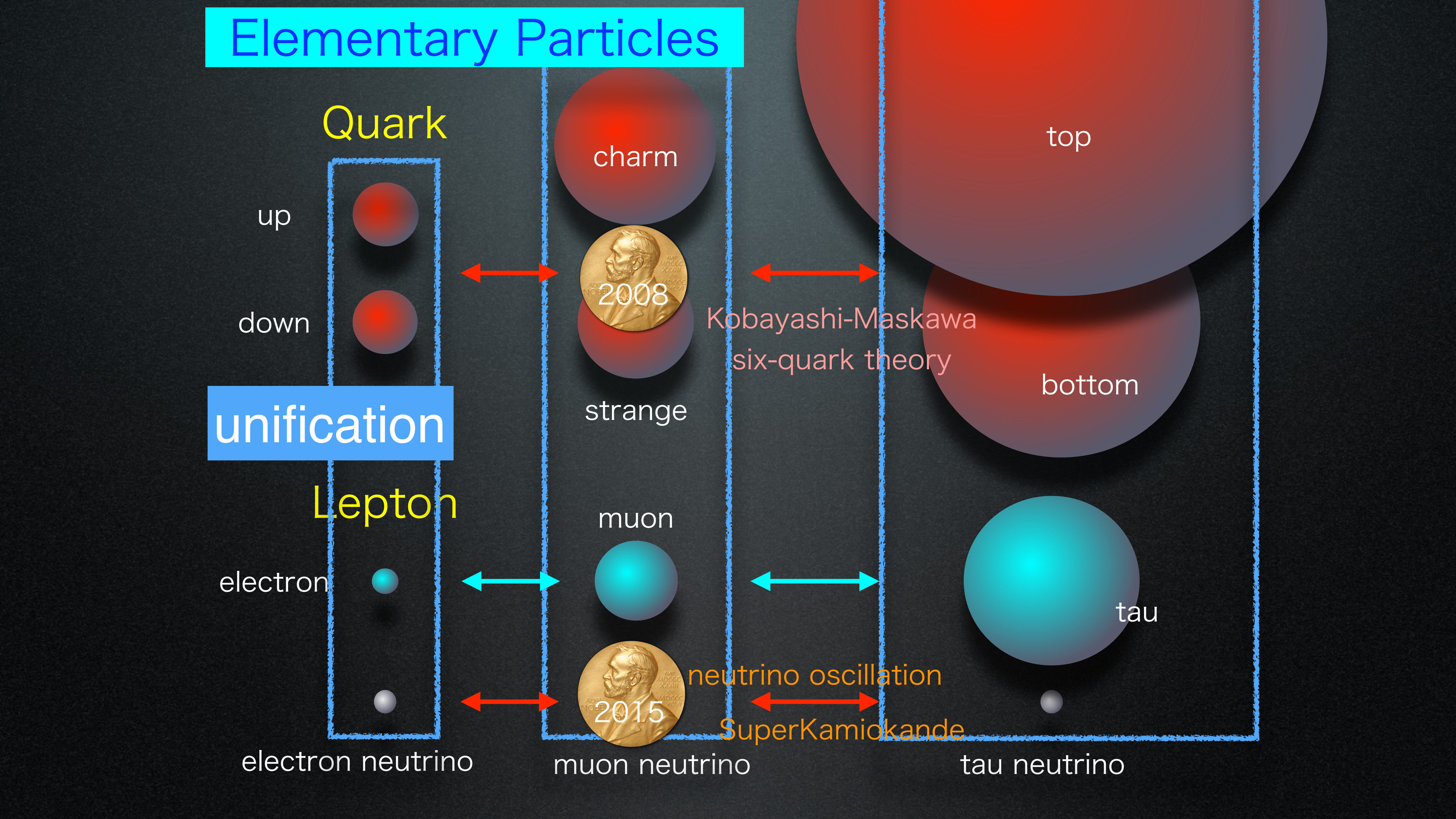
tau
2015
neutrino oscillation
SuperKamiokande
electron neutrino
muon neutrino
tau neutrino



Elementary Particles
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top
Kobayashi-Maskawa
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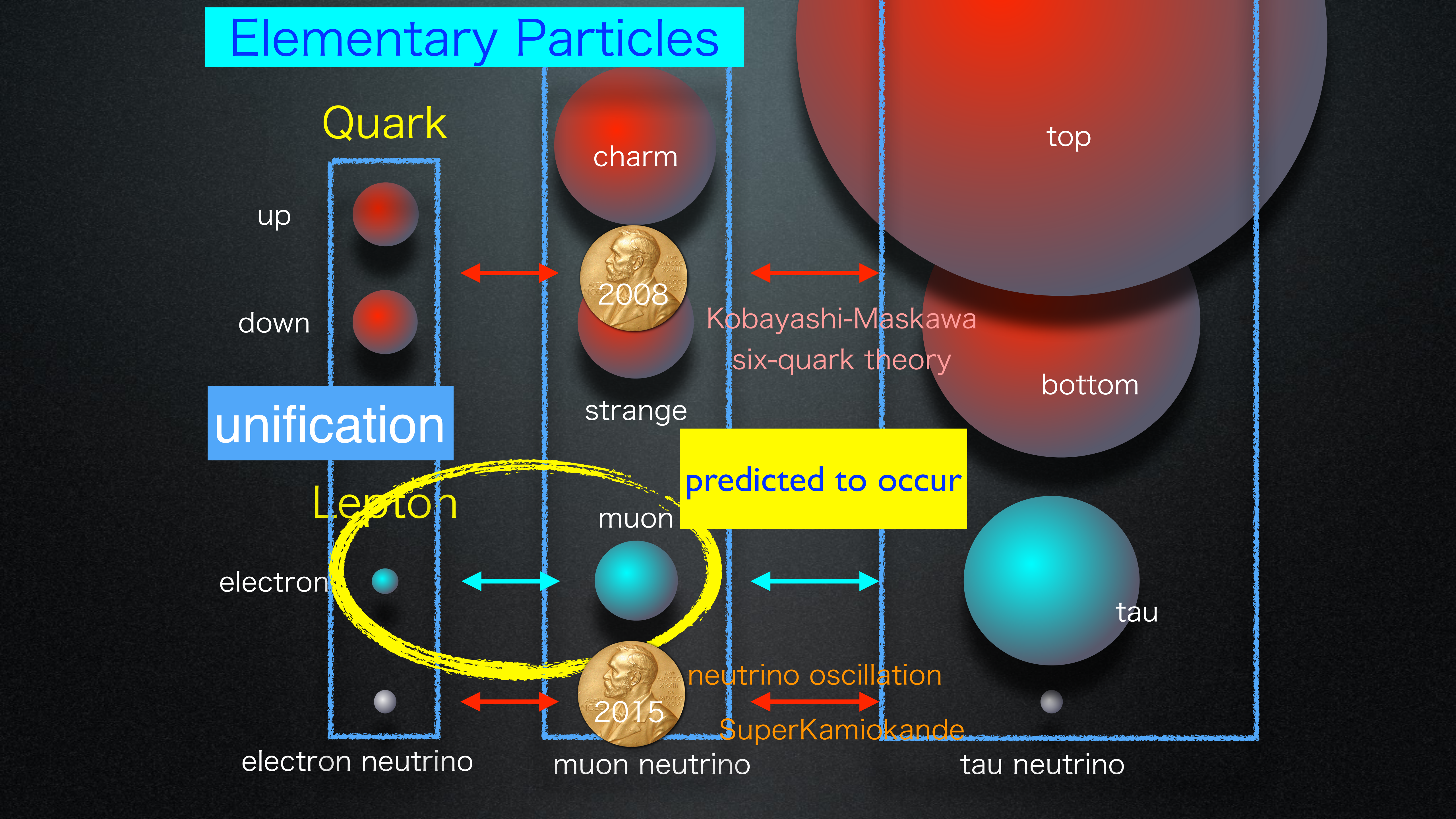

Elementary Particles
Quark
up
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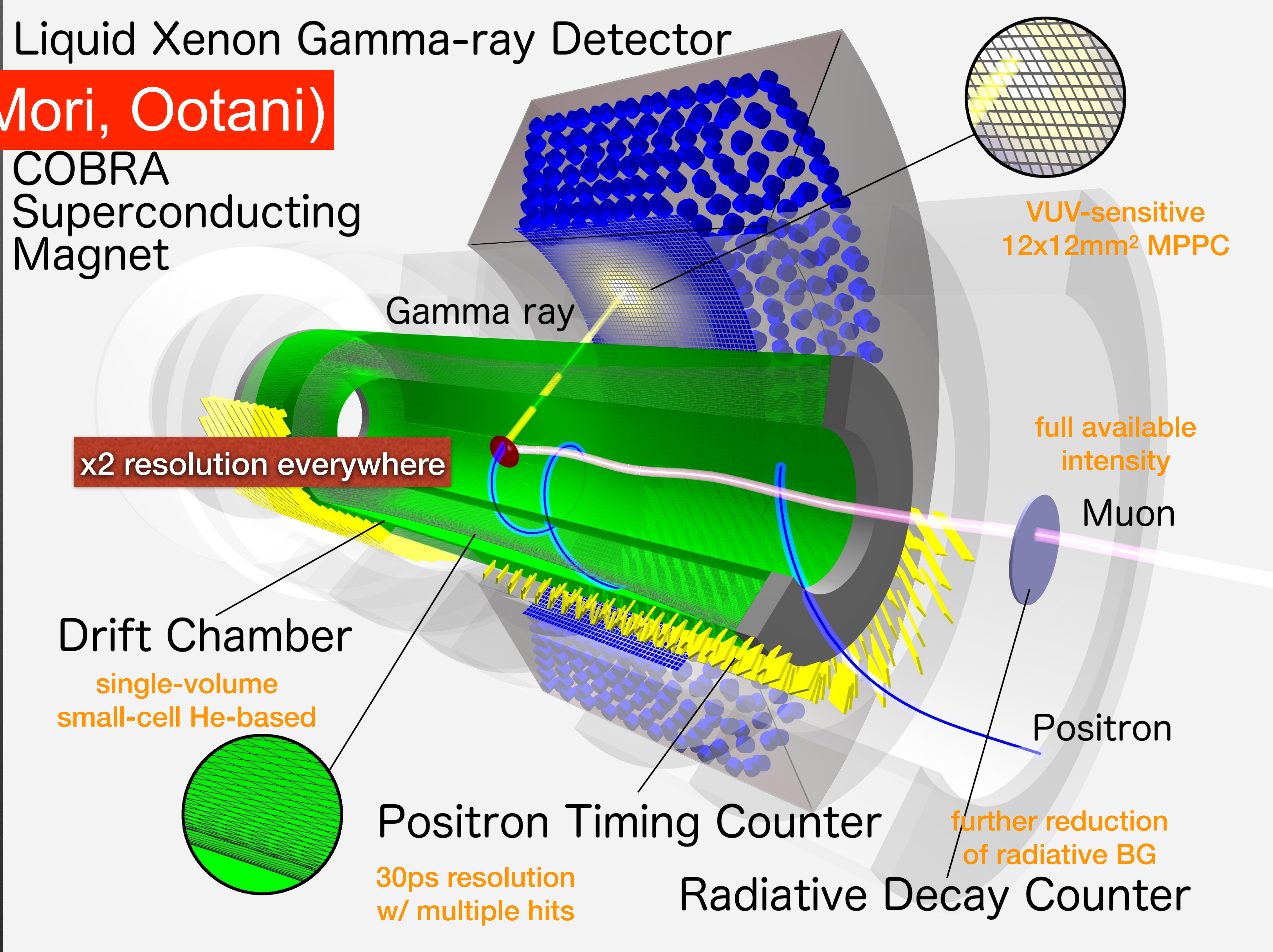
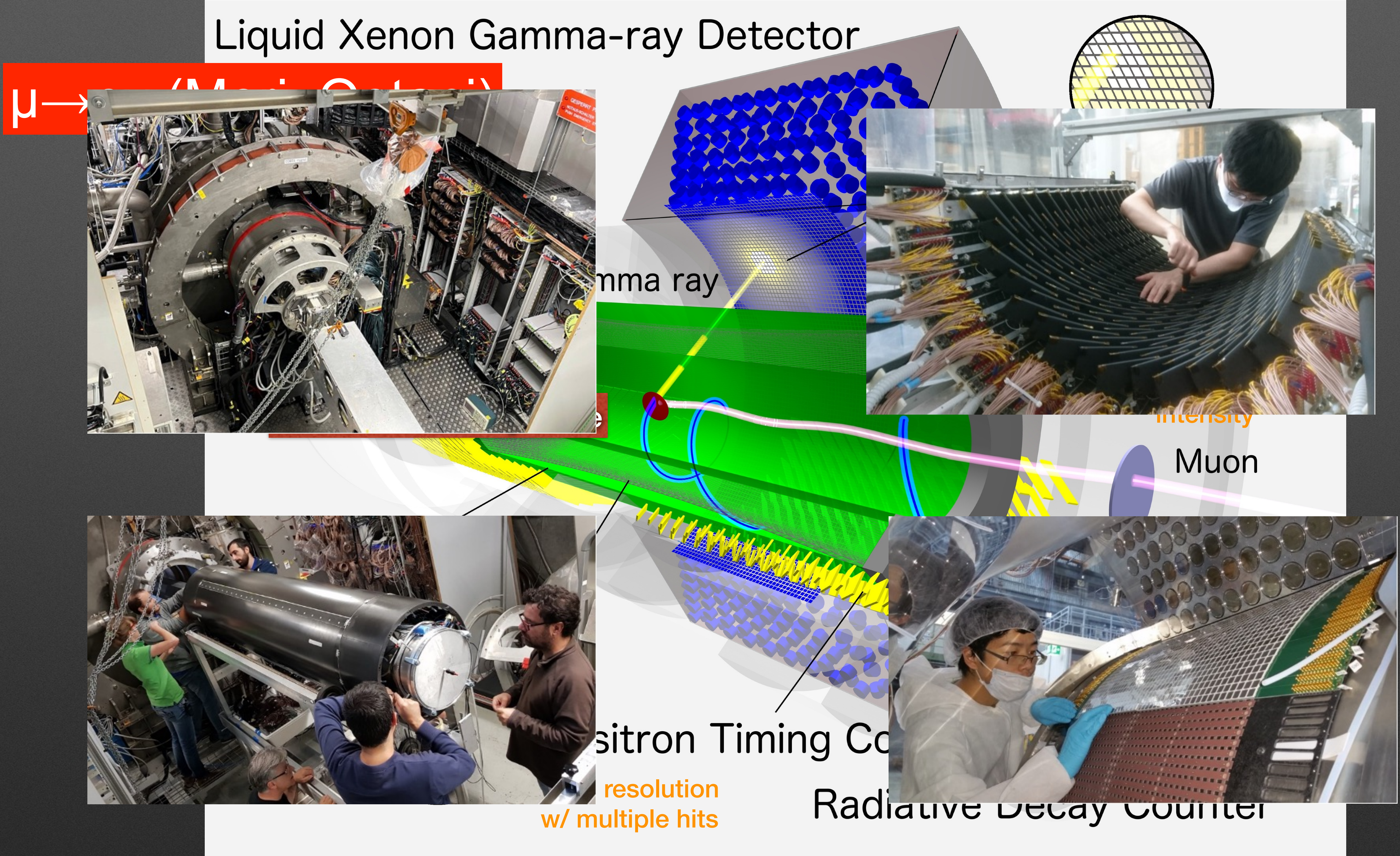
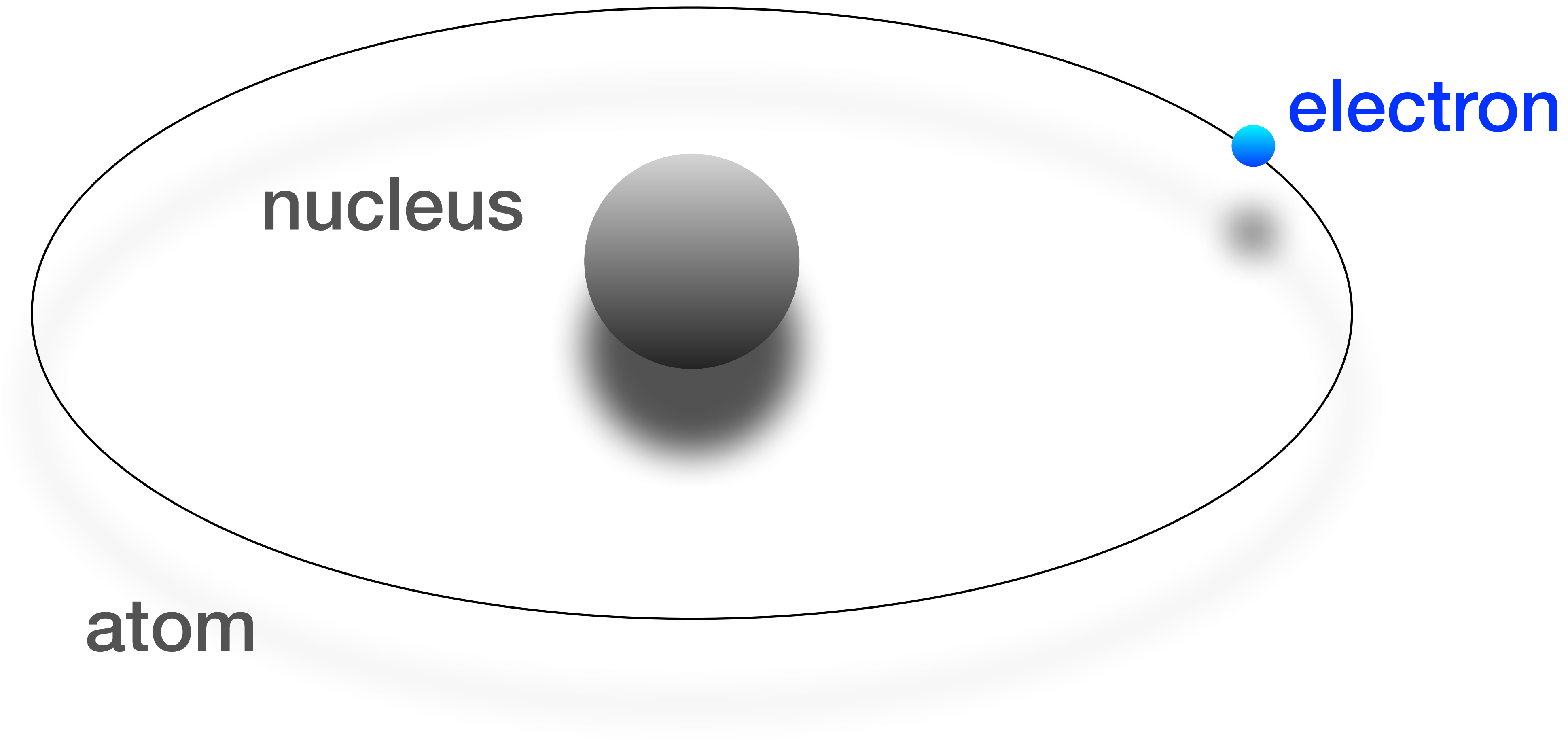
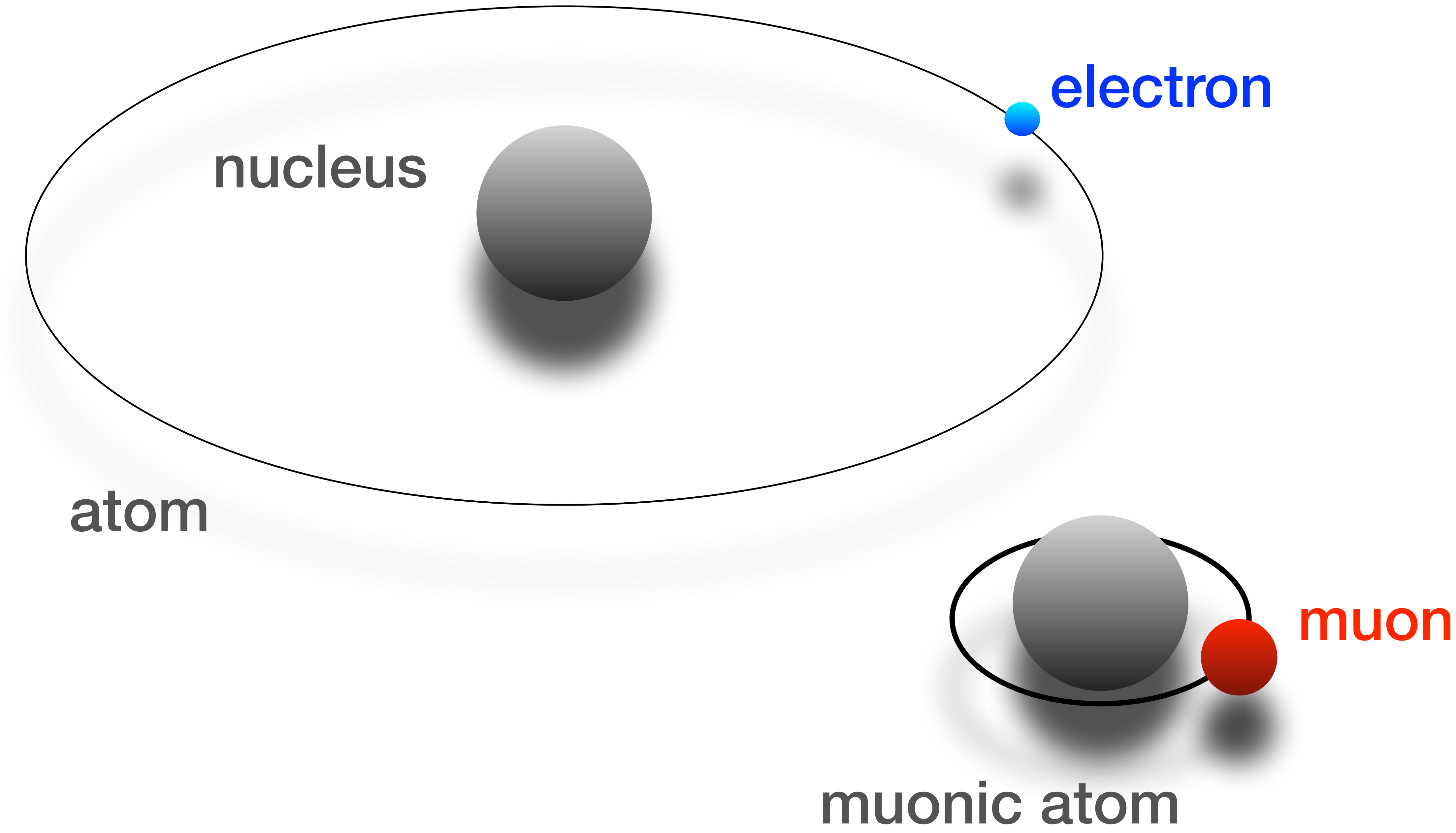
charm
2008
strange
top
bottom
Kobayashi-Maskawa
six-quark theory
unification
predicted to occur
Lepton
electron
muon
tau
2015
neutrino oscillation
SuperKamiokande
electron neutrino
muon neutrino
tau neutrino

μ→eγ (Mori, Ootani)




Liquid Xenon Gamma-ray Detector
μ→
mma ray
Muon
sitron Timing Co
resolution
w/ multiple hits
Radiative Decay Counter


electron
nucleus
atom


electron
nucleus
atom
muon
muonic atom

Kirch

To measure the charge radii of the light nuclei (p, d, ^{3}He, ^{4}He) with unprecedented precision, we pioneered laser spectroscopy of muonic atoms.

Presently, we are building a new custom laser system to measure magnetic properties of the proton using muonic hydrogen.

r_p=0.84087(39) fm

Kirch

Ootani Sakemi Mibe Mori

ETH zürich

東京大学
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PSI

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