International Review

Particle Physics and Nuclear Physics

Experimental Research Groups:

(Prof. Aihara
Vice President
Dep. direct of IPMU)

(Prof. Sakurai
Riken PI)

(Prof. Yokoyama)

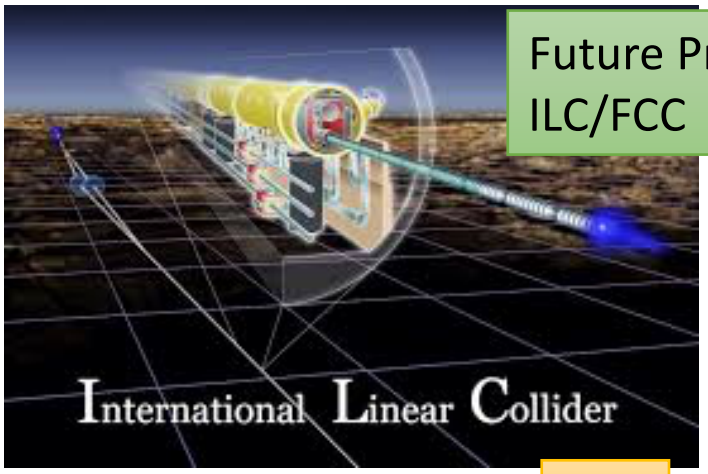
(Prof. Asai
Direct. ICEPP)

Summary of Strategy for Particle Physics

Dep. Phy. covers 2 Important Topics

Energy Frontier Collider

LHC/ATLAS
CERN



Future Project
ILC/FCC

Asai

Flavor・Neutrino

SuperK
HyperK
J-parc

Super
KEKB

Prof. Aihara + Yokoyama

We collaborate with “Powerful Centers”

Dep. Phy. covers 2 Important Topics

Energy Frontier Collider

LHC/ATLAS
CERN

東京大学
素粒子物理国際研究センター
International Center for Elementary Particle Physics
The University of Tokyo

Asai is a director of ICEPP

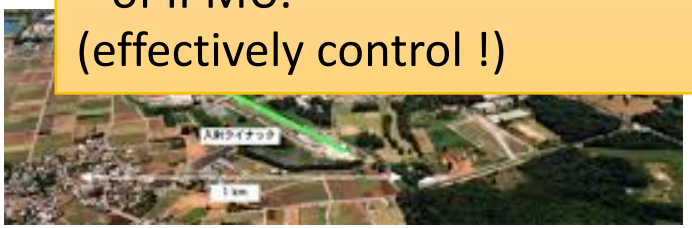
Flavor・Neutrino

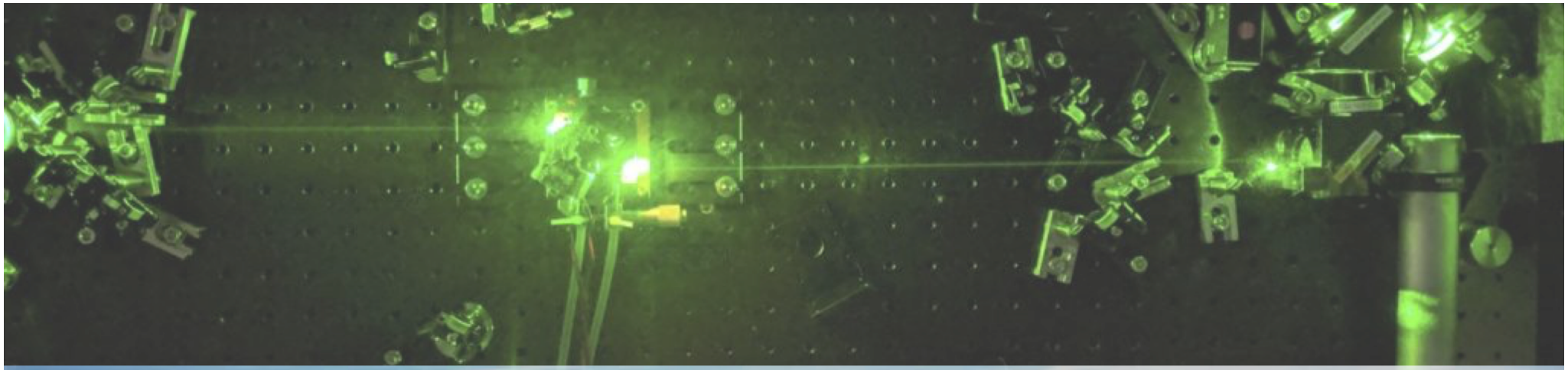
SuperK
HyperK
J-parc

KAVLI IPMU

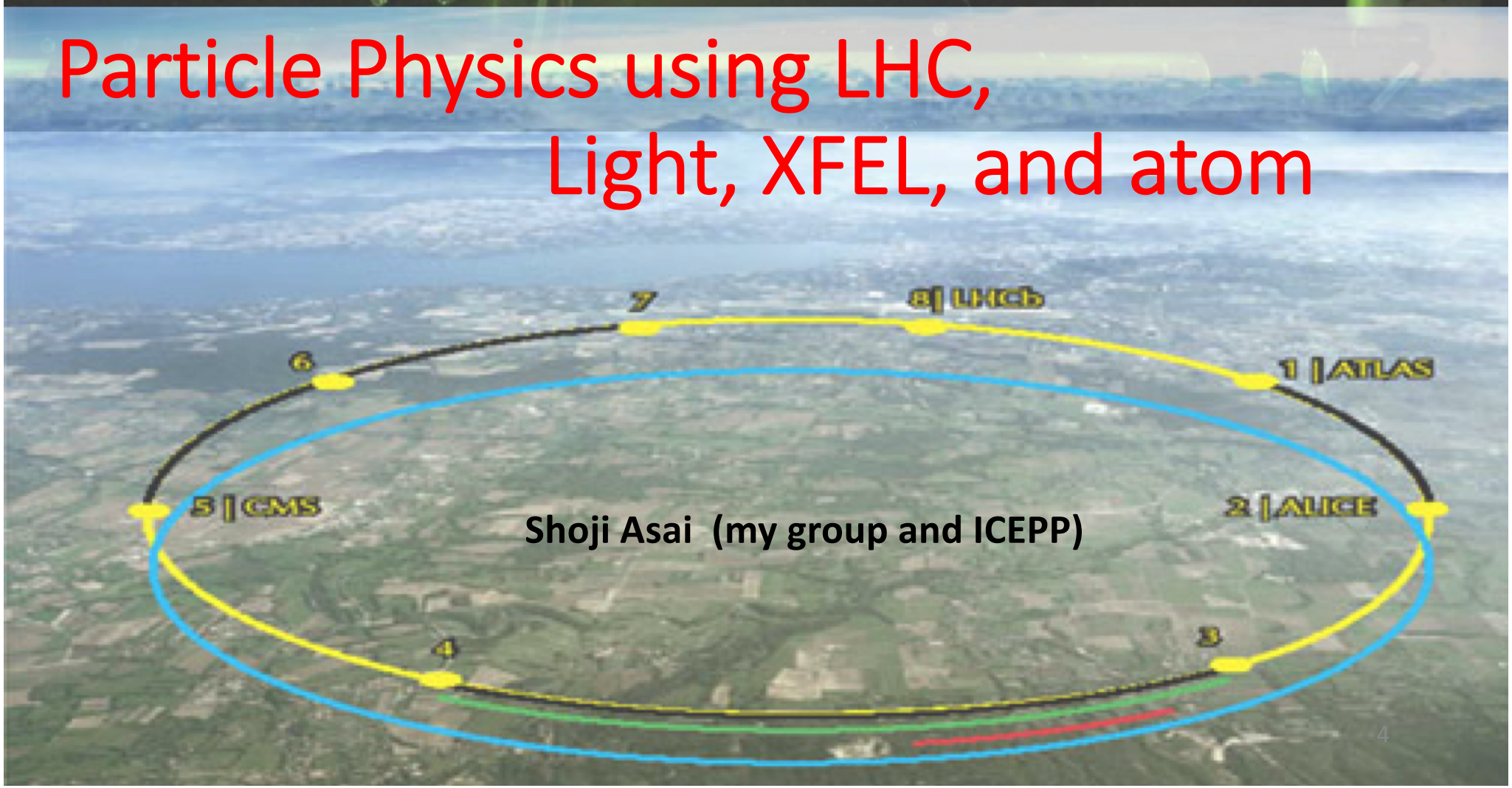
Super
KEKB

Prof. Aihara is a deputy director
of IPMU.
(effectively control !)



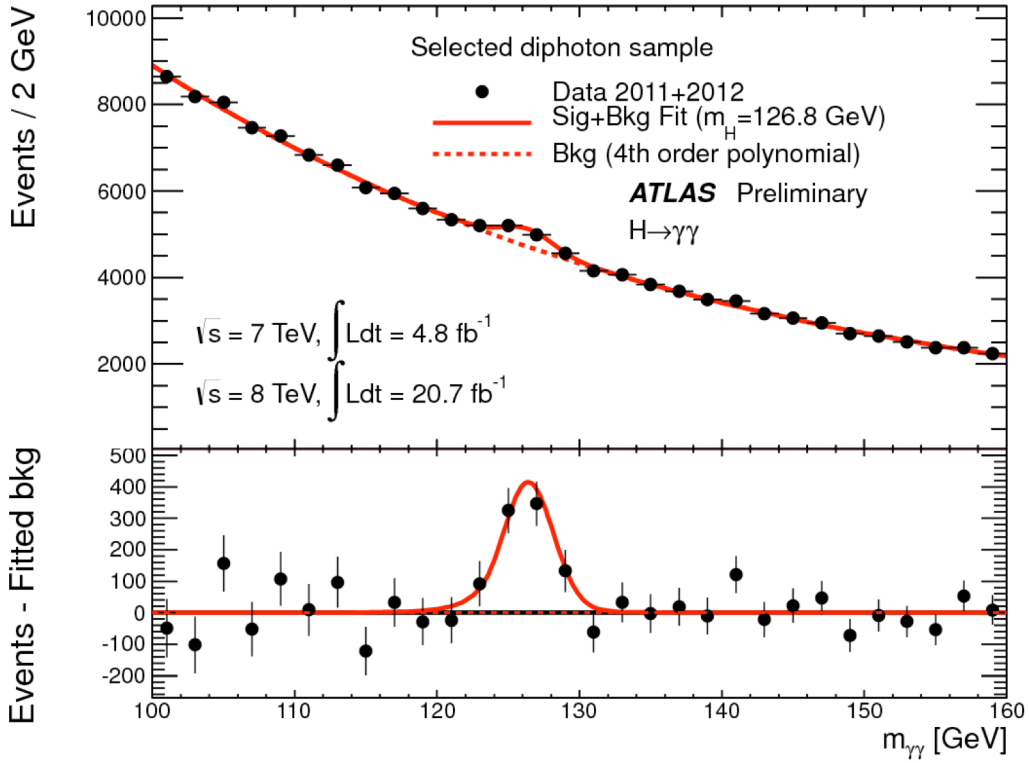


Particle Physics using LHC, Light, XFEL, and atom

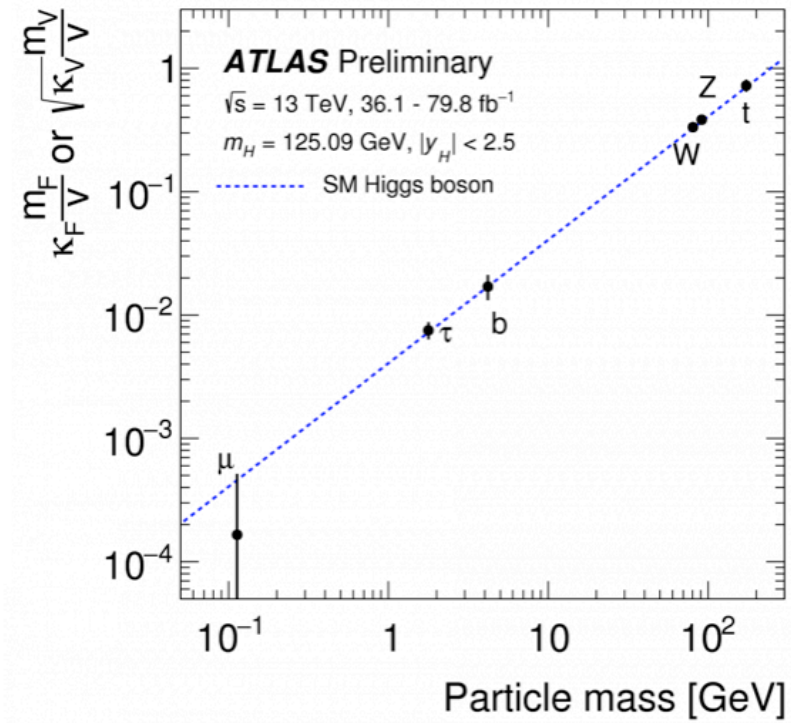


Shoji Asai (my group and ICEPP)

[1] Discovery of Higgs Boson and Study origin of mass



After discovery
Coupling constants are measured precisely.



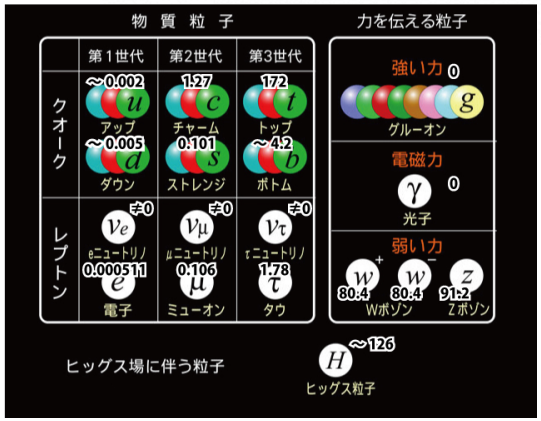
We discovered the Higgs Boson (2013)

LHC/ATLAS is big collaboration.

I concentrated all person power & CPU power of Japan into 3 discovery modes.

We plays important role on 3 discovery modes;

H->γγ, H->ττ (convener) and H->WW(subconvener).

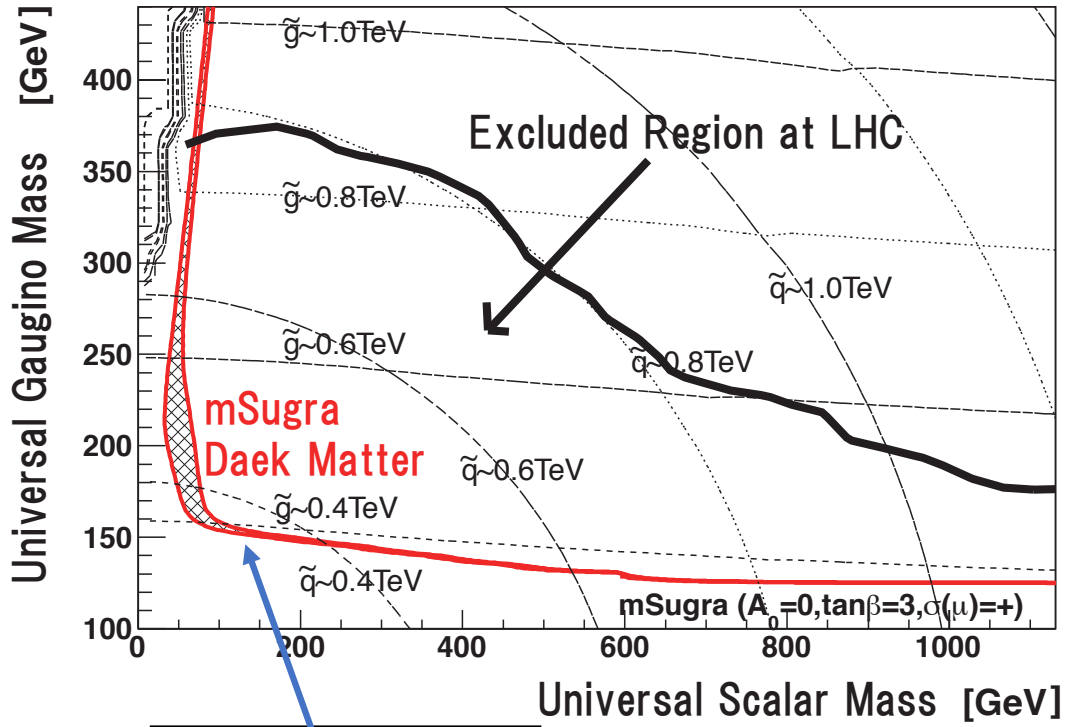


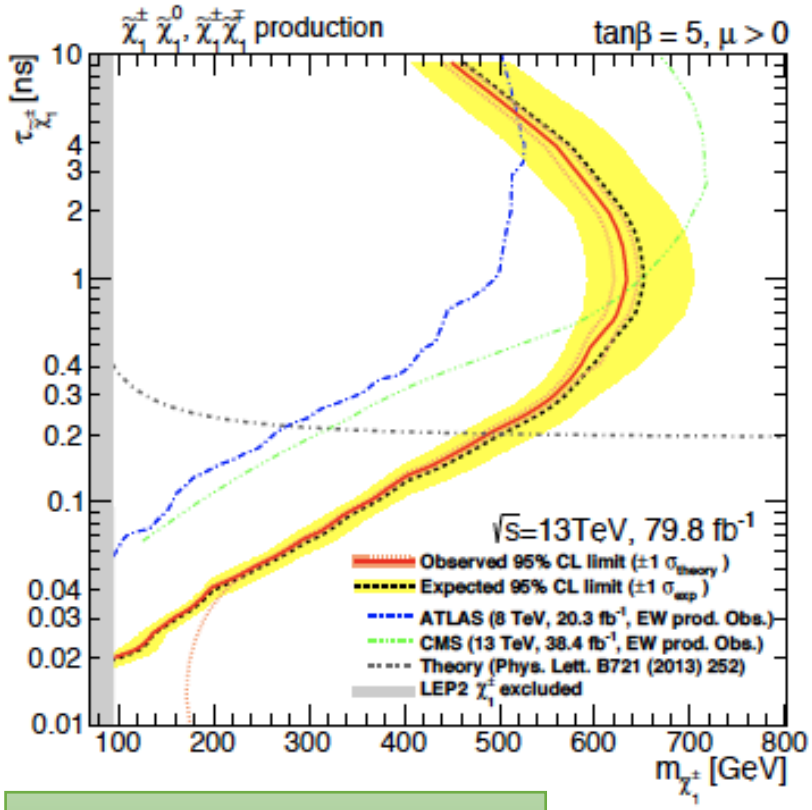
Origin of Mass
W/Z (gauge boson)
Fermion

Origin of generation
Higgs makes

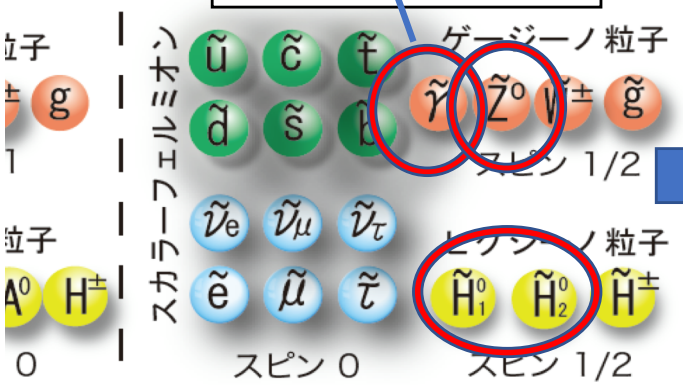
[2] SUSY Searches and new study on WIMP Dark matter

SUSY searches have been performed motivated on DM

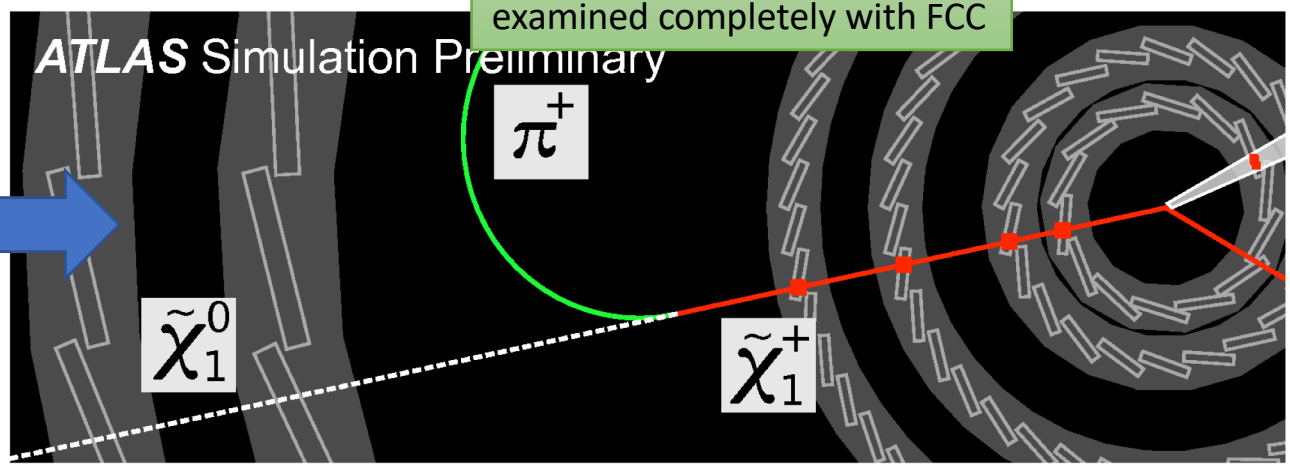




WIMP DM Cand.



WIMP scenario can be examined completely with FCC



[3] Tabletop experiments using light, XFEL, and atom

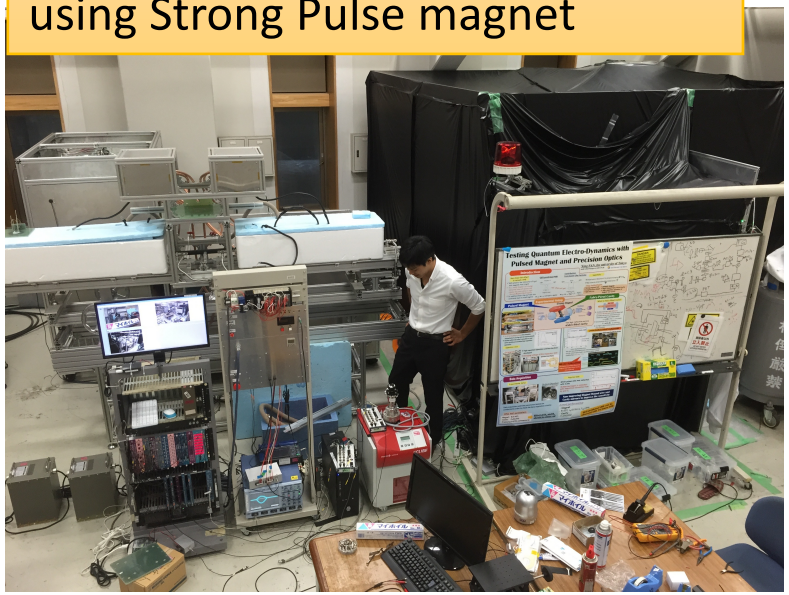
Divergence Programs are also deployed
for student education.
Each student has a responsibility on each topics

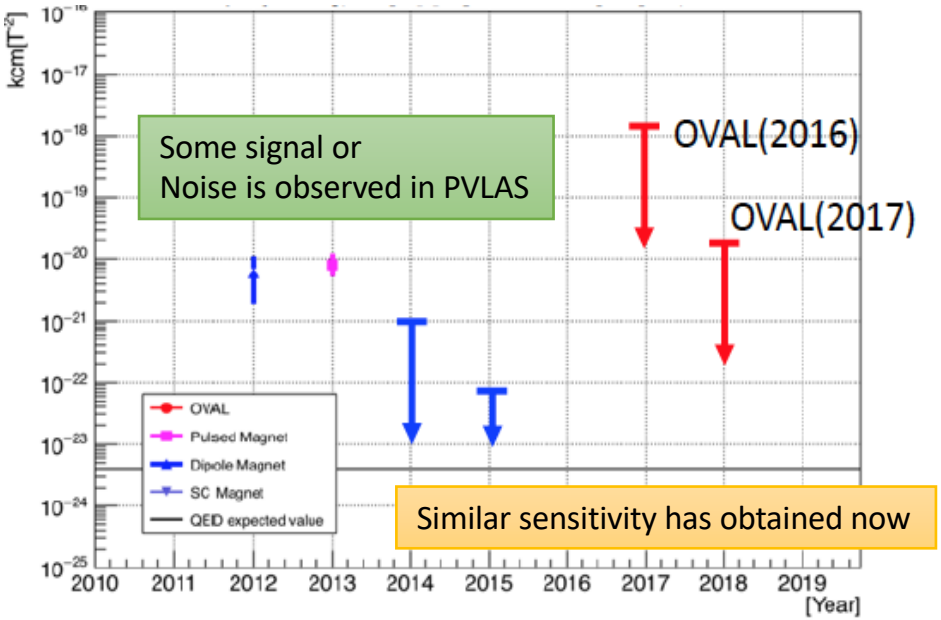
Th first search for photo-photon collision
at XFEL has been performed.
Now collide XFEL with 500TW high power laser

BEC of positronium, Axion searches ….

Many student awards are obtained as listed;

Search for Vacuum Birefringence
using Strong Pulse magnet



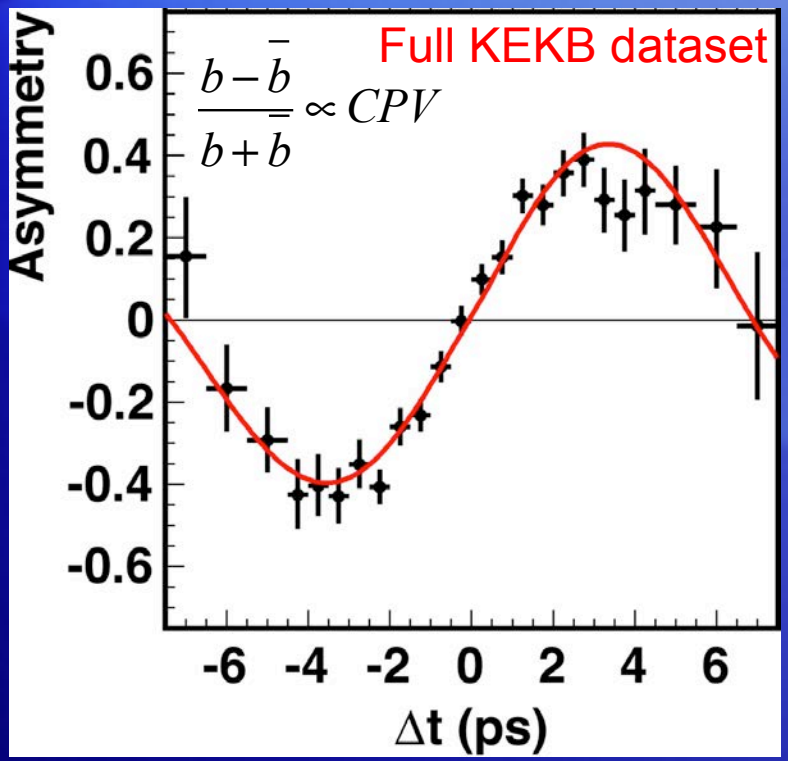


Prof. Aihara

Particle Physics

Precision *b-quark* and *tau-lepton* physics

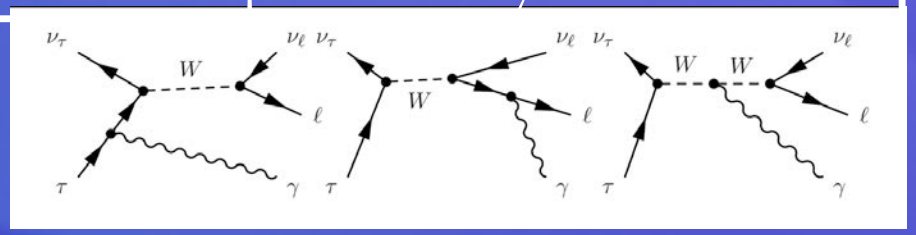
The Physics of the B Factories
Eur. Phys. J. C (2014) 74:3026



Particle-antiparticle asymmetry in weak interaction is ***predominantly*** due to Kobayashi-Maskawa mechanism (i.e. the standard model of particle physics).

Rare tau-lepton decays to probe physics beyond the standard model

PTEP2018 023C01
First measurement of novel tau weak decay parameters
using radiative leptonic decays $Br \sim 10^{-3}$

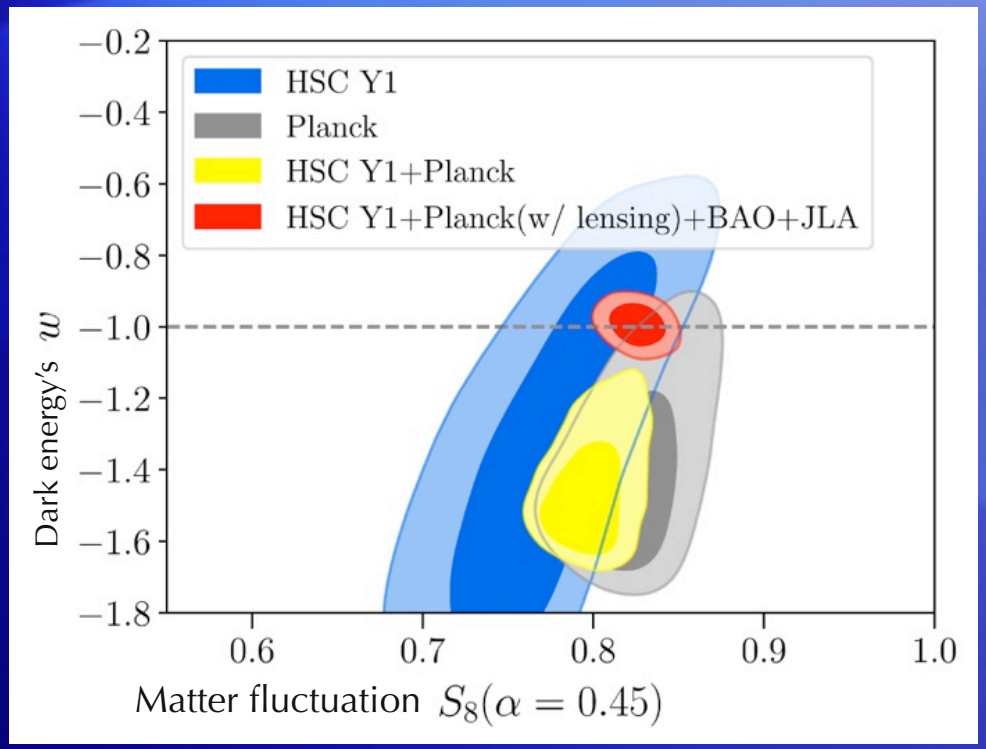


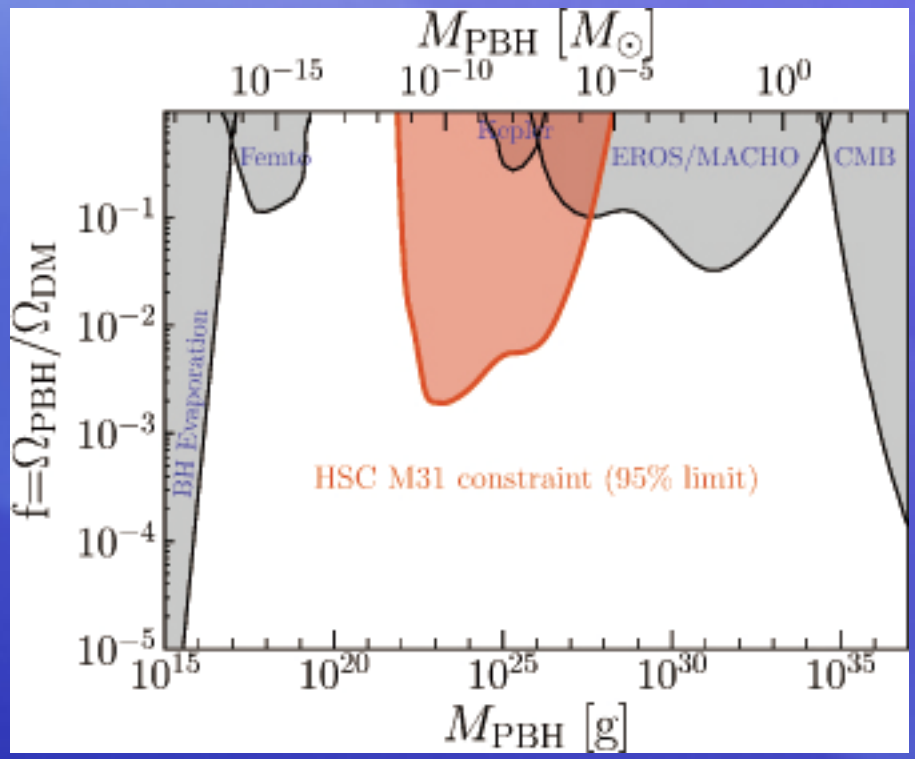
Physical Review D 100, 071101(R) 2019
First measurements of rare tau decays
τ (tau) → pion + neutrino + lepton pairs
(e^+e^- or $\mu^+\mu^-$) $Br \sim 10^{-5}$

No sign of new physics yet,
On to Super KEKB (x40 KEKB)

Precision observational cosmology

HSC (a wide-field camera on Subaru telescope) survey
with Kavli IPMU, NAOJ, Princeton et al.





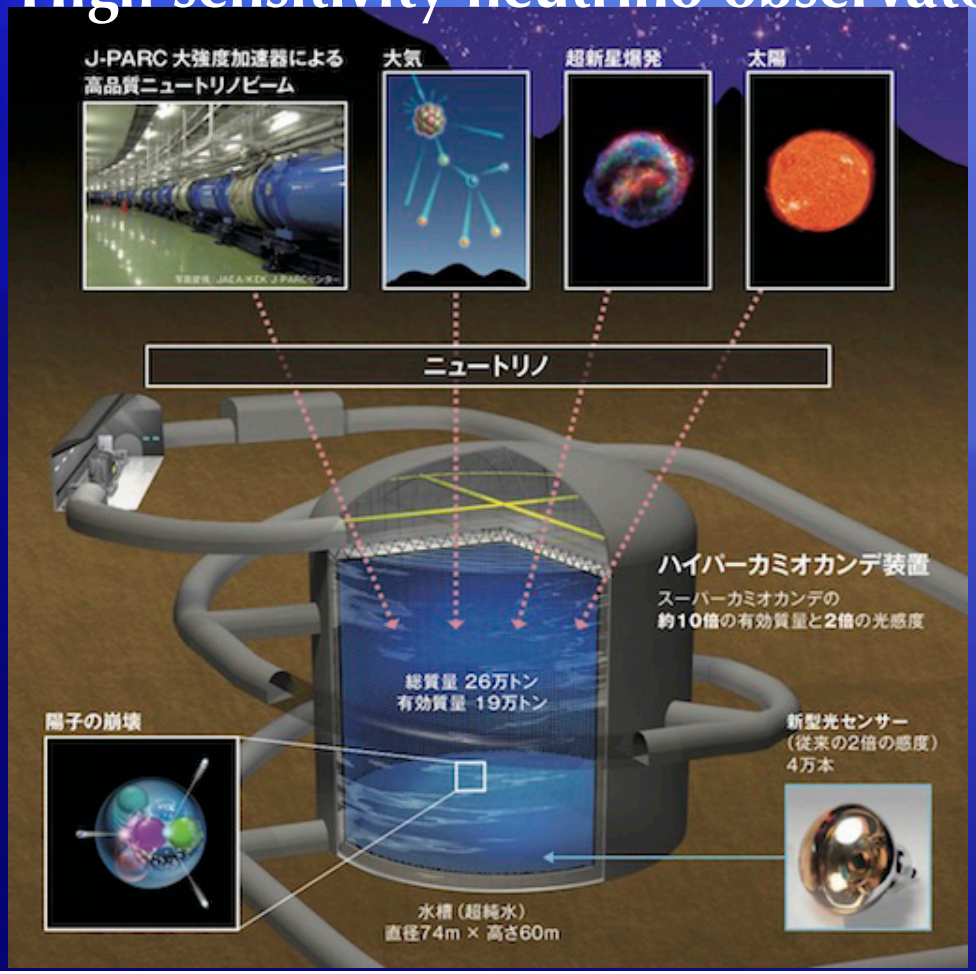
Chiaki Hikage, Masamune Oguri et al.,
"Cosmology from cosmic shear power spectra with Subaru Hyper Suprime-Cam first-year data,"
Publications of the Astronomical Society of Japan, 71, (2019) 43.

Hiroko Niikura, Masahiro Takada et al.,
"Microlensing constraints on primordial black holes with the Subaru/HSC Andromeda observation,"
Nature Astronomy 3, 524-534 (2019).

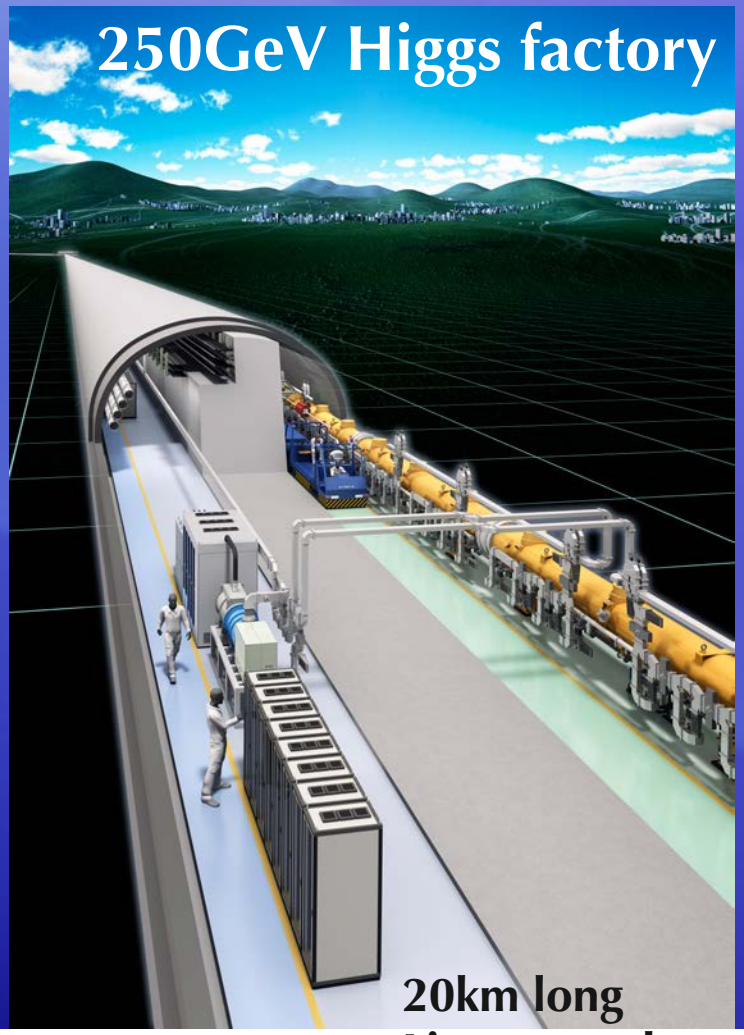
Continue to fully support Hyper-K and ILC

Precision neutrino physics and Higgs physics

High sensitivity neutrino observatory



250GeV Higgs factory



20km long
Linear accelerator

Prof. Yokoyama

Particle Physics

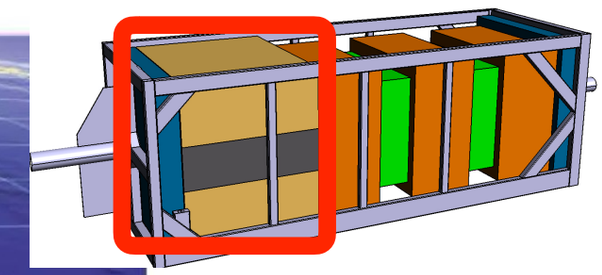
Research Highlight: Masashi Yokoyama

Particle physics experiments using Super-(/Hyper-)KamiokaNDE and the J-PARC accelerator

Search for proton decay

Leading new projects

Super-Kamiokande
(ICRR, Univ. Tokyo)



New T2K near detector
CERN-NP07

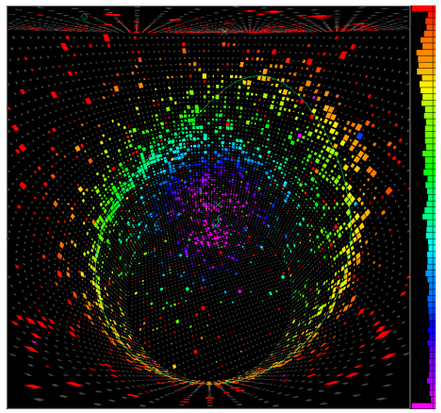
J-PARC Main Ring
(KEK-JAEA, Tokai)

Studies of neutrino oscillation

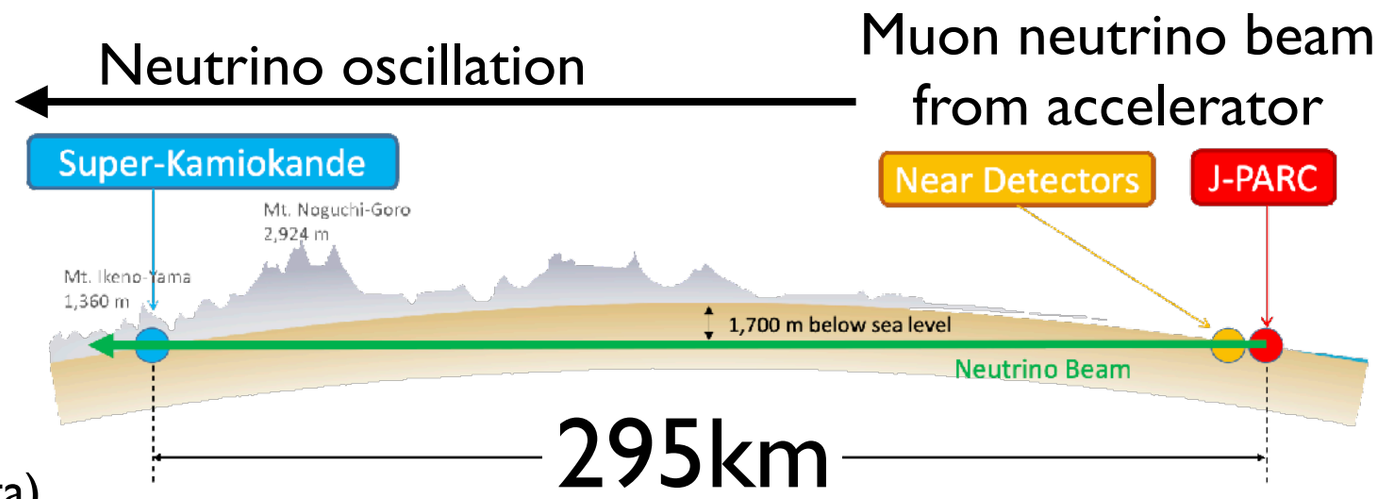
Department of Physics External review
February 13, 2020

Studies of neutrino oscillation (T2K experiment)

Precise study of neutrino oscillations (T. Kajita, Nobel Prize 2015) using an artificial neutrino beam from the J-PARC accelerator

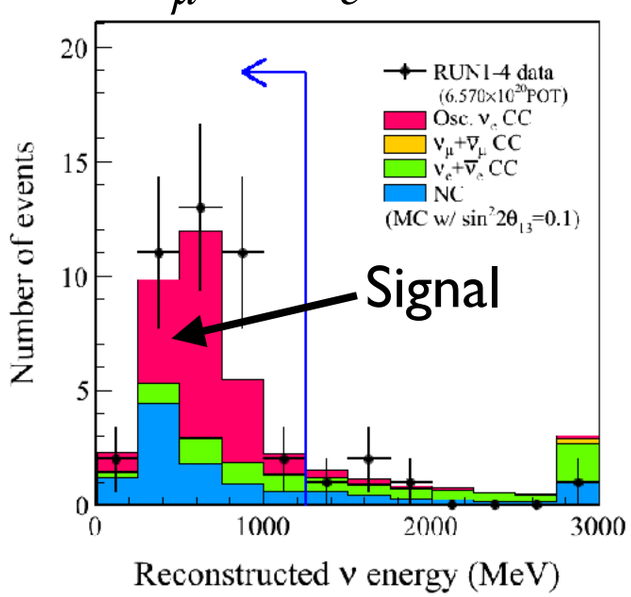


Electron neutrino event at Super-K (T2K beam data)



Observation of muon to electron neutrino oscillation

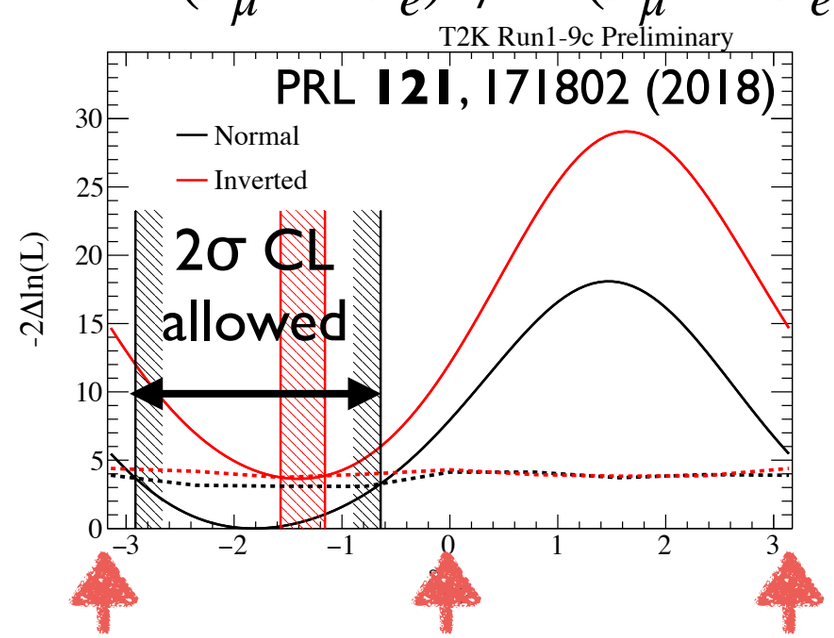
$$P(\nu_\mu \to \nu_e) \neq 0?$$



PRL **112**, 061802 (2014)

First hint of particle-antiparticle asymmetry (CP violation) in the lepton sector

$$P(\nu_\mu \to \nu_e) \neq P(\bar{\nu}_\mu \to \bar{\nu}_e)?$$

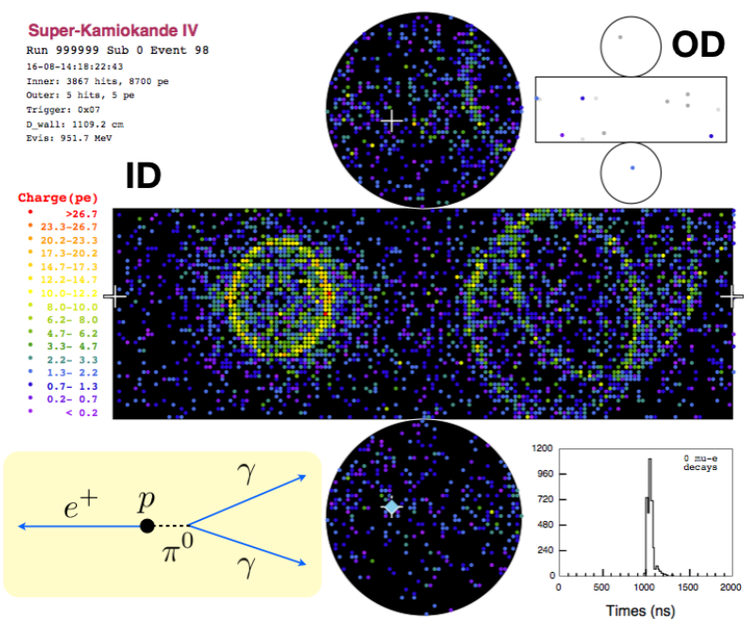


[T.Koga, N.Chikuma, Ph.D theses]

Latest result has been just accepted by Nature

CP conserving points

Search for proton decay (Super-Kamiokande)



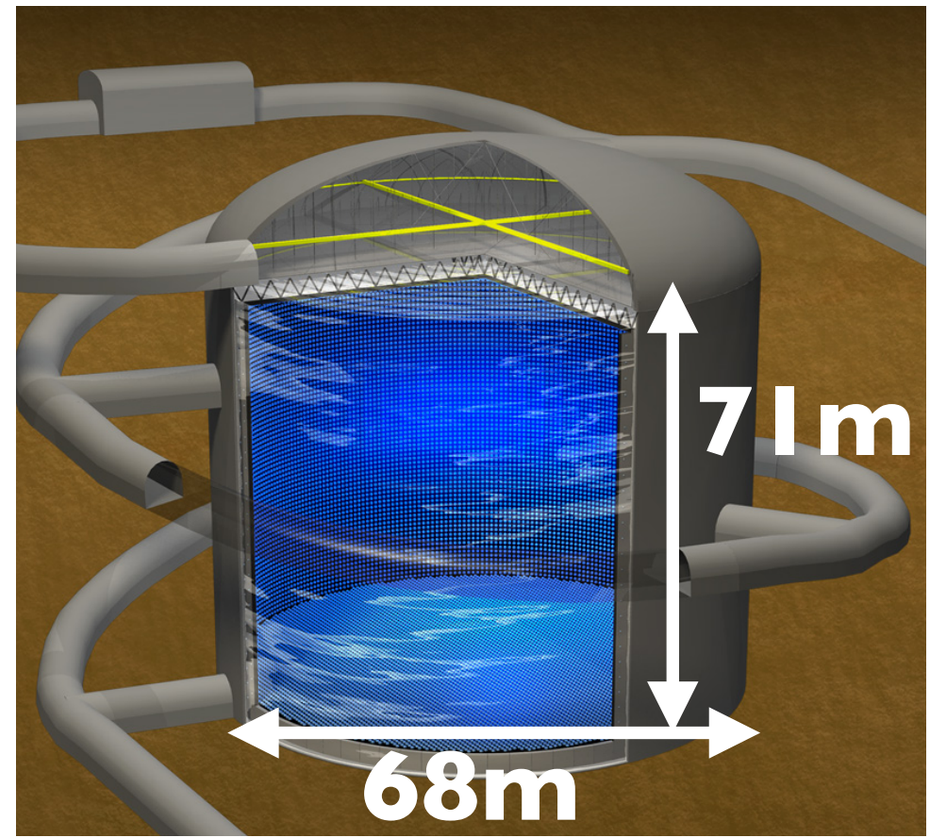
Simulated $p \to e^+\pi^0$ event in Super-Kamiokande

Set world best limit for $p \to e^+\pi^0$ (>1.88×10^{34}years) with an improved reconstruction algorithm

PRD **95**, 012004 (2017)
[Yusuke Suda, Ph.D thesis]

Hyper-Kamiokande

Lead the group to define science goals



Proposal of a long baseline experiment with J-PARC

PTEP **2015** 053C02

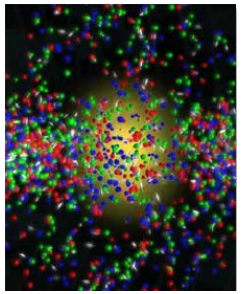
Hyper-Kamiokande has been approved.
Construction to start in 2020, experiment in 2027

Prof. Sakurai

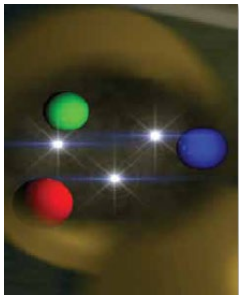
Nuclear Physics
including Strategy

Nuclear Physics

Quark-gluon



Baryon-meson



Nuclei

Quark-Gluon-Plasma

Nucleon-structure

Hadron-spectroscopy

Meson in nuclear matter

Interactions with S=-1, -2 Baryons

three-body forces

Exotic nuclei

Super heavy element

Medium- & High-Energy

J-PARC

Hayano (-2017)

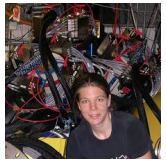
"It would be beneficial to the Department as well as J-PARC to strengthen the interactions of faculty and students with J-PARC"
Report of Review Committee in 2012

Low-Energy

RIBF

Sakurai (2011-)

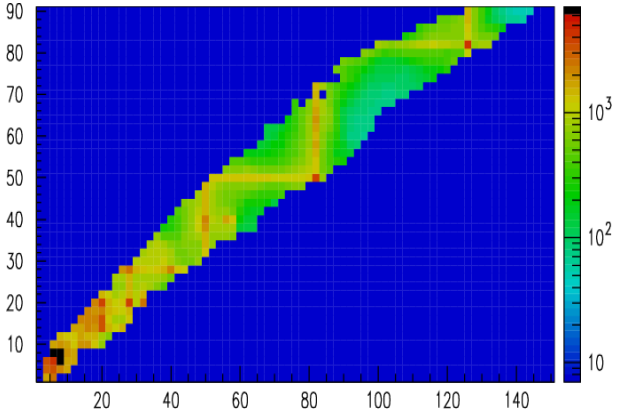
Wimmer (2014-2019)



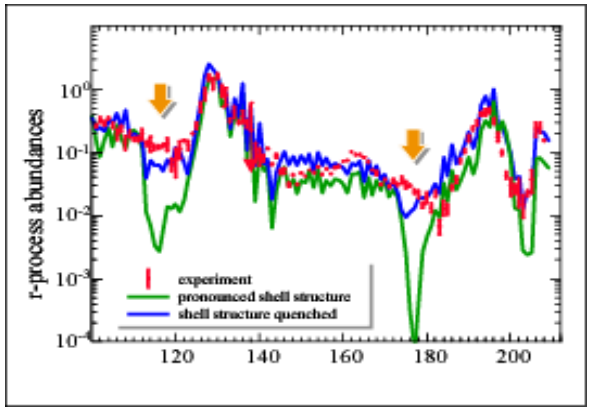
SAKURAI Group

Sakurai, Niikura (Associate),
4 PhD students, 2 Master students

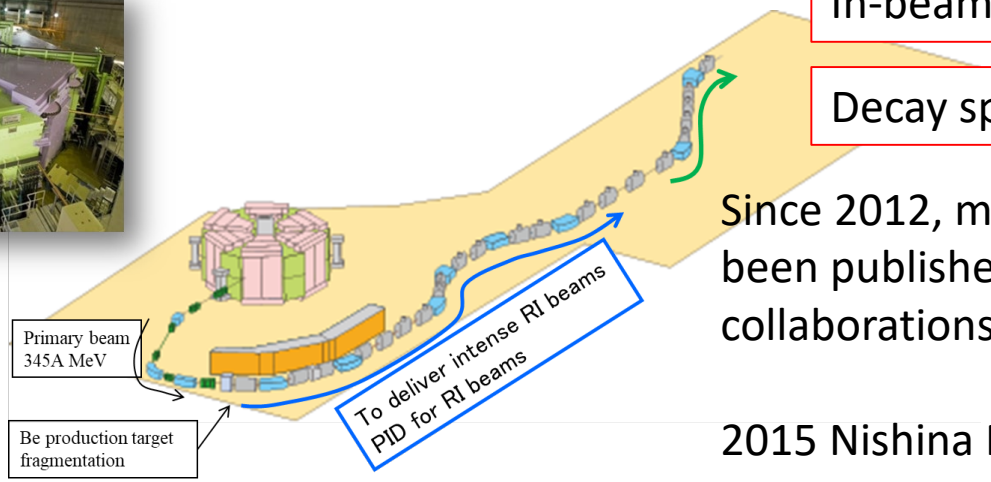
Shell Evolution :
magicity loss and new magicity



R-process path: Synthesis up to U



Radioactive Isotope Beam Factory (RIBF) at RIKEN
the world-leading heavy-ion accelerator facility



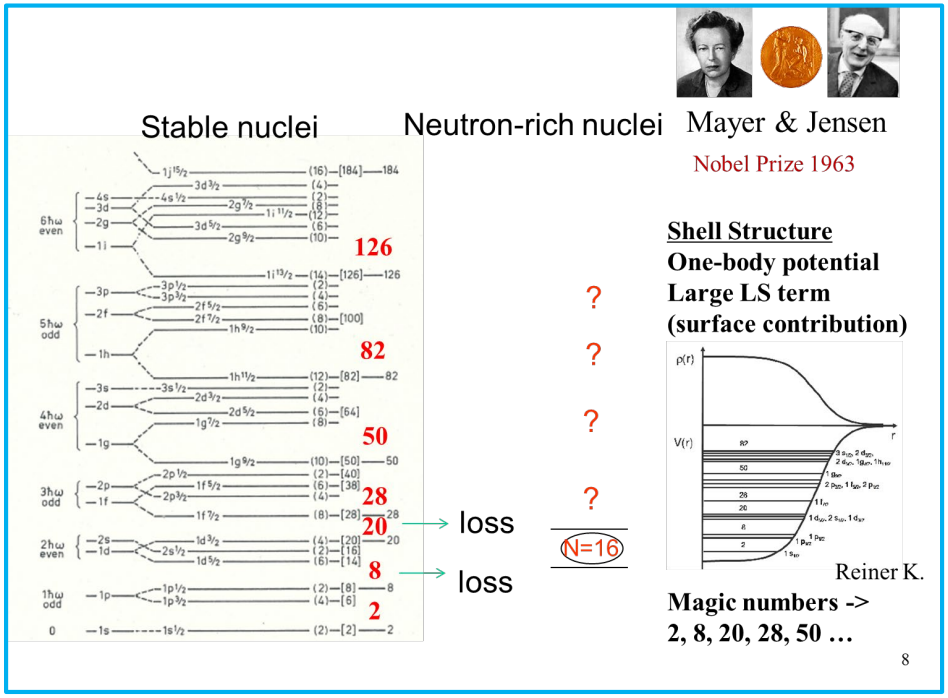
In-beam gamma spectroscopy

Decay spectroscopy

Since 2012, more than 150 papers have been published under international collaborations

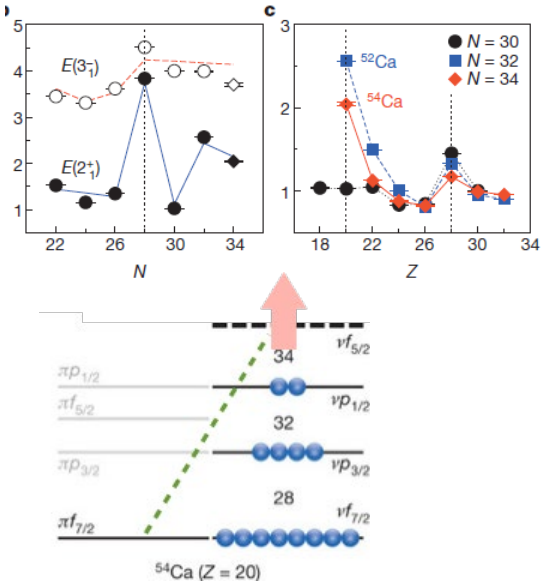
2015 Nishina Memorial Prize

Shell Evolution



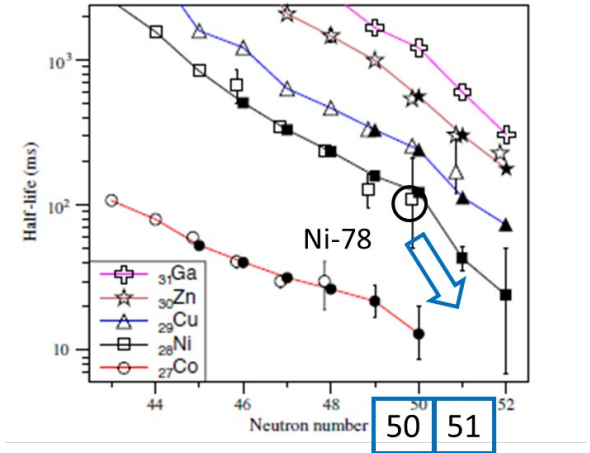
New Magicity at N=32, 34

^{54}Ca: Steppenbeck, Nature 502, 207 (2013)



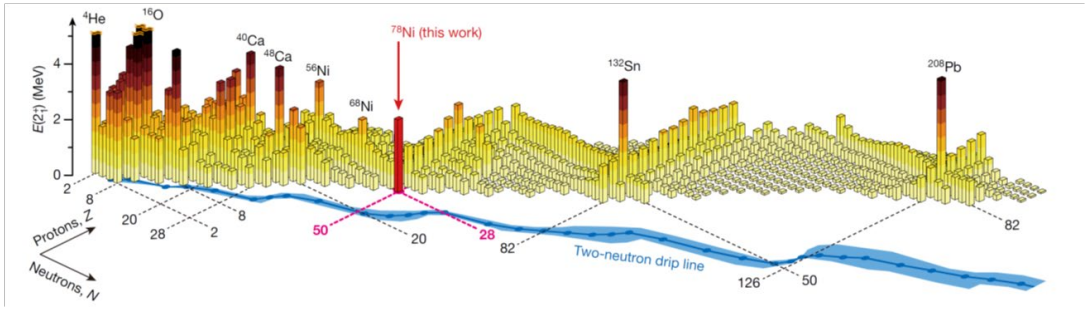
Double magicity at Z=28 and N=50

^{78}Ni: Xu, PRL 113, 032505 (2014)

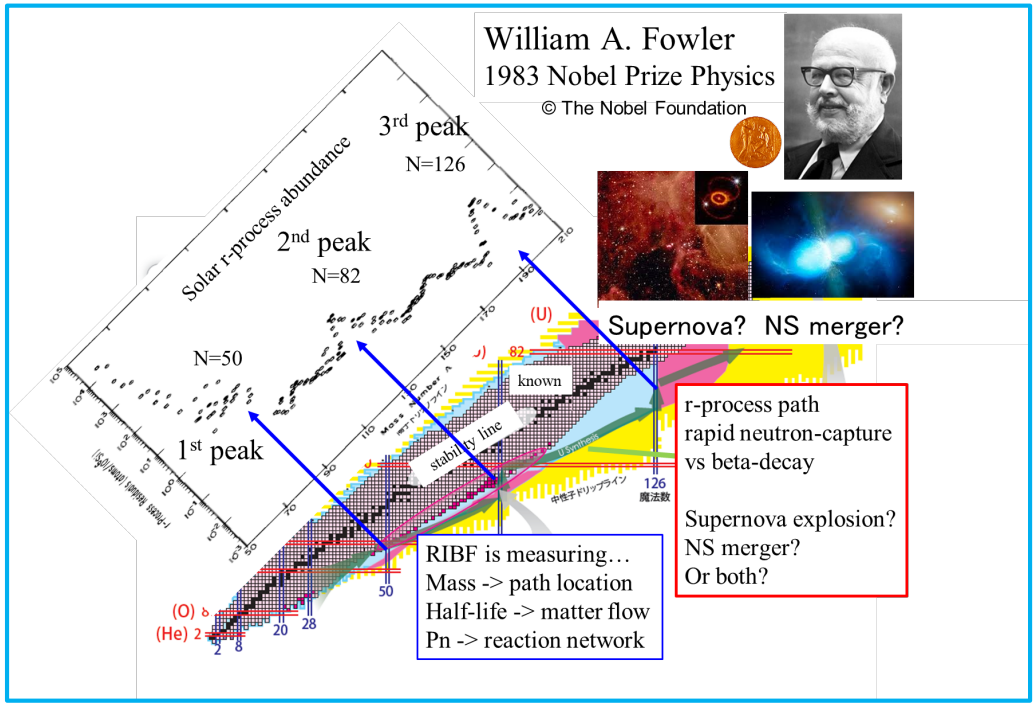


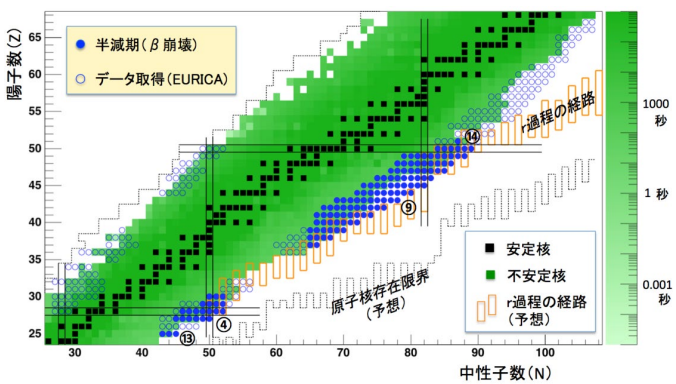
^{78}Ni: Taniuchi, Nature 569, 53 (2019)

^{78}Ni revealed as a doubly magic stronghold against nuclear deformation

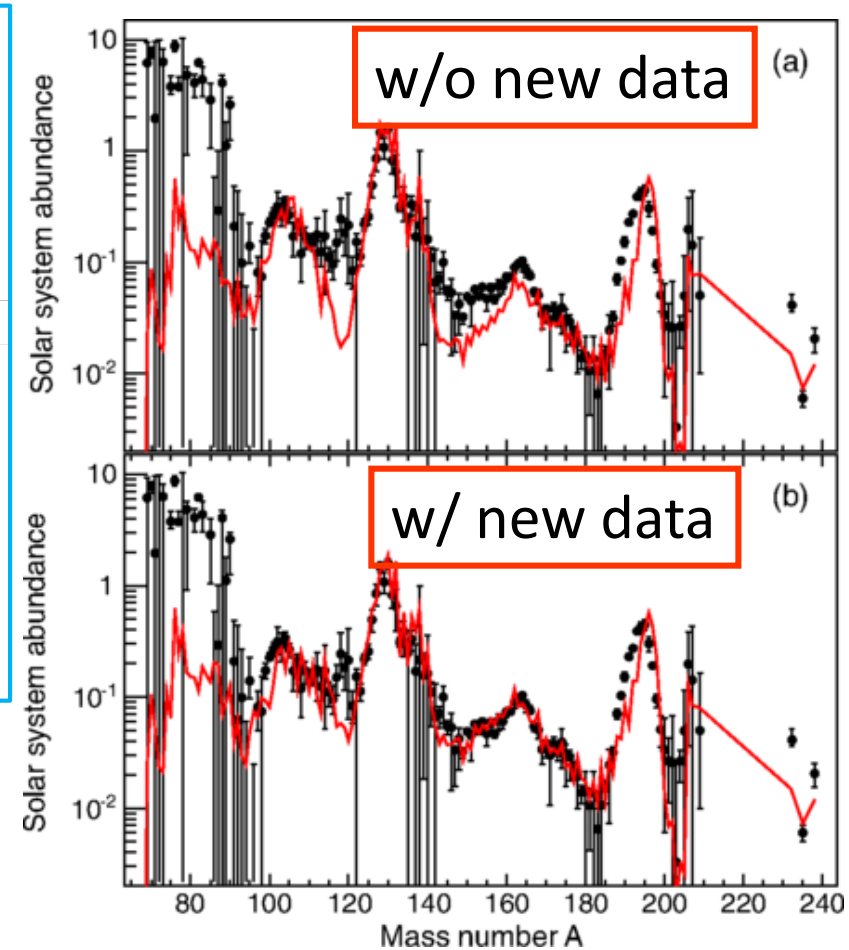


“Revolution” for the r-process path





Bunch of T1/2 data for A~100 have been obtained



A standard model assuming (n,γ) equilibrium reproduces the r-abundance up to rare-earth region

G. Lorusso, S. Nishimura Z.Y. Xu *et al. PRL*. 114, 192501 (2015)