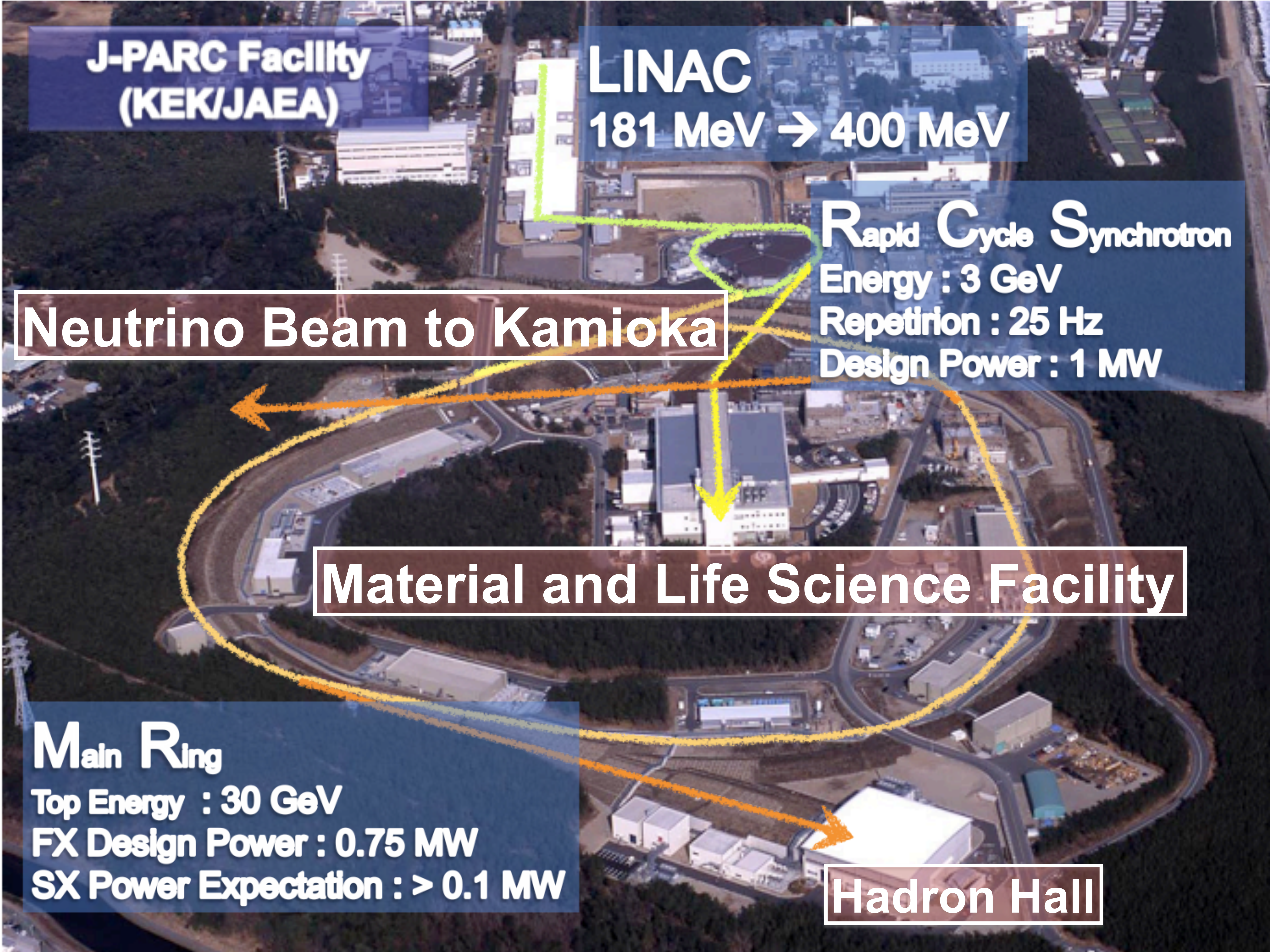
Current Status of J-PARC

Frontier Detectors for Frontier Physics

13th PISA Meeting on Advanced Detectors

May 24-30, 2015, La Biodola, Isola d'Elba, Italy

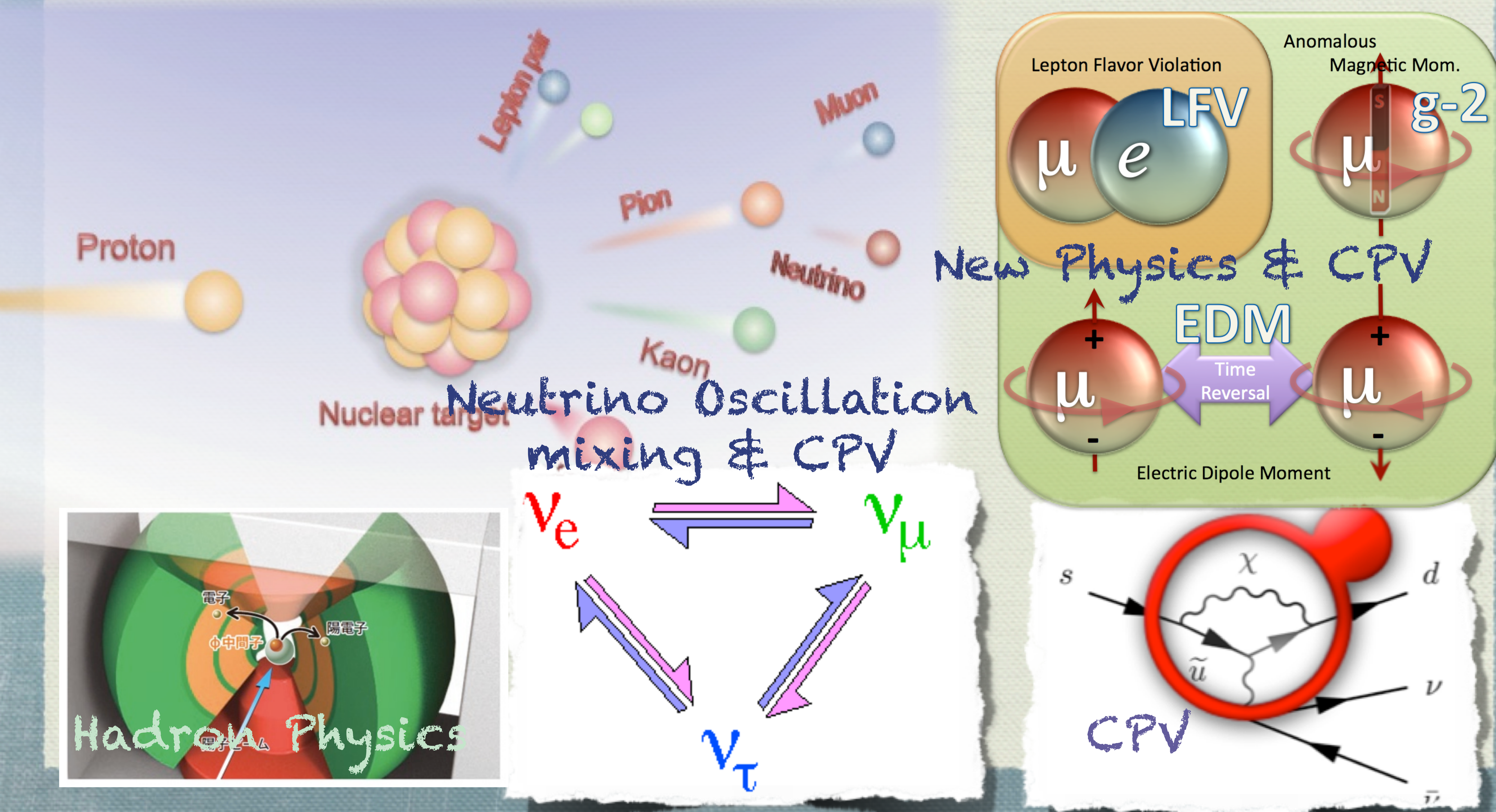
Naohito SAITO (J-PARC / KEK)


J-PARC Facility
(KEK/JAEA)
LINAC
181 MeV → 400 MeV
Rapid Cycle Synchrotron
Energy : 3 GeV
Repetirion : 25 Hz
Design Power : 1 MW
Neutrino Beam to Kamioka
Material and Life Science Facility
Main Ring
Top Energy : 30 GeV
FX Design Power : 0.75 MW
SX Power Expectation : > 0.1 MW
Hadron Hall

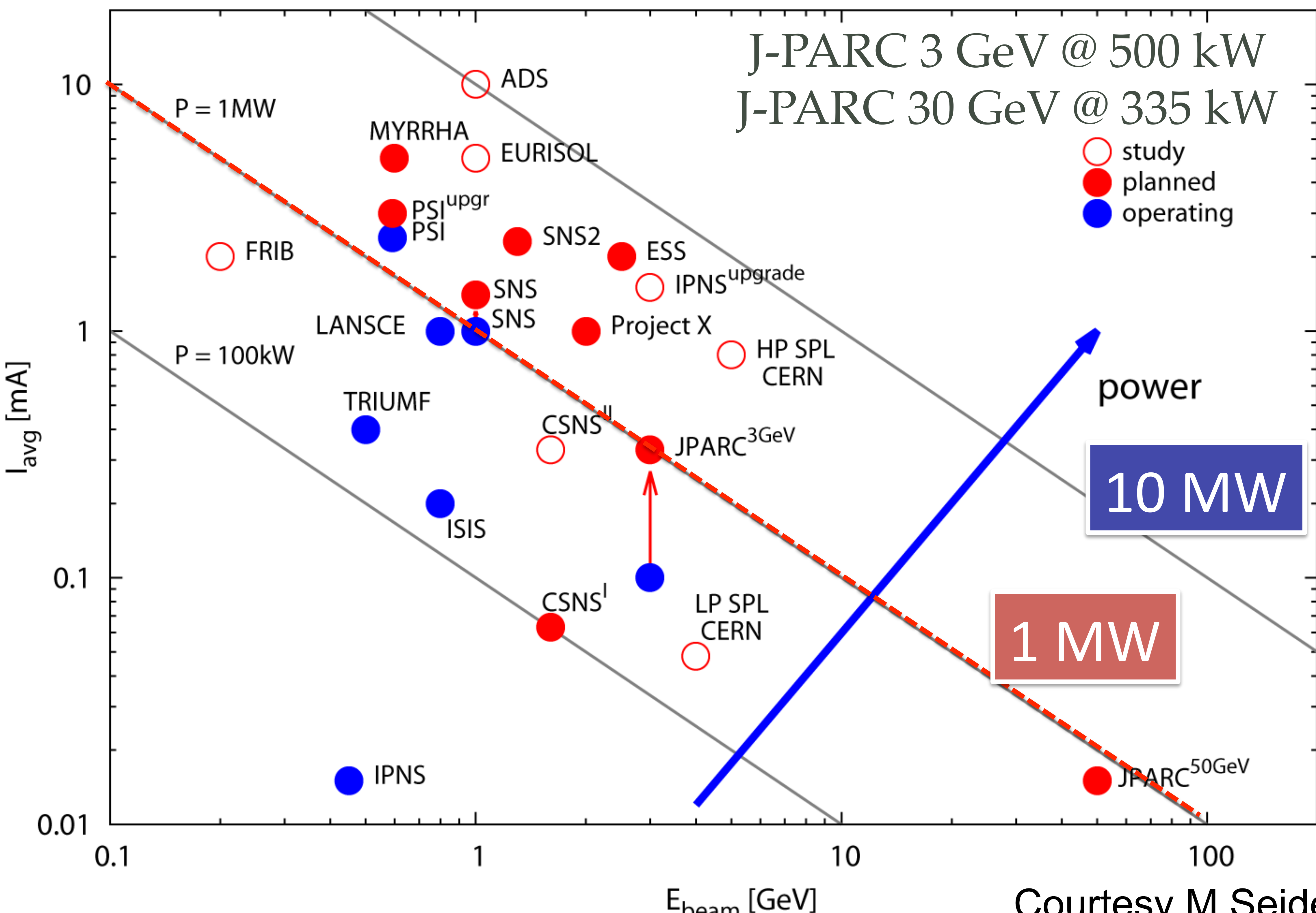
High Intensity Frontier

J-PARC (Japan Proton Accelerator Research Complex)

- Multi-purpose facility with high-intensity proton driver



Power Frontier Growing!



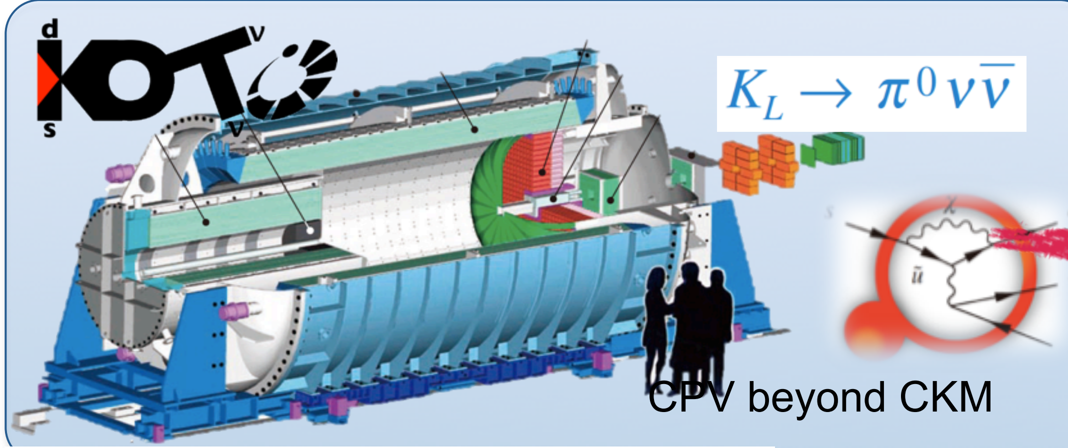
Courtesy M.Seidel

Origin of Matter :
Explored with High Intensity Proton Driver = J-PARC

Super Kamiokande

J-PARC

Neutrino Experiment : T2K
〜Mixing Angle, CP phase, and Mass Hierarchy 〜

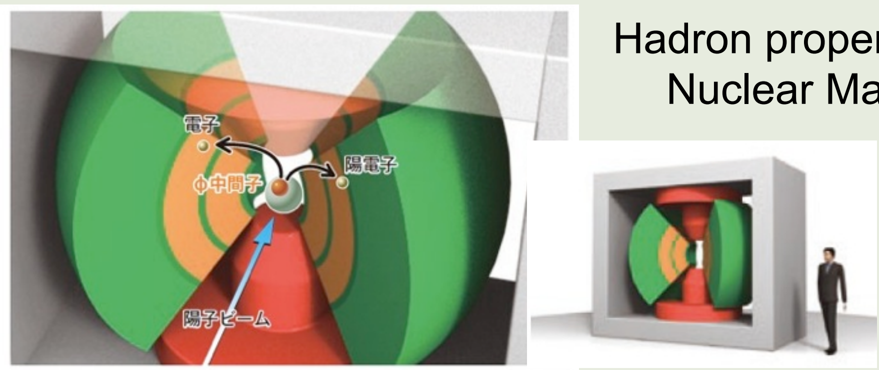


$K_L \to \pi^0 \nu \bar{\nu}$

CPV beyond CKM

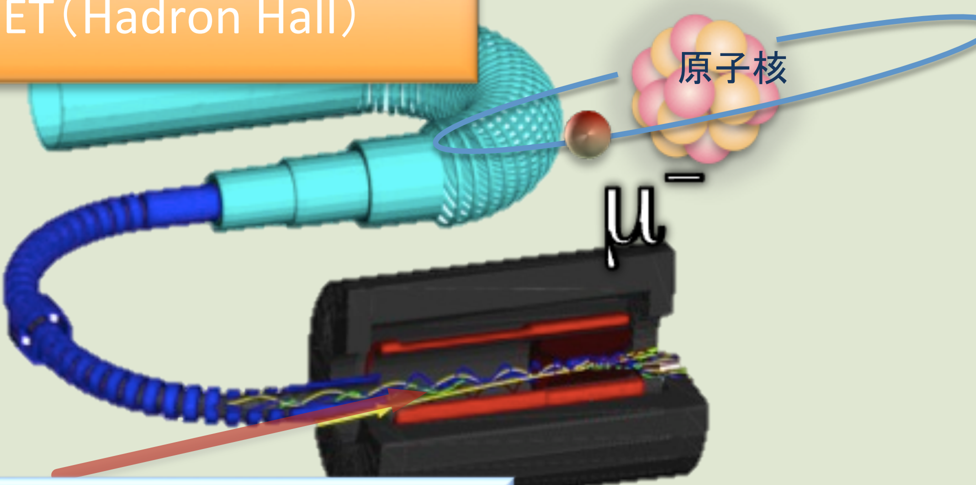
Hadron Experiments
〜CP beyond CKM; Mass modification〜

Hadron properties in Nuclear Matter

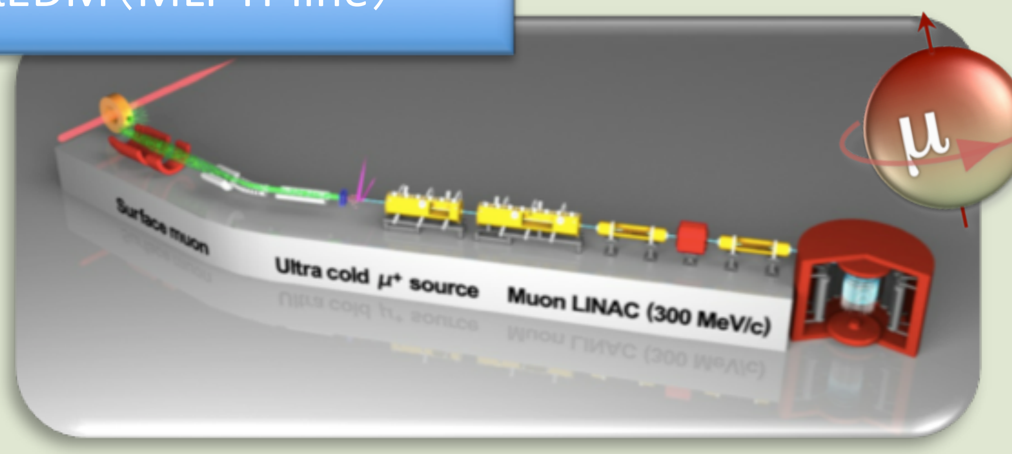


Muon Fundamental Physics
〜Flavor and CP are violated in the charged Leton sector?〜

COMET（Hadron Hall）



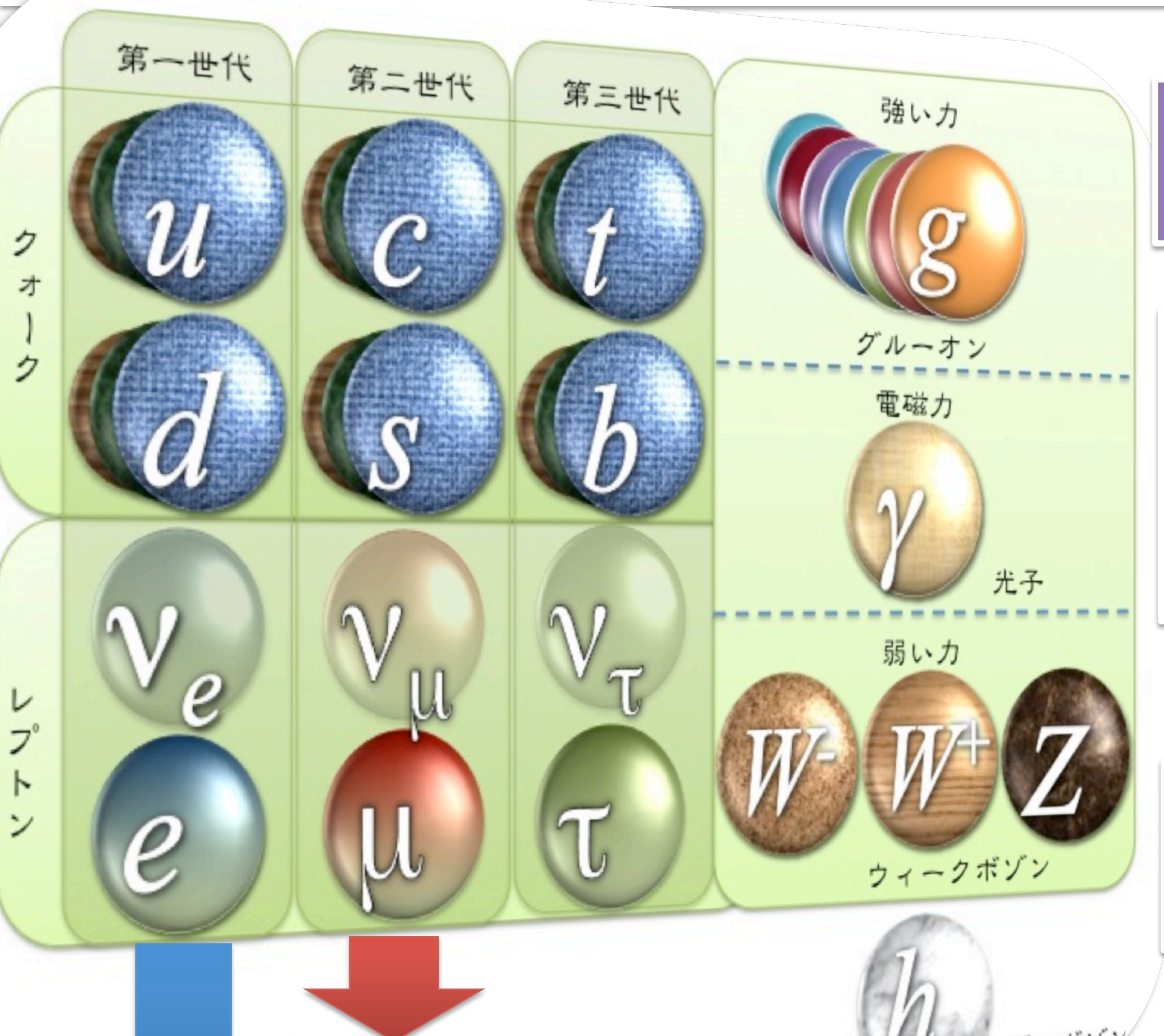
g-2/μEDM（MLF H-line）



Origin of Matter

- Search for Physics Beyond SM in Quark and Lepton sectors
- Deeper understanding of Strong Int.

Matter = Remnant of 1/10^9 Asymmetry



Origin of Matter =

Matter-Antimatter Asym.
CPV and Flavor Mixing
CPV beyond CKM
Role of muon as a charged Lepton

+

Role of Strong Interaction
Strangeness and Charm

Explored with J-PARC Hi-Intensity Beams

Our Stable World

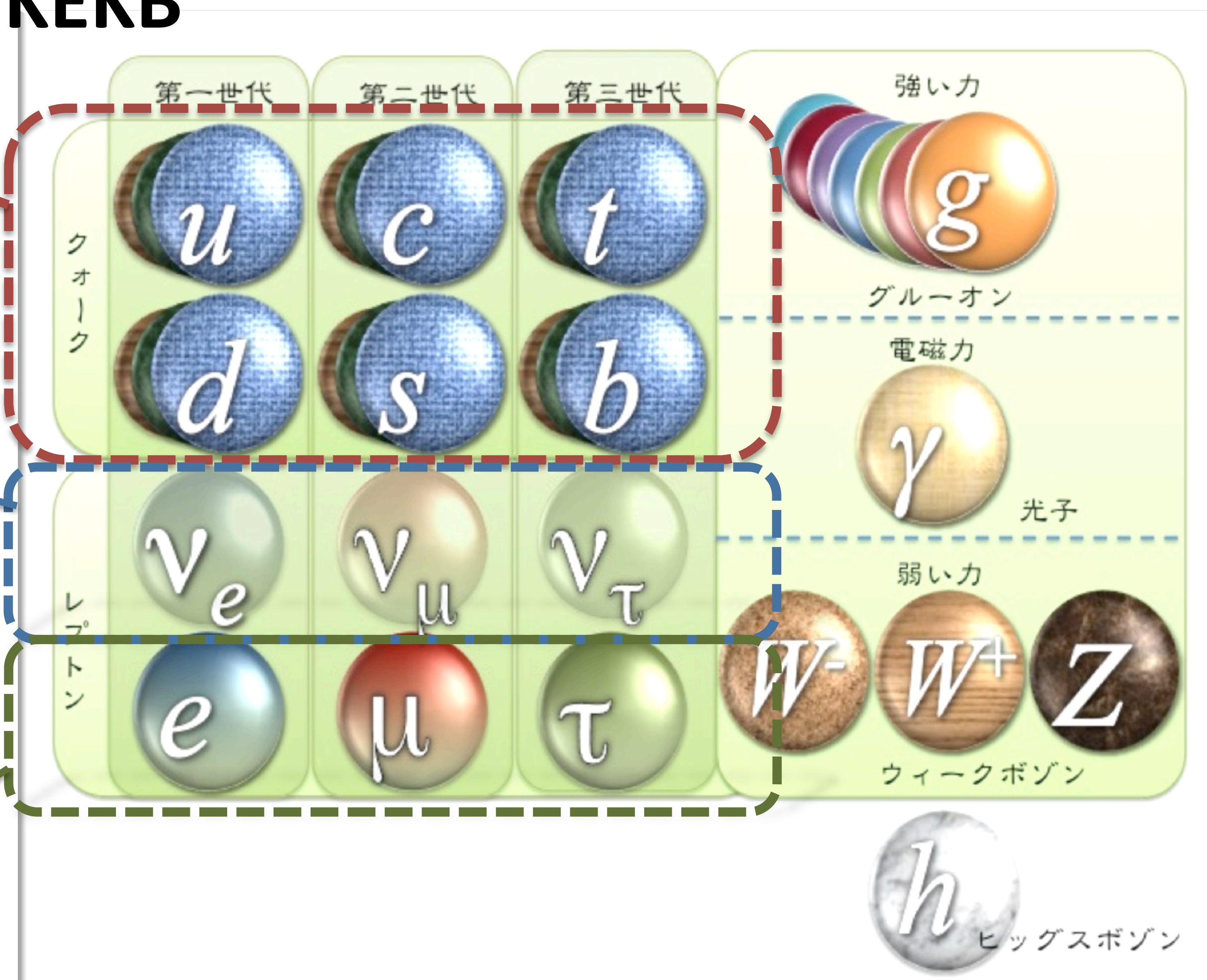
Flavour Mixing and CPV

CKM Theory

CPV thru quark mixing

KOTO@J-PARC HEF and **SuperKEKB**

PMNS theory



CP violated?
Thru Neutrino mixing?

Explore with T2K@J-PARC

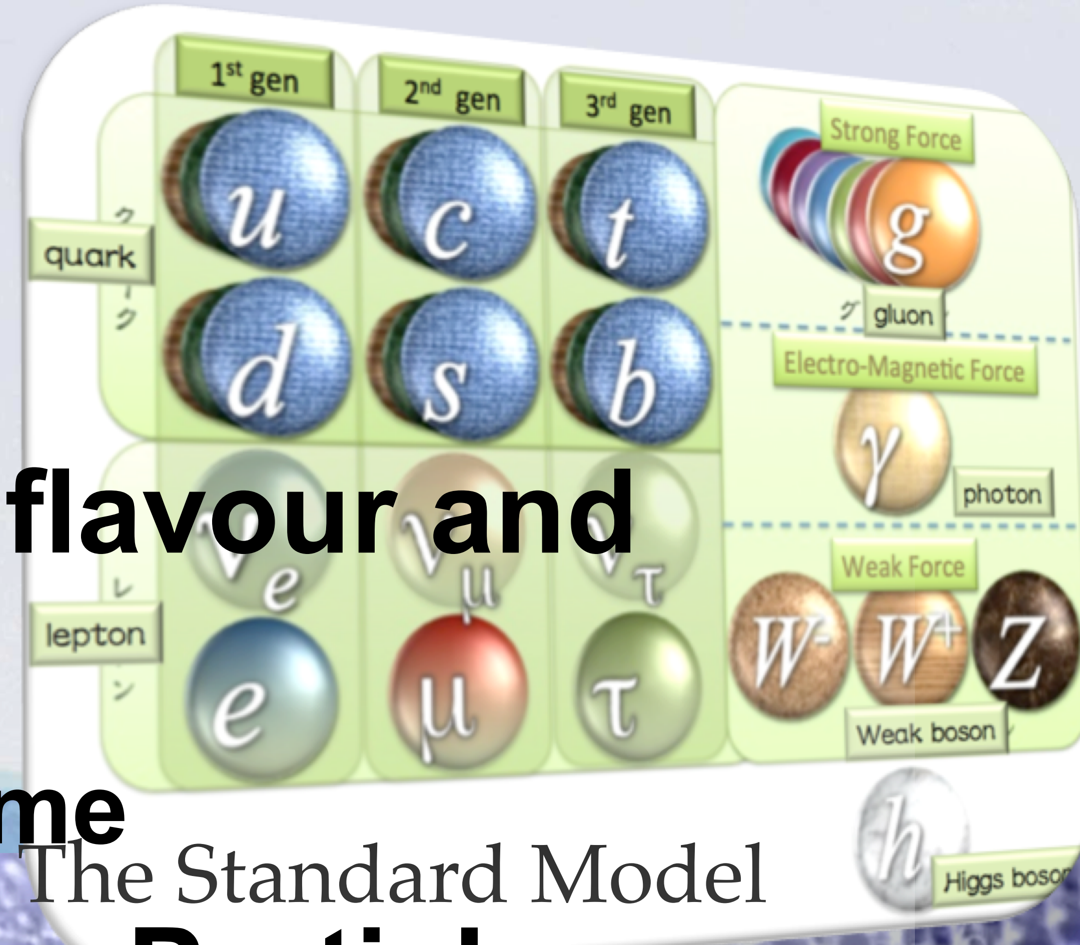
Flavor mixing in charged lepton?
CP violated?

COMET@J-PARC HEF

g_μ-2/μEDM@J-PARC MLF

Just a Dream of an Experimentalist

- **Elucidate the relation btw flavour and space-time structure**
  - **Particle, Force, and Space-time**



The Standard Model

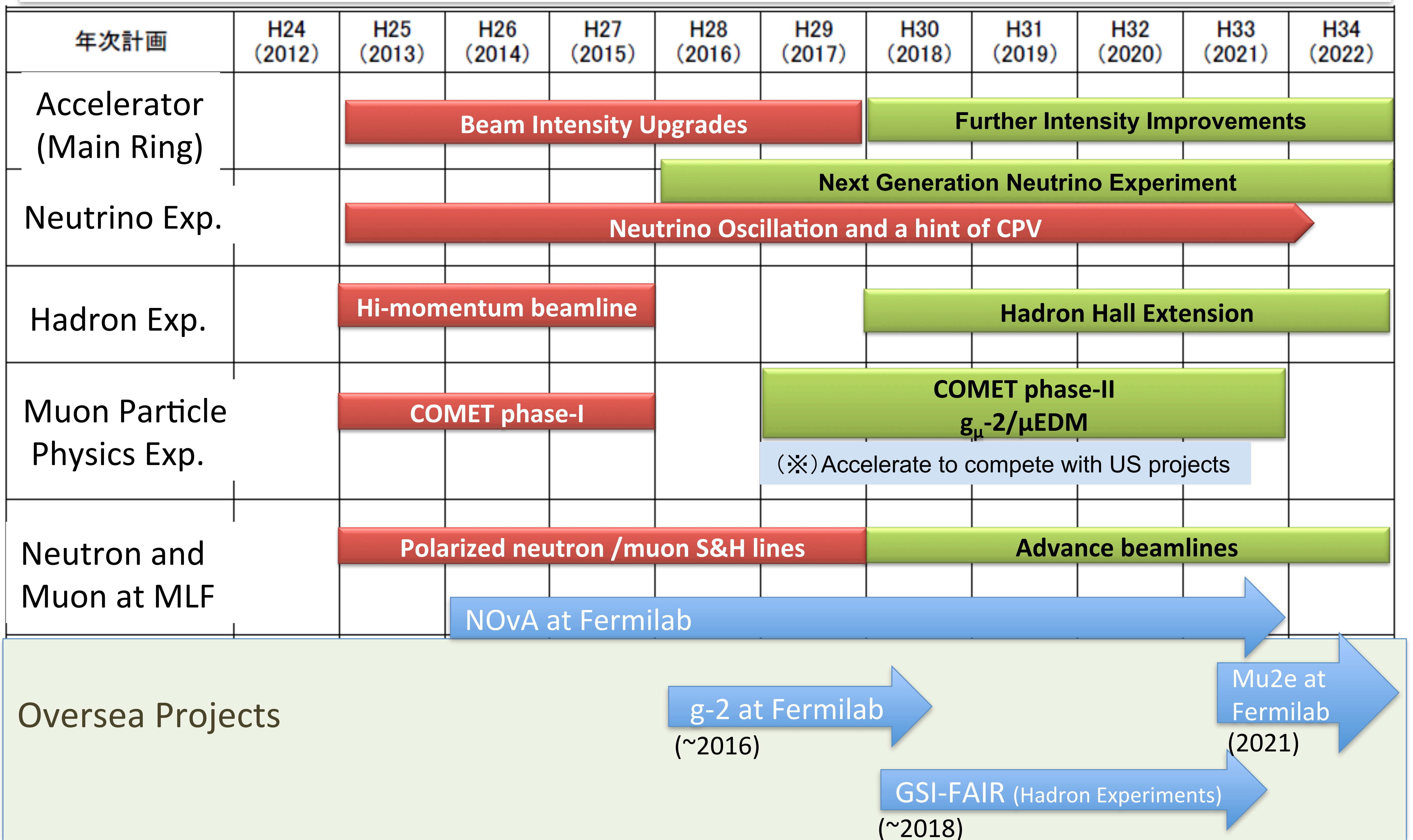
- **Comments at the 2nd WS on Particle Physics of Dark Universe**

  http://kds.kek.jp/conferenceTimeTable.py?confId=11916#20130404.detailed

  - ***"Certainly flavor physics could provide some constraints for compactification … but not enough"***
  - ***"Need to combine accelerator based results and gravity, cosmology"***

Elucidation of the origin of matter with an upgrade of J-PARC

Intended Schedule (JFY2017-)



in/for J-PARC

Sensor and
rad tol FE

Radiation Resistive

High density
integration
and speed

High rate tolerant

Network
DAQ
framework

Large scale Integration

Open resou

Multidisciplinary collaboration

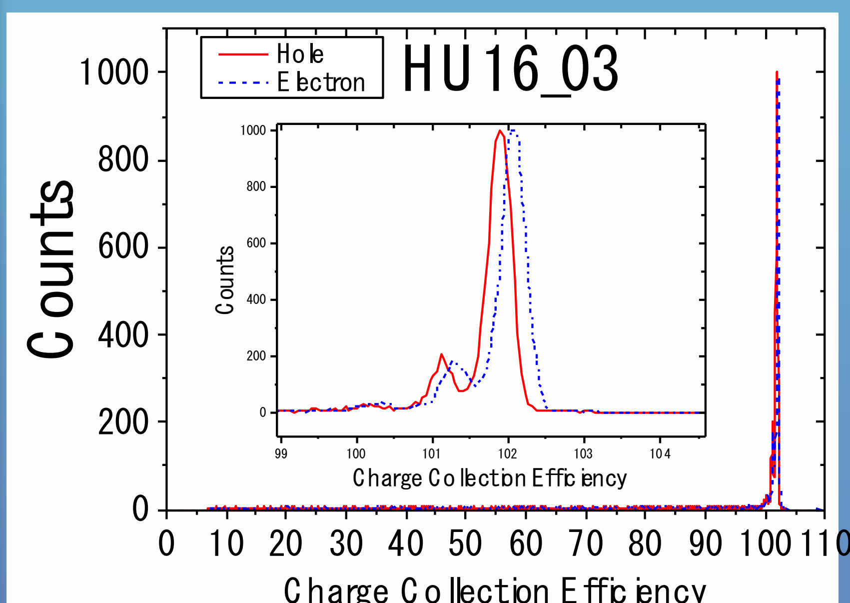
Education

Slide by Manobu Tanaka

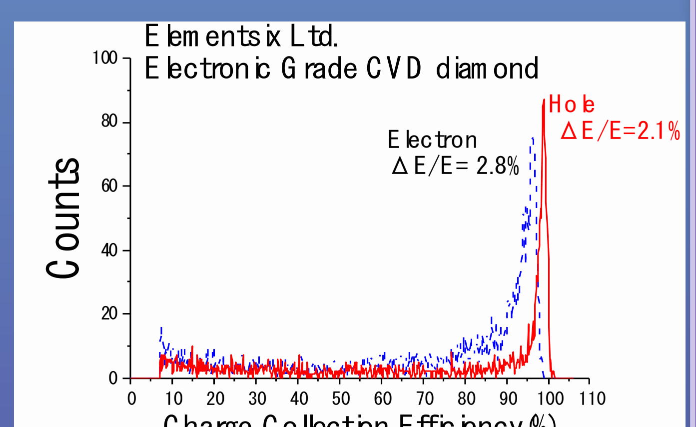
Radiation resistive -beyond 10^8 n,p/cm^2/sec-

Sensor materials(ex.scCVD Diamond)

Hokkaido Univ.



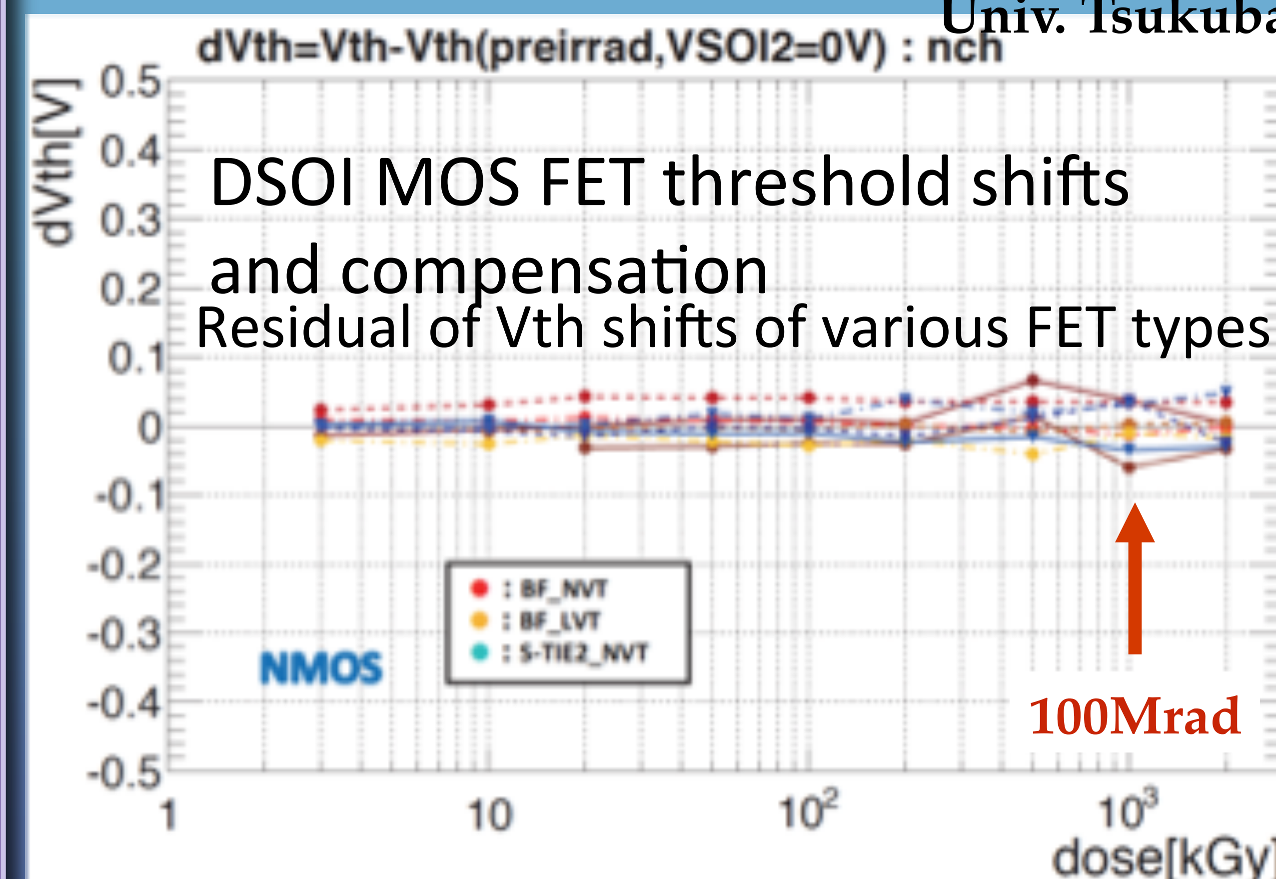
Charge Collection Efficiency:100%
Ileak < 5pA/cm^2



Beyond 10^{16}n/cm^2

Rad tol. process evaluation
-ex. SOI process-

Univ. Tsukuba



Evaluation of other processes also are planned.

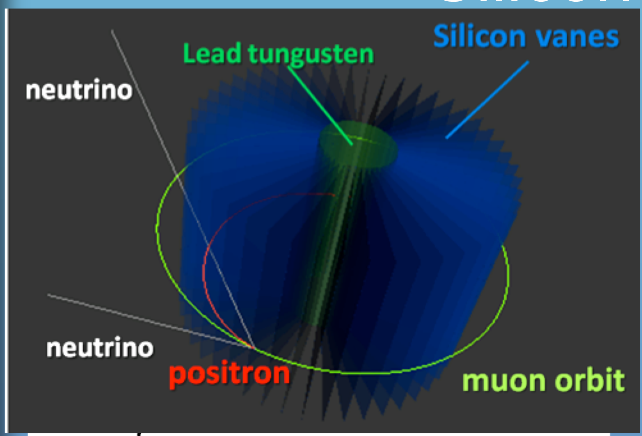
toward Grad

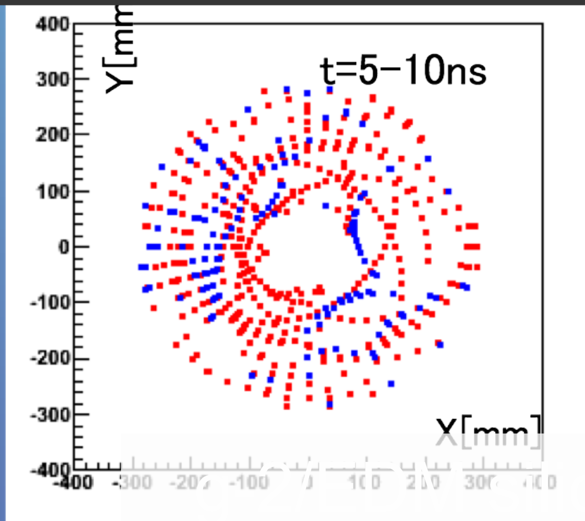
Slide by Manobu Tanaka

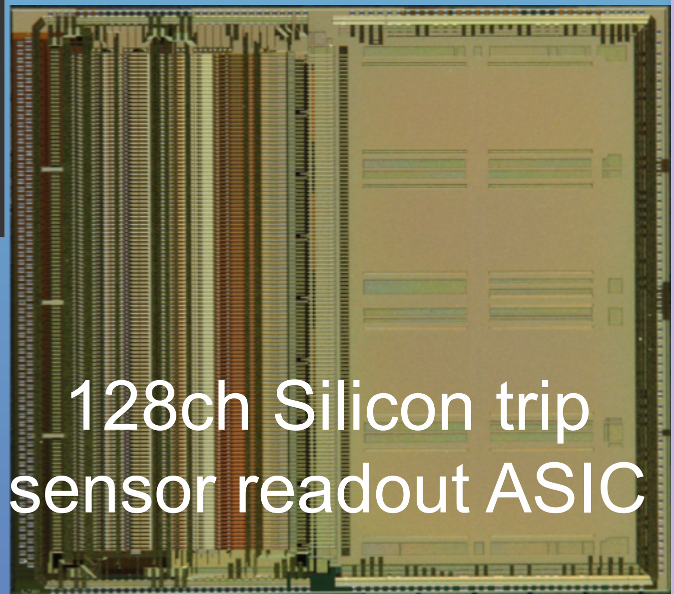
High rate tolerant
-fine grain, high density-

Silicon sensor

Kyushu Univ
,KEK





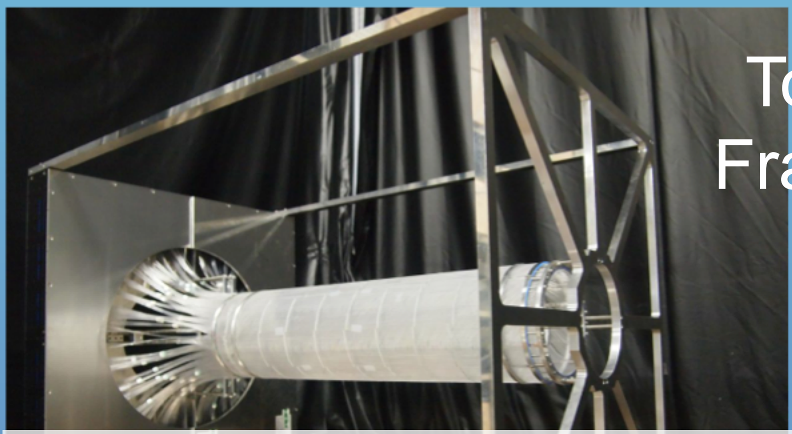


128ch Silicon trip
sensor readout ASIC

...con tracker requires
Peaking time<40ns, S/N >10
and time walk <5ns

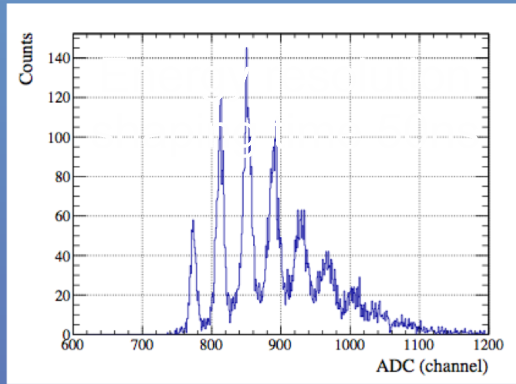
Fast and Fine grain tracker
based on silicon sensor

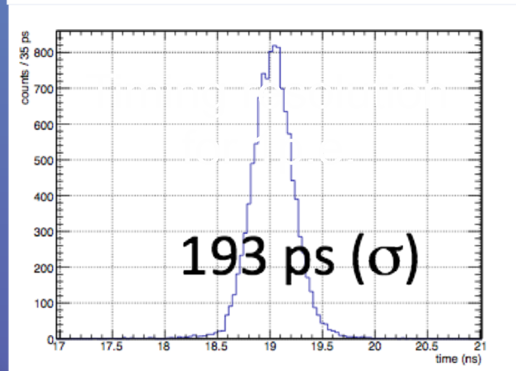
Photon sensor

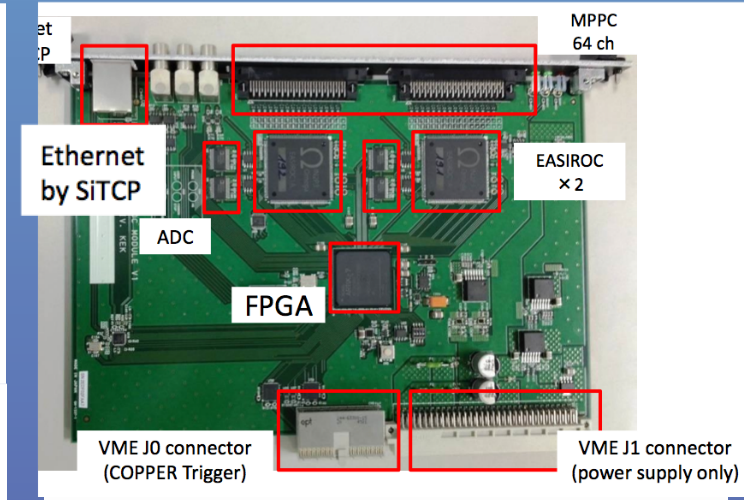


Tohoku Univ.
France Omega
,KEK

Cylindrical fiber tracker requires
5000 ch MPPC readout





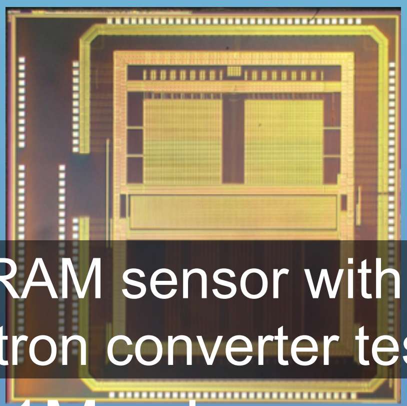


Fast and Fine grain
tracker based on
photon sensor

Slide by Manobu Tanaka

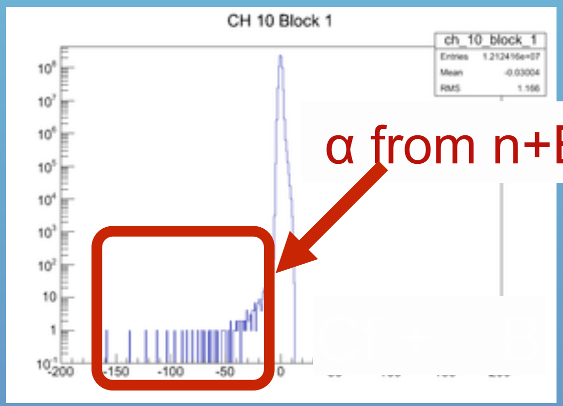
High rate tolerant -fine grain, high density-

MLF-Neutron pixel sensor

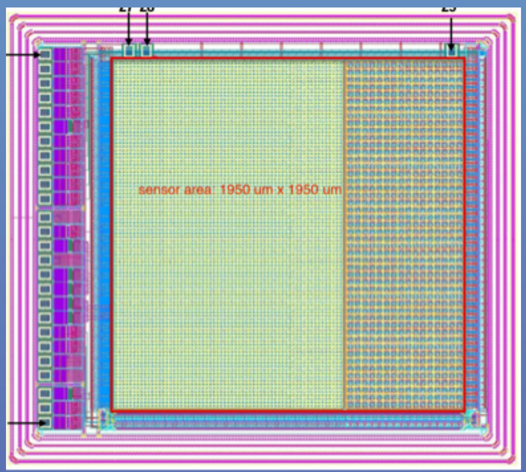


DRAM sensor with neutron converter test

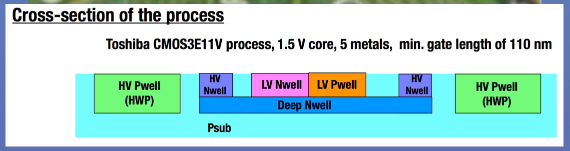
< 1Mrad



more rad tol



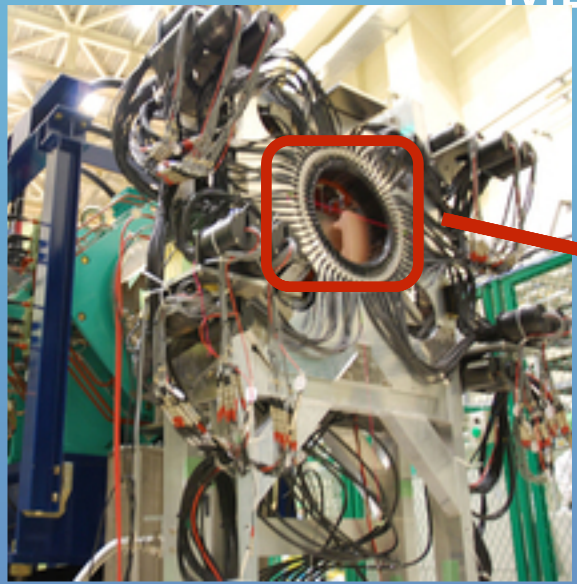
Bonn Univ Kishihsita, KEK

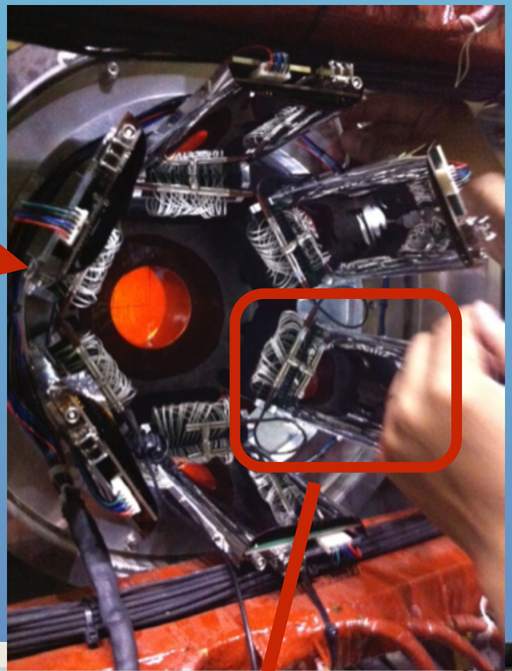


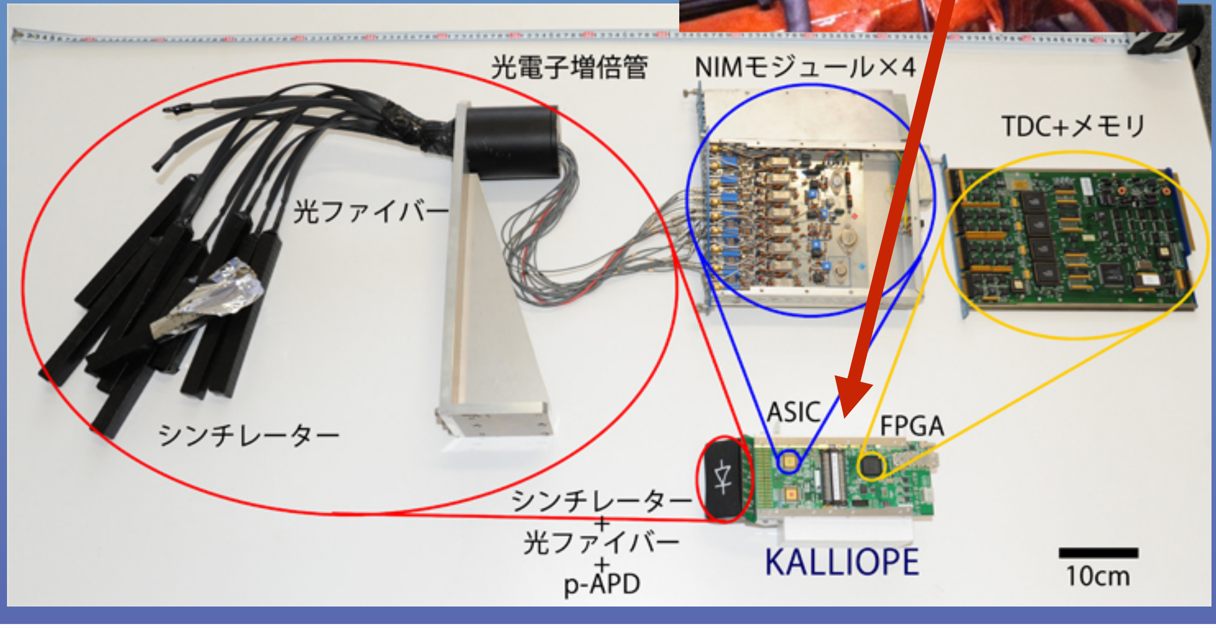
Rad hard study, Efficiency v.s. converter thichness,etc

Neutron imager under high intenisity, beyond He gas detectors

MLF-μSR







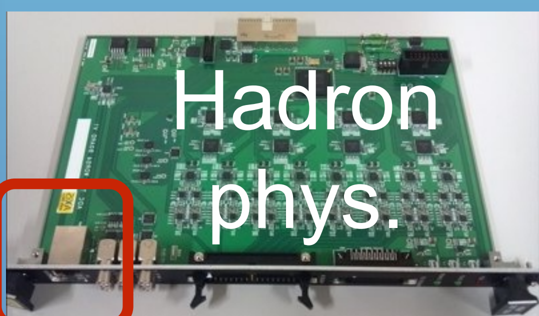
High rate μSR, beyond GHz rate

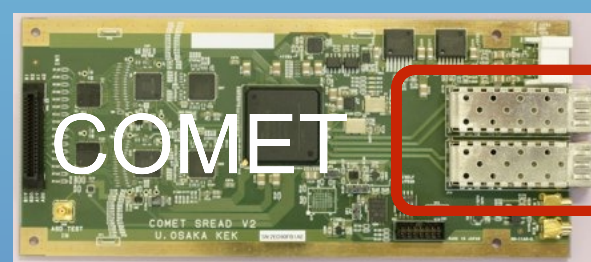
Slide by Manobu Tanaka

Network distributed DAQ for large scale system integration

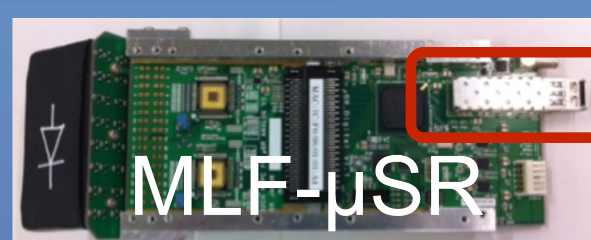
for many groups in J-PARC/Open-It

Sharing know-how on
SiTCP as a commodity tool





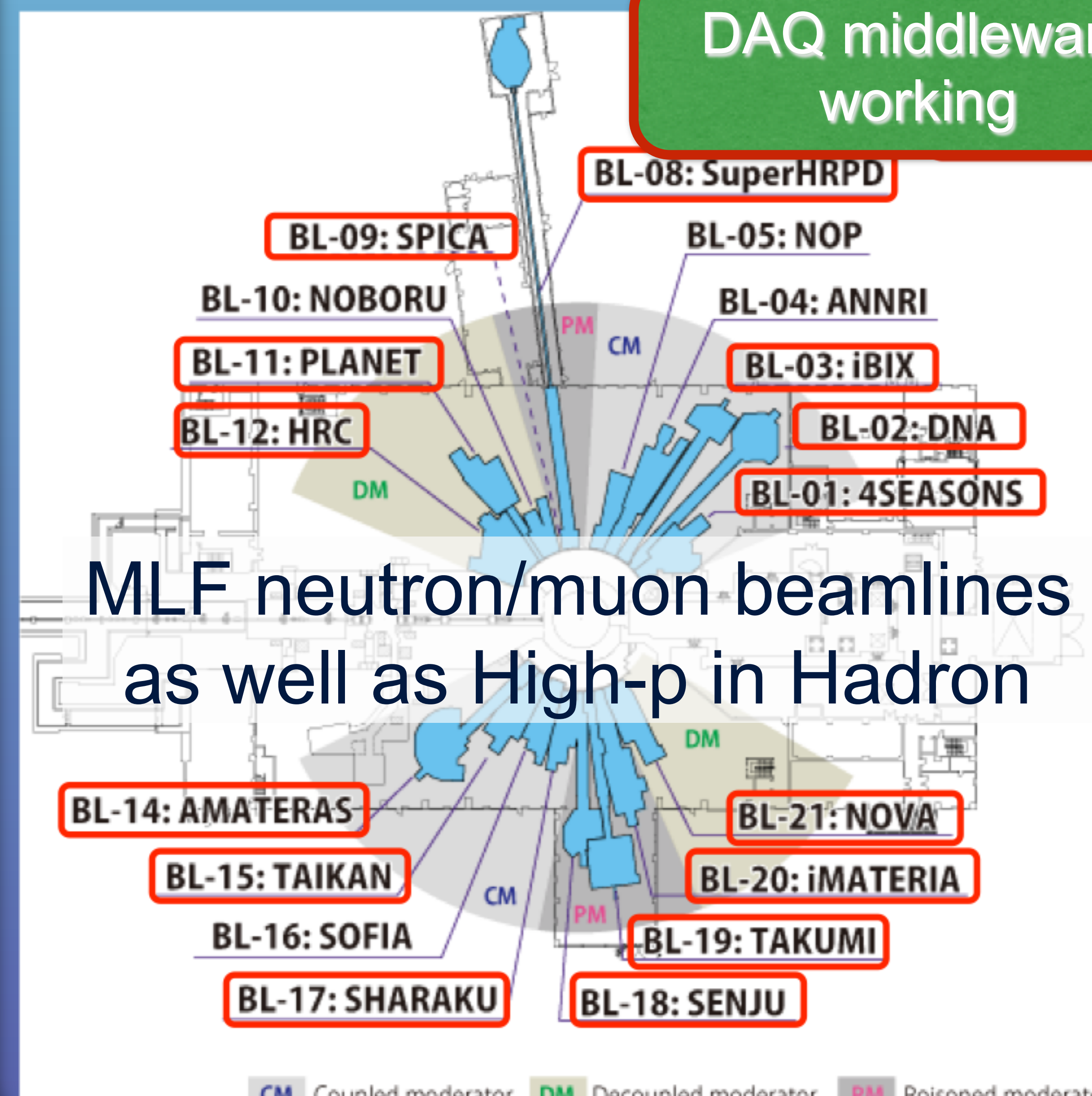
SiTCP
1Gsps TCP/IP data link



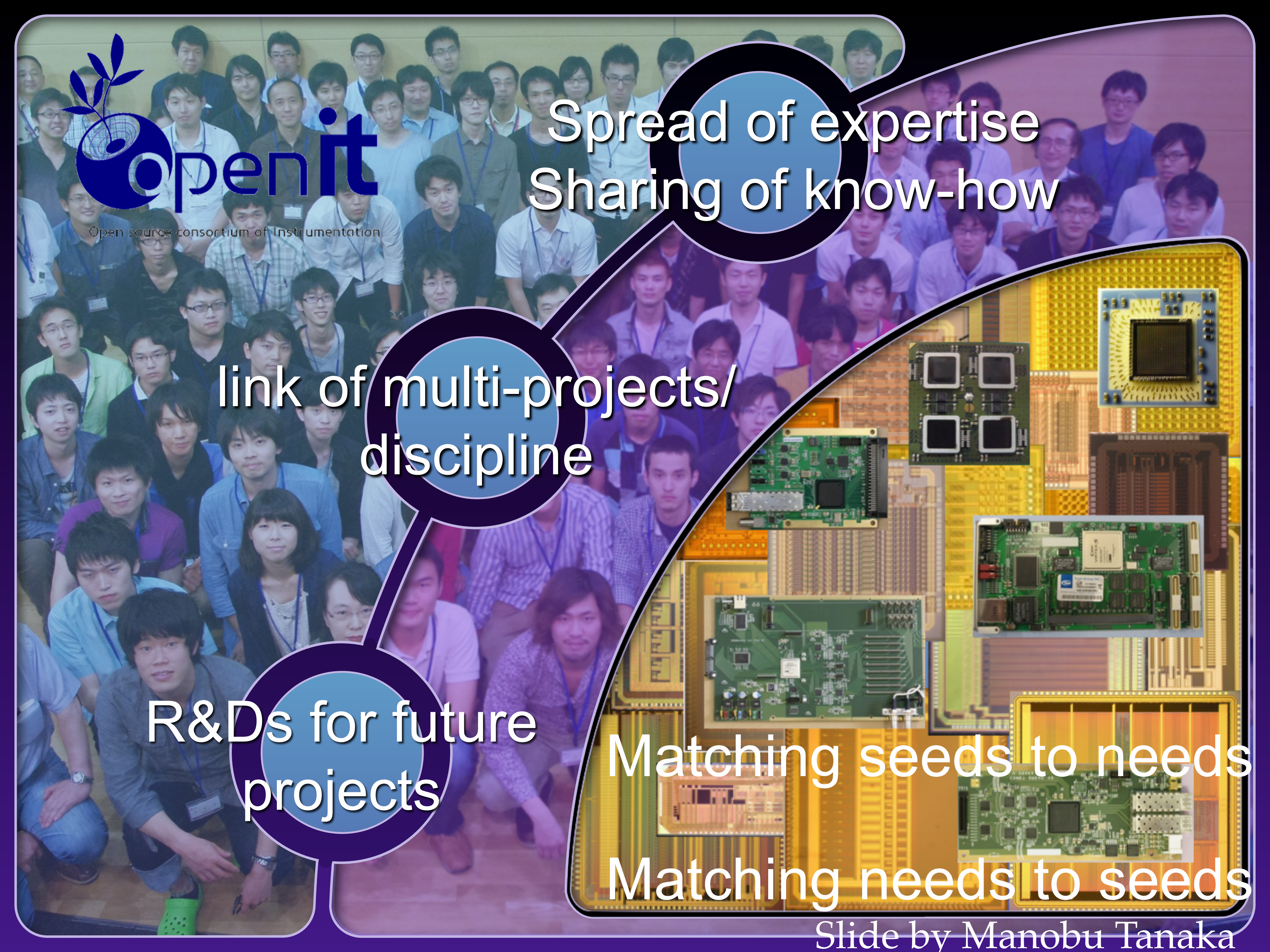
will be able to replace to
10Gsps and more

Sharing know-how on
DAQ middleware as a commodity tool

DAQ middleware
working



Slide by Manobu Tanaka


open it
Open source consortium of Instrumentation
Spread of expertise
Sharing of know-how
link of multi-projects/
discipline
R&Ds for future
projects
Matching seeds to needs
Matching needs to seeds
Slide by Manobu Tanaka

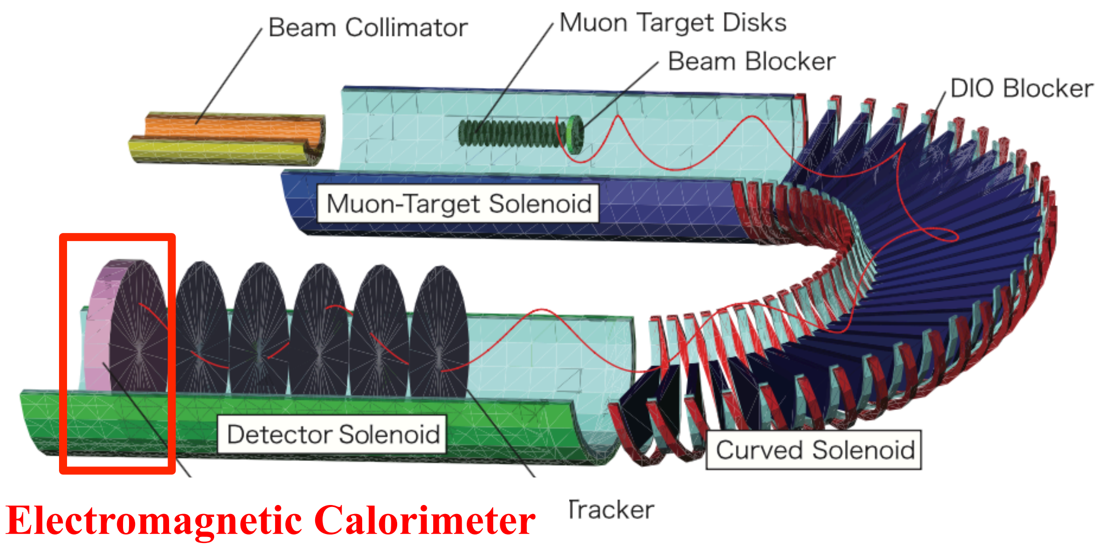
R&D for Hyper-Kamiokande

Slide by Masashi Yokoyama

COMET Electromagnetic Calorimeter

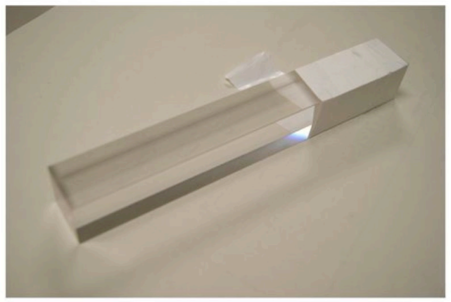
High granularity, high energy resolution and fast timing calorimeter for 100 MeV region

COMET Phase-II setup

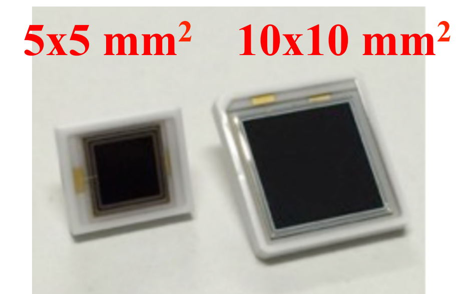


- Requirements
  - Energy resolution < 5 % at 105 MeV
  - Position resolution < 10 mm
  - Fast time response < 100 ns
  - Operation in vacuum and 1 T magnetic field
- Candidate crystals
  - GSO : 20x20x150 mm^3, 10.9 X_0
  - LYSO : 20x20x120 mm^3, 10.5 X_0
- Prototype module
  - Teflon tape + Al Mylar wrapping
  - Hamamatsu APD S8664-55 (5x5 mm^2) readout
  - Custom-made fast shaping preamplifier
- A prototype of 7x7 crystals was beam-tested with an electron beam and our choice is LYSO.
- Activities towards the full calorimeter are ongoing.
  - LYSO crystal pre-production
  - Larger area APD
    5x5 mm^2 → 10x10 mm^2
  - Optimization of preamplifier
  - Monitoring/calibration system

GSO crystal



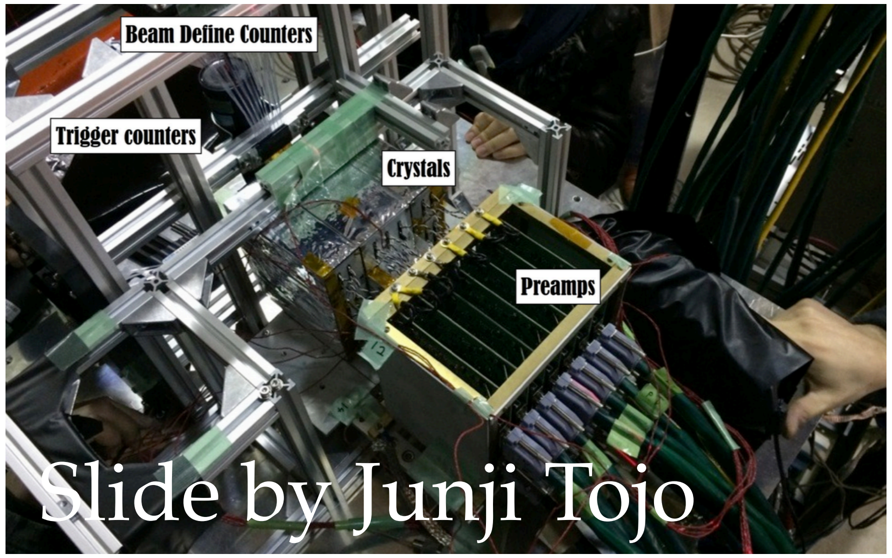
Hamamatsu APD S8664



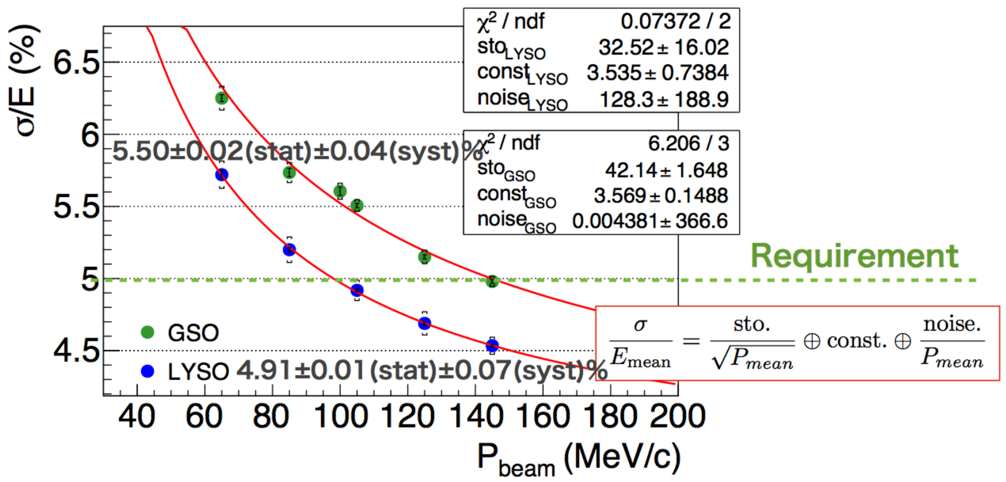
GSO and LYSO property

	GSO(Ce)	LYSO
Density (g/cm^3)	6.71	7.40
Radiation length (cm)	1.38	1.14
Moliere radius (cm)	2.23	2.07
Decay constant (ns)	600^s, 56^f	40
Wave length (nm)	430	420
Refraction index	1.85	1.82
Light yield (NaI(Tl)=100)	3^s, 30^f	83

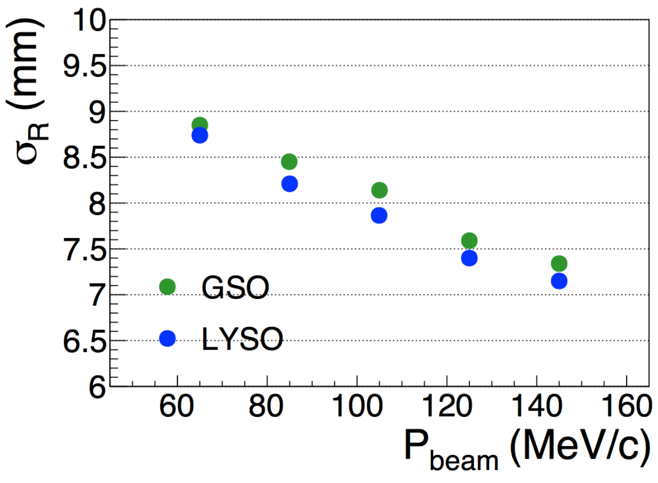
Beam test of a 7x7-crystal prototype



Energy Resolution

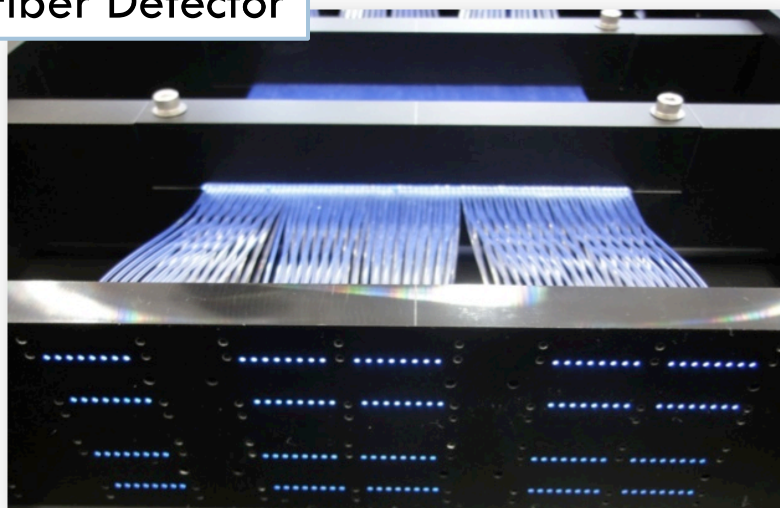


Position Resolution

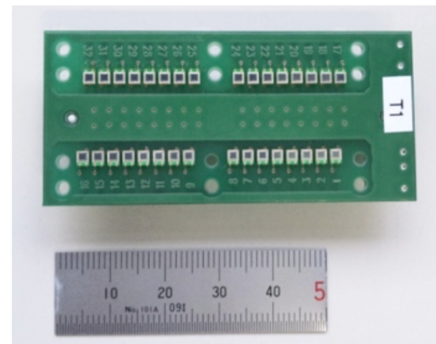


Fiber Tracker for High Intensity Beam

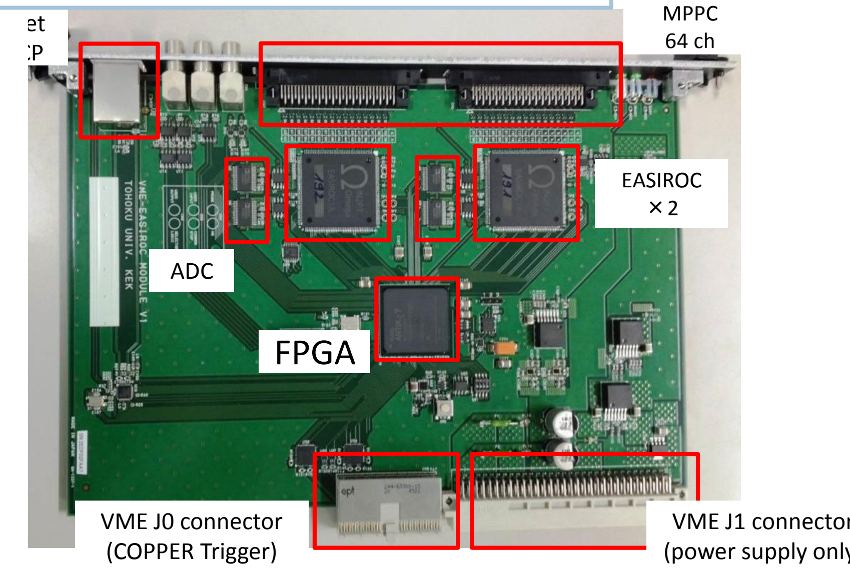
Fiber Detector



Photon Sensor (MPPC)



Readout board (EASIROC board)



10^7 Hz beam handling at J-PARC 2ndary beamline

- Requirement
  - Stable operation up to 10^8 Hz beam
  - Time resolution better than 0.8 ns

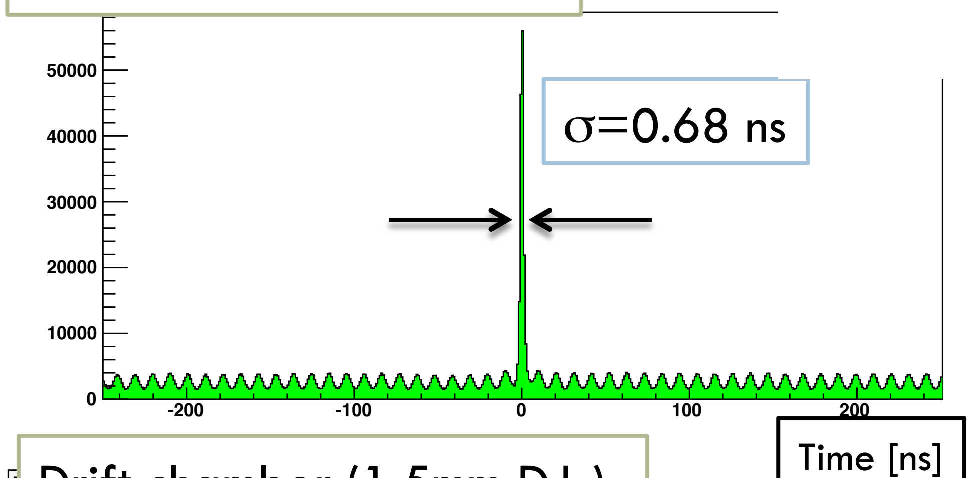
Fiber tracker with MPPC readout

- Scintillation fiber tracker
- Compact MPPC PCB
  - 32 ch MPPCs
- Readout board (EASIROC board)
  - 32 ch operation
  - Multihit TDC, ADC

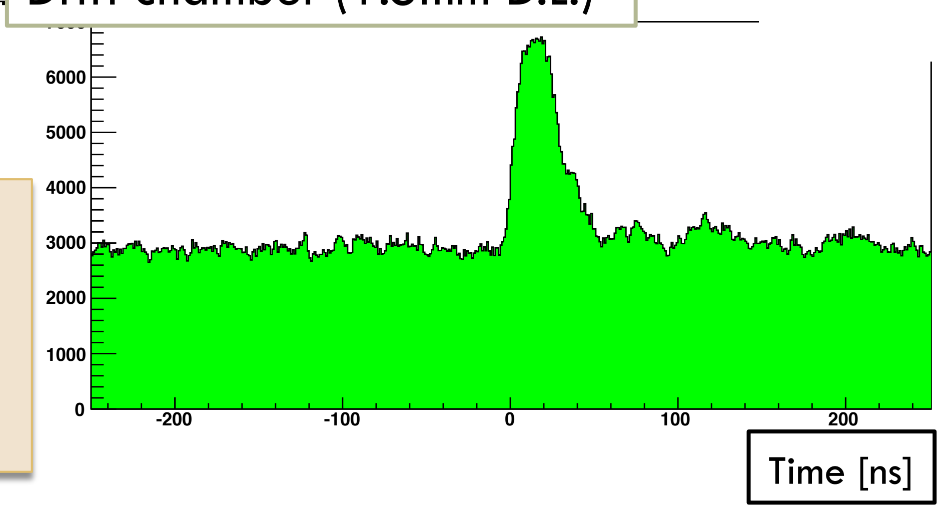
Slide by Koji Miwa

Operation E10
@ 12 M/spill
- Time resolution = 0.68 ns
- Efficiency 98%

BFT-X Time distribution



Drift chamber (1.5mm D.L.)



J-PARC Research Building

- Gathering place for users
  - No permanent office due to limited space but Large Open Space for users
    - Permanent office space at IQBRC etc.
  - Meeting facilities
    - Small ~ mid size collaboration meeting / workshop
    - Seminar
  - Cafeteria
    - Lunch / decent coffee and tea
- Supporting staff office
  - User's office (in discussion)
  - Safety division in the annex
- Small workshop

Full Open in July

Including Young at Heart!

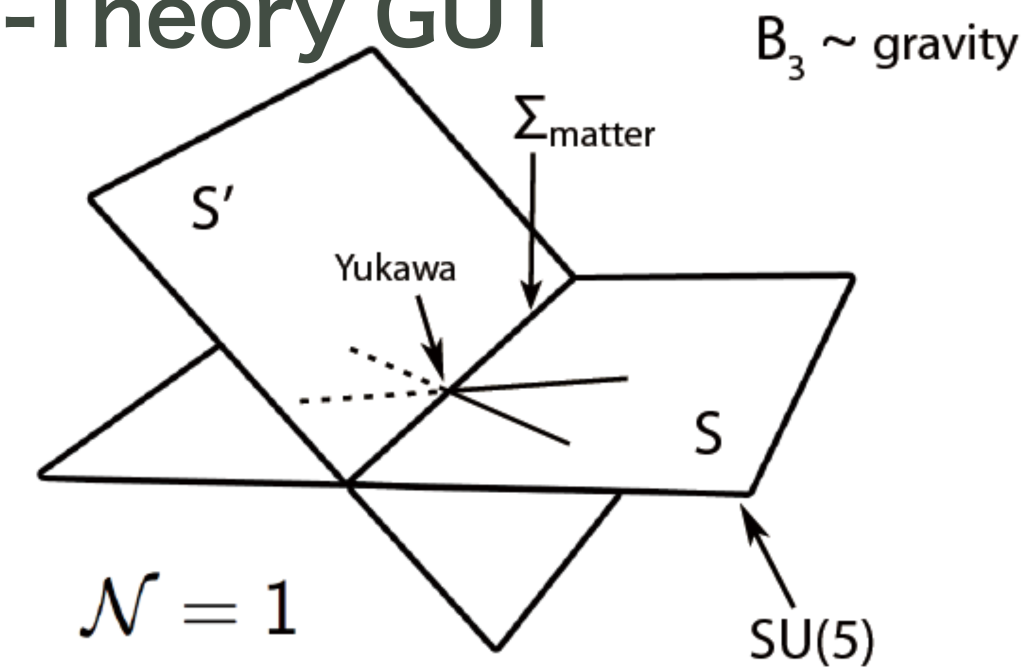
We invite young scientists to join us!

Flavor and Space-Time

J.J. Heckman, C.Vafa, Phys.Lett. B694 (2011) 482-484

- **CPV and Flavor Structure can be explained from higher dimensions / higher energies?**

F-Theory GUT



dim.	internal dim.	feature
10	$6 = \dim(B_3)$	gravity
8	$4 = \dim(S)$	gauge fields
6	$2 = \dim(S \cap S')$	matter
4	$0 = \dim(S \cap S' \cap S'')$	interactions

$$|V_{CKM}^{F-th}| \sim \begin{pmatrix} 1 & \alpha_{GUT}^{1/2} & \alpha_{GUT}^{3/2} \\ \alpha_{GUT}^{1/2} & 1 & \alpha_{GUT} \\ \alpha_{GUT}^{3/2} & \alpha_{GUT} & 1 \end{pmatrix} \sim \begin{pmatrix} 1 & 0.2 & 0.008 \\ 0.2 & 1 & 0.04 \\ 0.008 & 0.04 & 1 \end{pmatrix}$$

$$|V_{CKM}^{\mathrm{obs}}| \sim \begin{pmatrix} 0.97 & 0.23 & 0.004 \\ 0.23 & 0.97 & 0.04 \\ 0.008 & 0.04 & 0.99 \end{pmatrix}$$

$$|V_{PMNS}^{F-th}| \sim \begin{pmatrix} U_{e1} & \alpha_{GUT}^{1/4} & \alpha_{GUT}^{1/2} \\ \alpha_{GUT}^{1/4} & U_{\mu 2} & \alpha_{GUT}^{1/4} \\ \alpha_{GUT}^{1/2} & \alpha_{GUT}^{1/4} & U_{\tau 3} \end{pmatrix} \sim \begin{pmatrix} 0.87 & 0.45 & 0.2 \\ 0.45 & 0.77 & 0.45 \\ 0.2 & 0.45 & 0.87 \end{pmatrix}$$

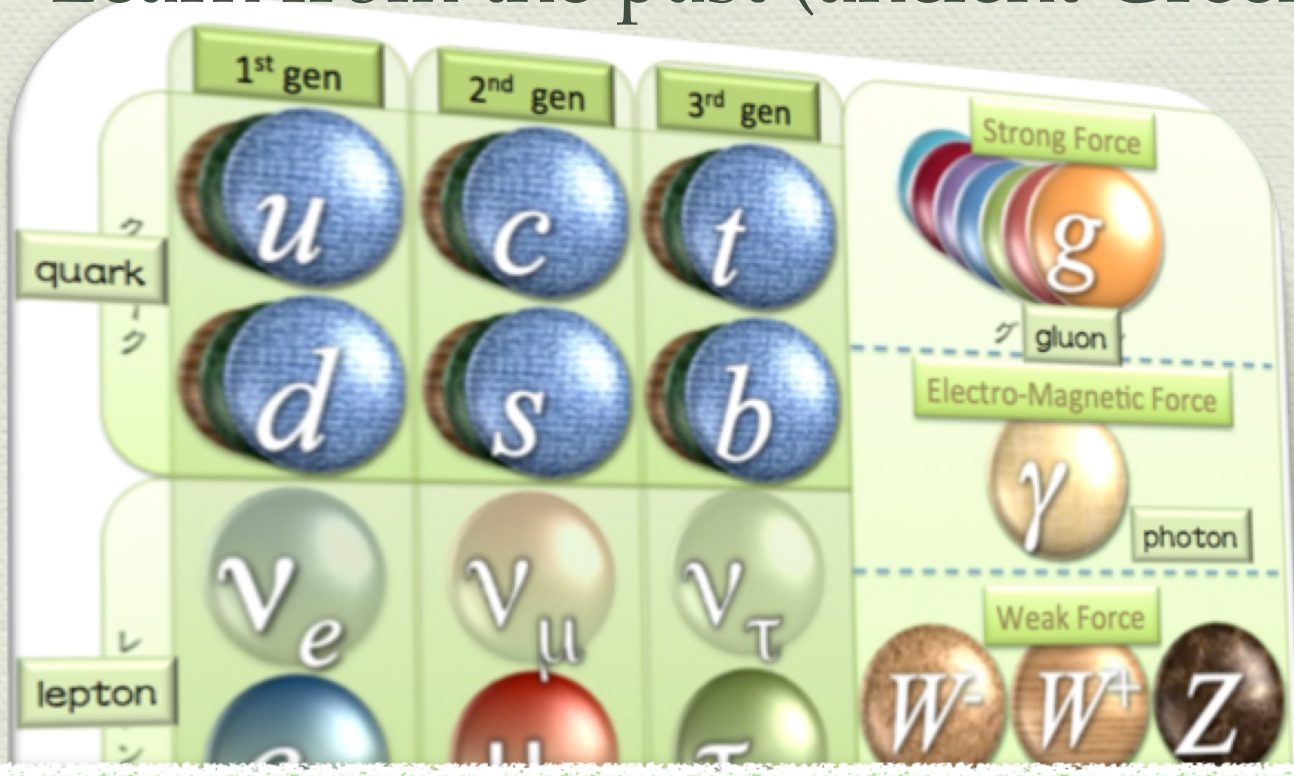
$$|V_{PMNS}^{\mathrm{obs}}| \sim \begin{pmatrix} 0.77-0.86 & 0.50-0.63 & 0-0.22 \\ 0.22-0.56 & 0.44-0.73 & 0.57-0.80 \\ 0.21-0.55 & 0.4-0.71 & 0.59-0.82 \end{pmatrix}$$

$$\left|J_{\mathrm{quark}}^{F-th}\right| \sim \alpha_{GUT}^3 \sim 6 \times 10^{-5}$$

$$\left|J_{\mathrm{lepton}}^{F-th}\right| \sim \alpha_{GUT} \sim 4 \times 10^{-2}.$$

Go Beyond the SM

- Learn from the past (ancient Greek Philosophy) !

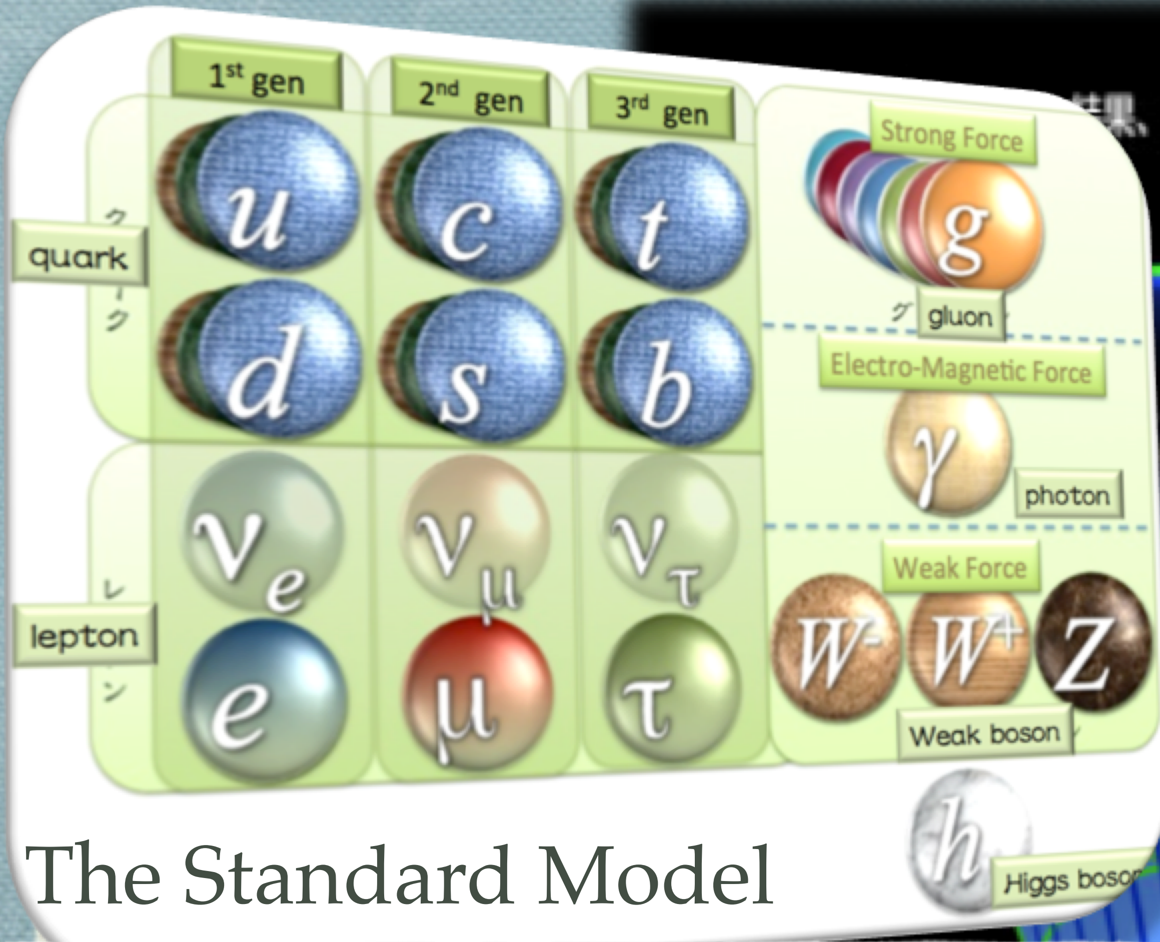


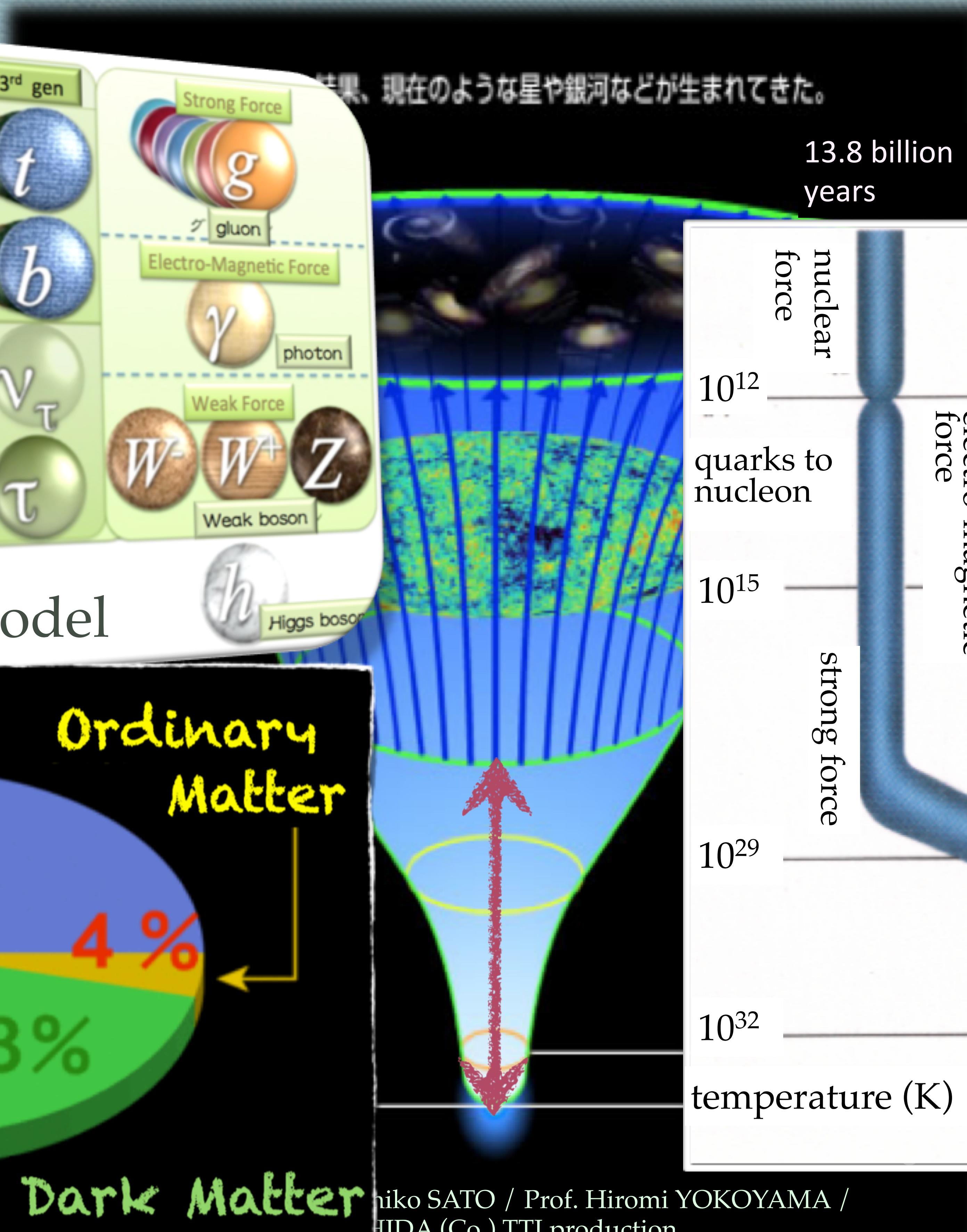
The basic framework is identical; small number of elements interacts thru a number of interaction to produce everything!

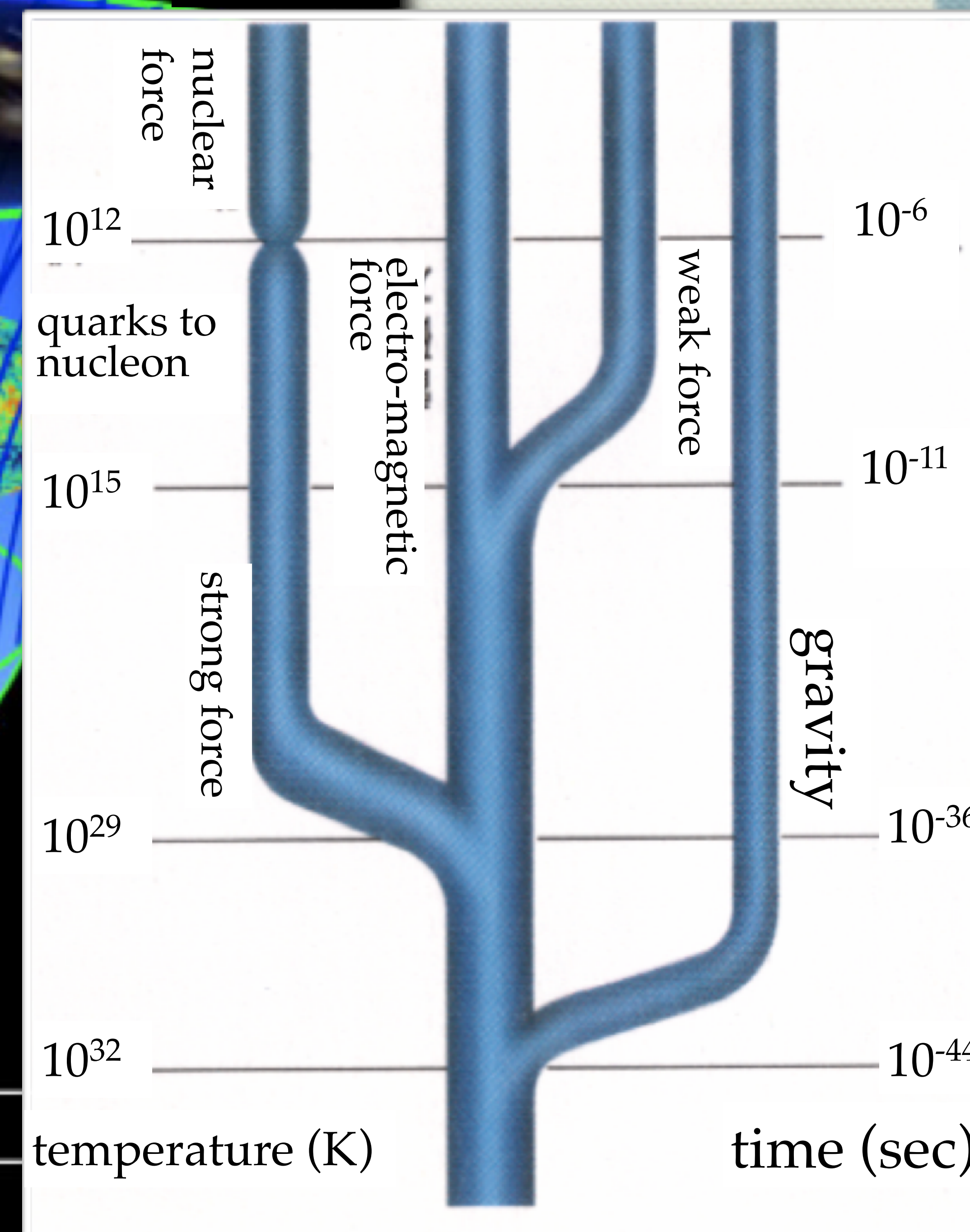
Our view is limited by what we can see, touch, and feel !

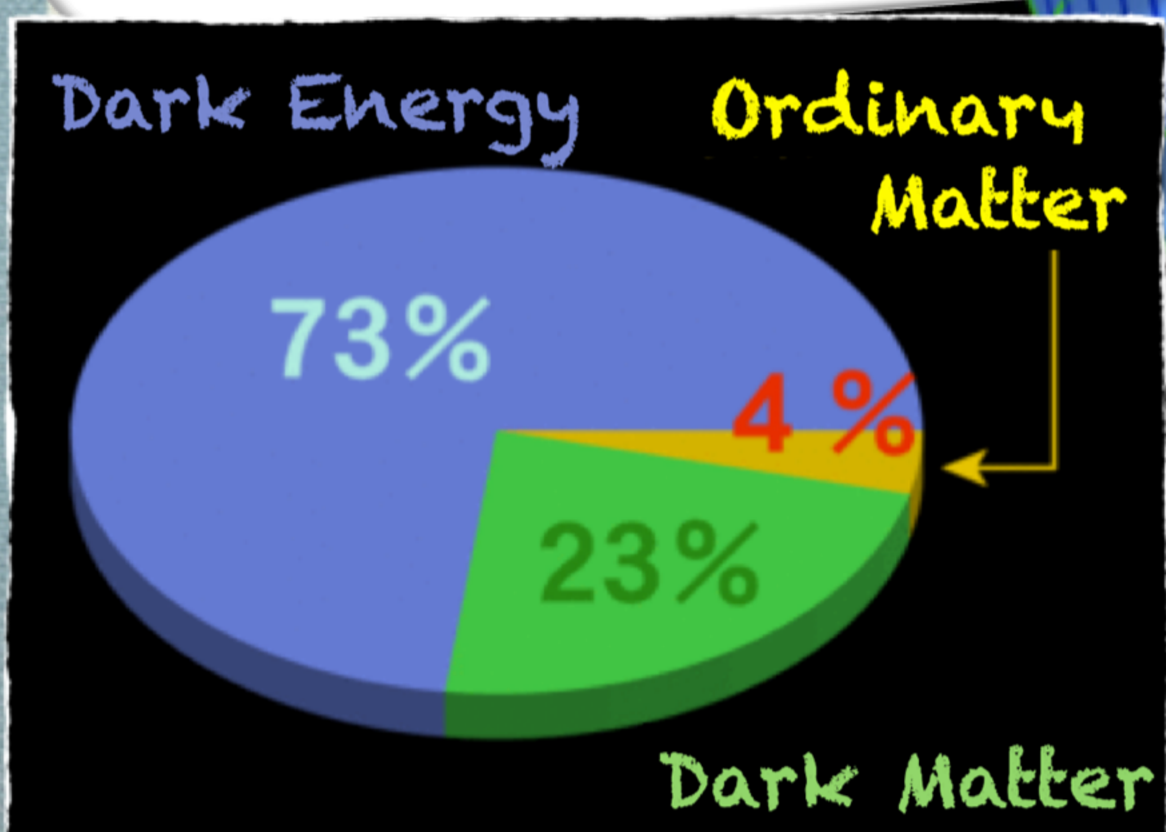
We need to extend our "sense" ; micro scope / ultra-sensitive devices

History of Universe & the Standard Model









J-PARC: Next 5 Years

- Achieve Design Intensity
- More Science Outputs
- Lead Intensity Frontier

Accelerator

- RCS:1 MW / MR 0.75 MW
- Explore Multi-MW Possibility

ADS (Acc. Driven System)

Staged approach from ADS Target Test Facility to Transmutation Exp. Facility

Neutrino

- Established non-zero θ_{13}
- Constrain CPV. Hiarachy?
- Prepare next gen. of Exp.

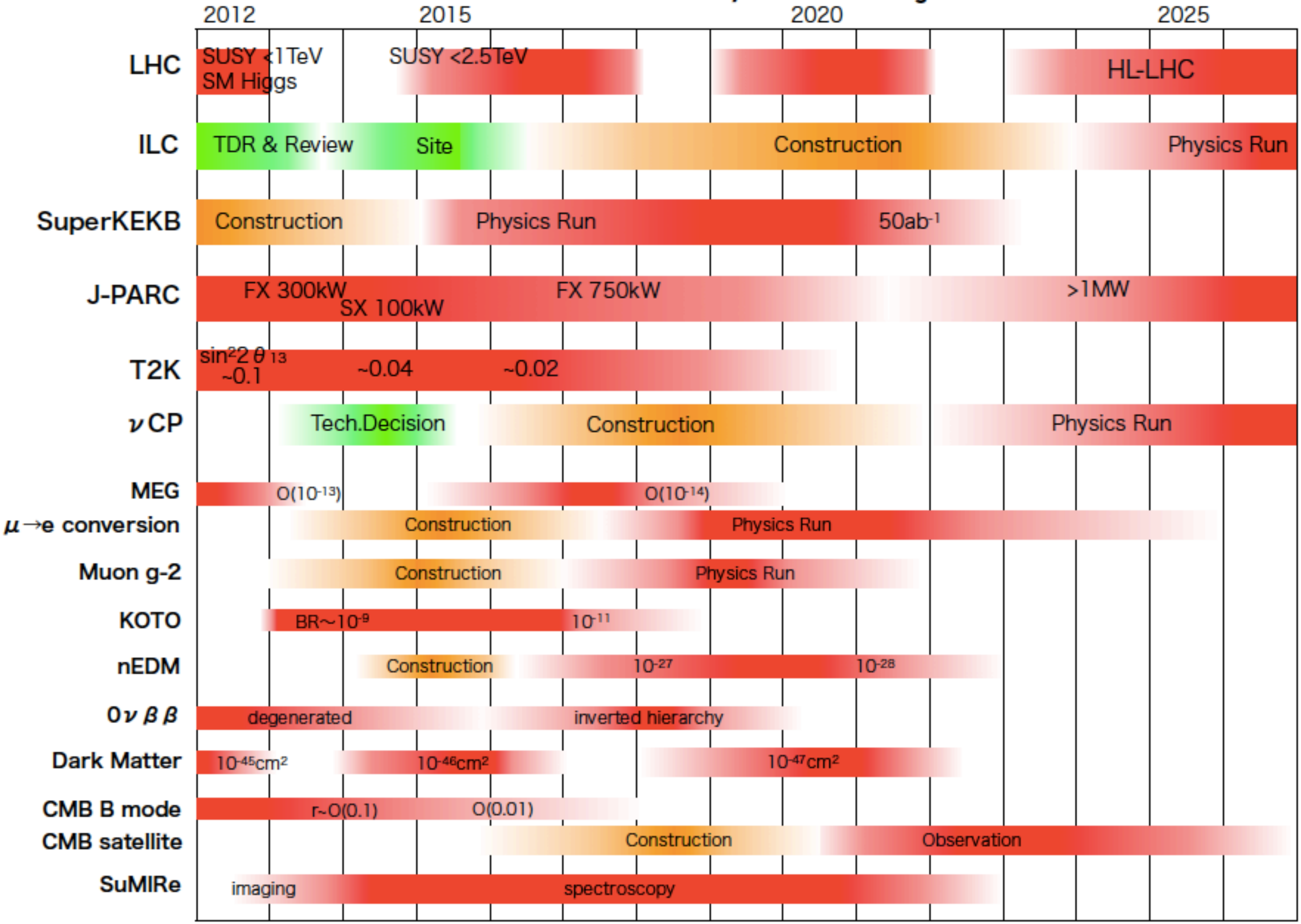
Hadron

- Restart "Physics Production" : Hyper-nucleus, K-rare decays
- Complete new beam line for COMET and 1^{st} results

MLF

- Neutron : Diverse Material and Life Science
- Muon : Produce outputs from D and U lines / New beam lines to extend Muon Science Frontier (g-2/EDM/HFS/

Timelines of Current/Future Projects

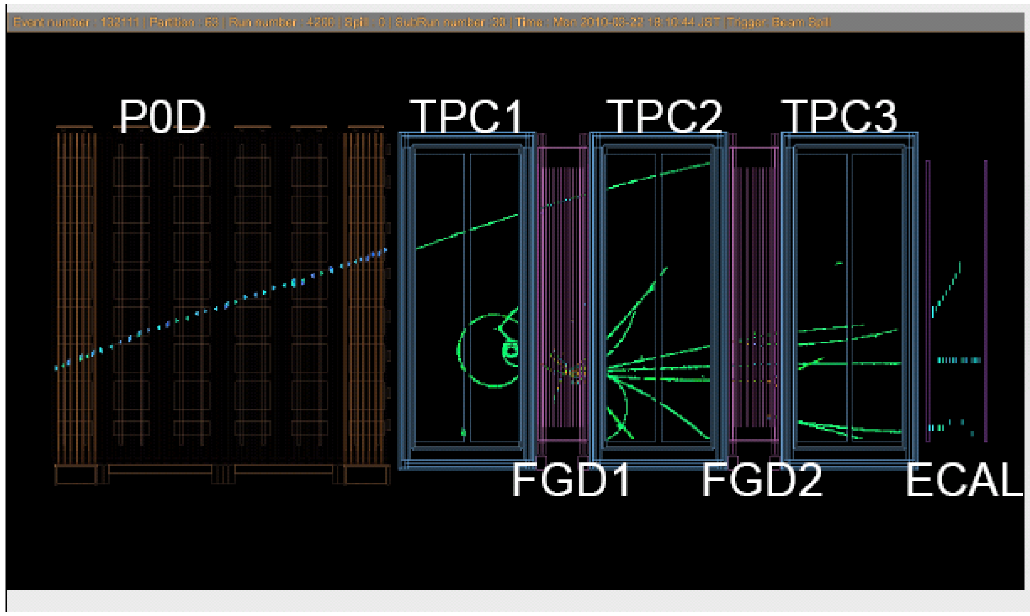


Neutrino detectors

- Neutrino detector development at J-PARC neutrino facility
  - Near detector upgrade
  - Test experiments (T59, T60,)
  - New ideas (nuPRISM,)
- Hyper-K R&D

T2K near detector upgrade

Current T2K-ND280

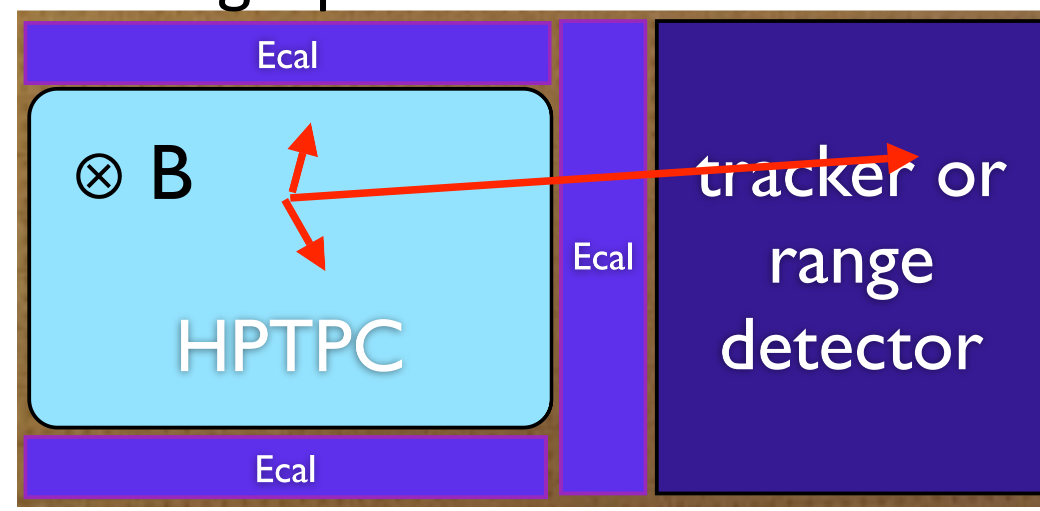


- 3 TPCs (2×2×1m³ each) with bulk micromegas
- Scintillator detectors with >50,000 MPPCs in total
- Inside UA1 magnet

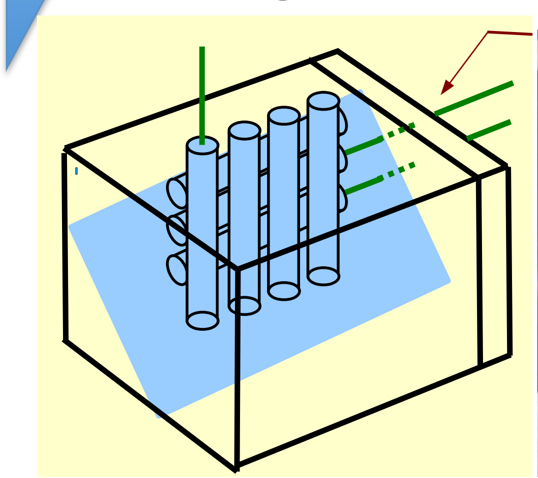
Possible upgrade under discussion

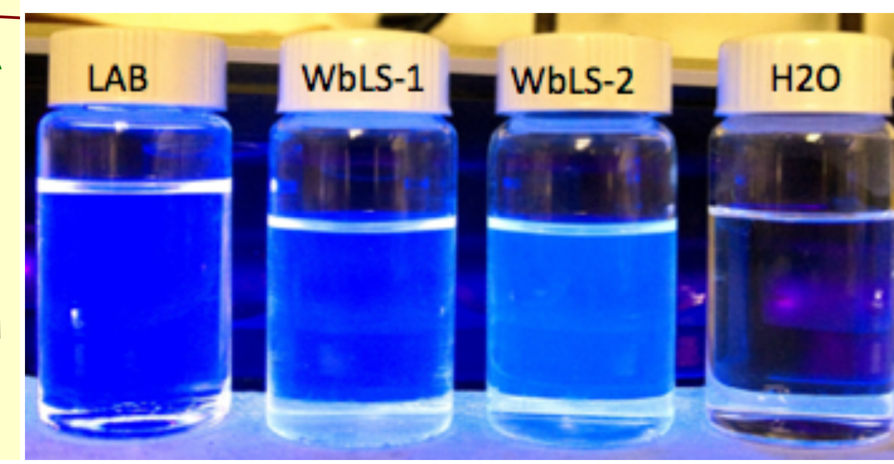
More precise study of ν interaction

High-pressure TPC?



Finer segmentation with water-based scinti.?



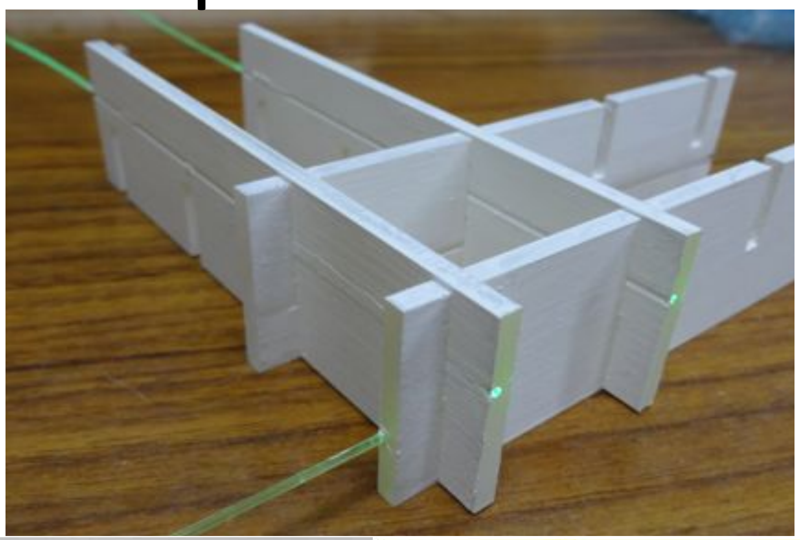


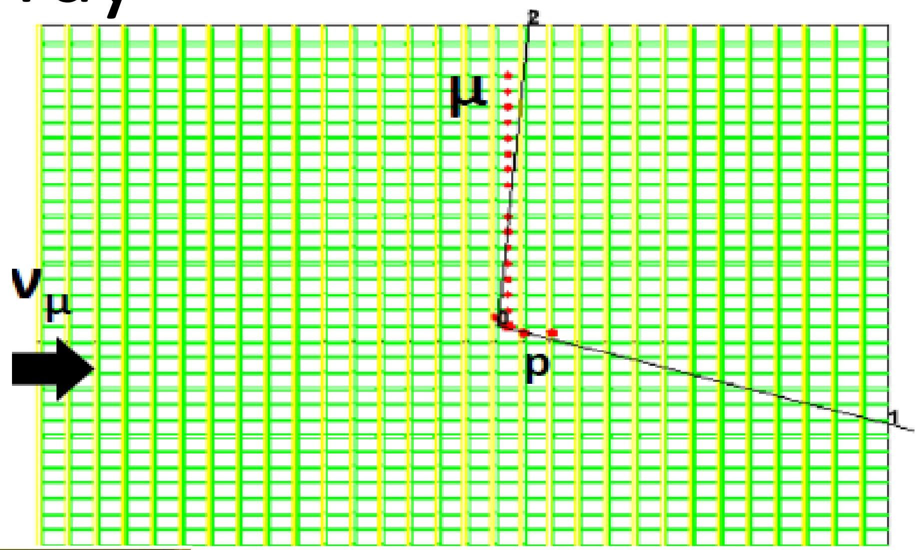
Scintillating fiber with improved MPPCs?

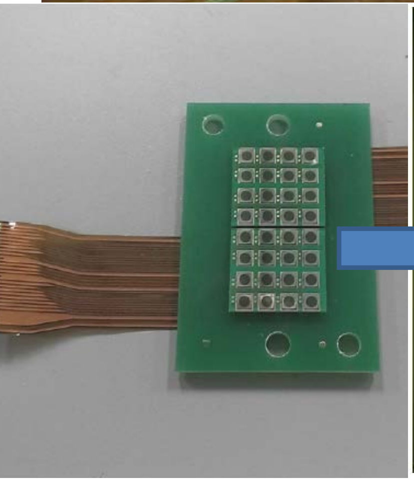
Test experiments for neutrino detector development

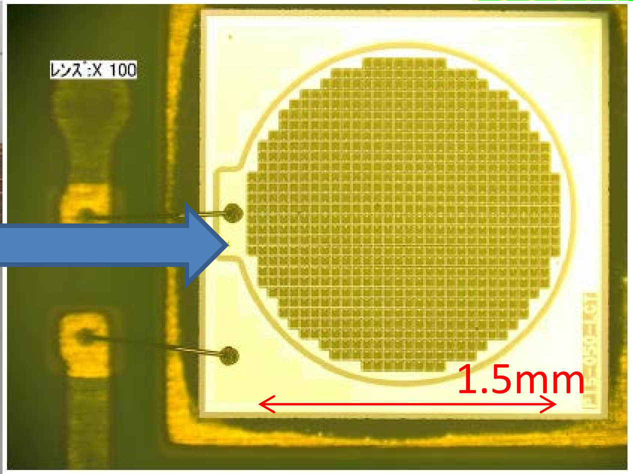
T59("WAGASCI")

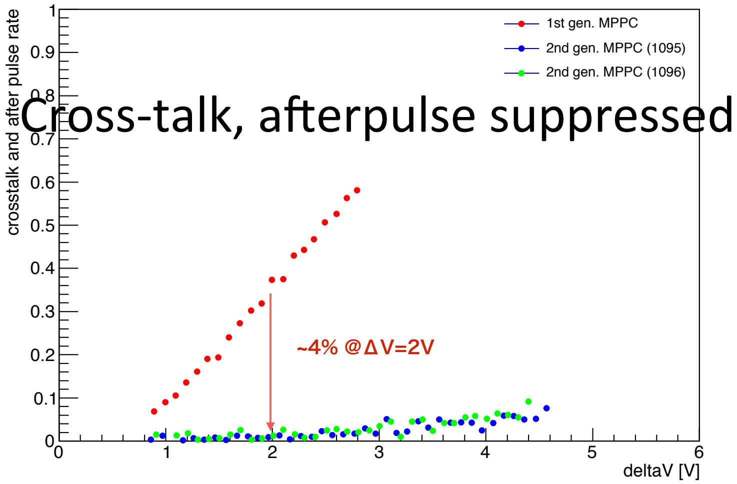
Large acceptance with H_2O target
By 3D grid structure of thin scintillator
+ improved MPPC array









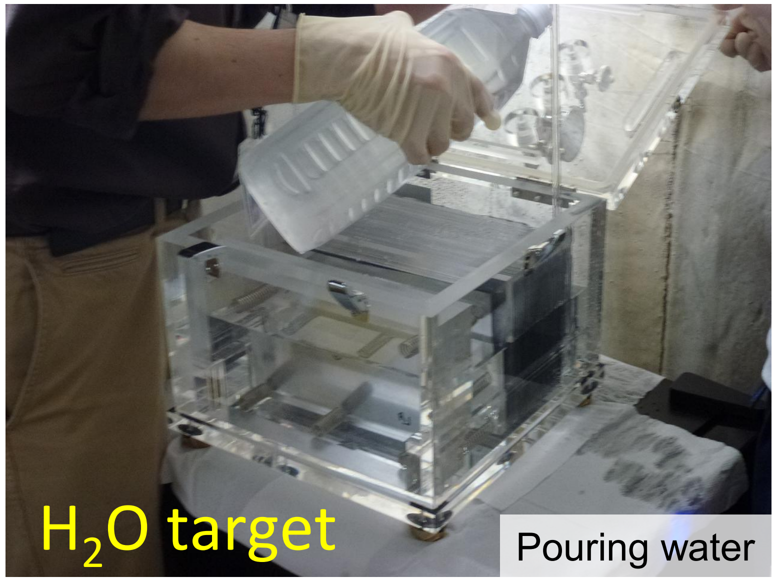


Cross-talk, afterpulse suppressed

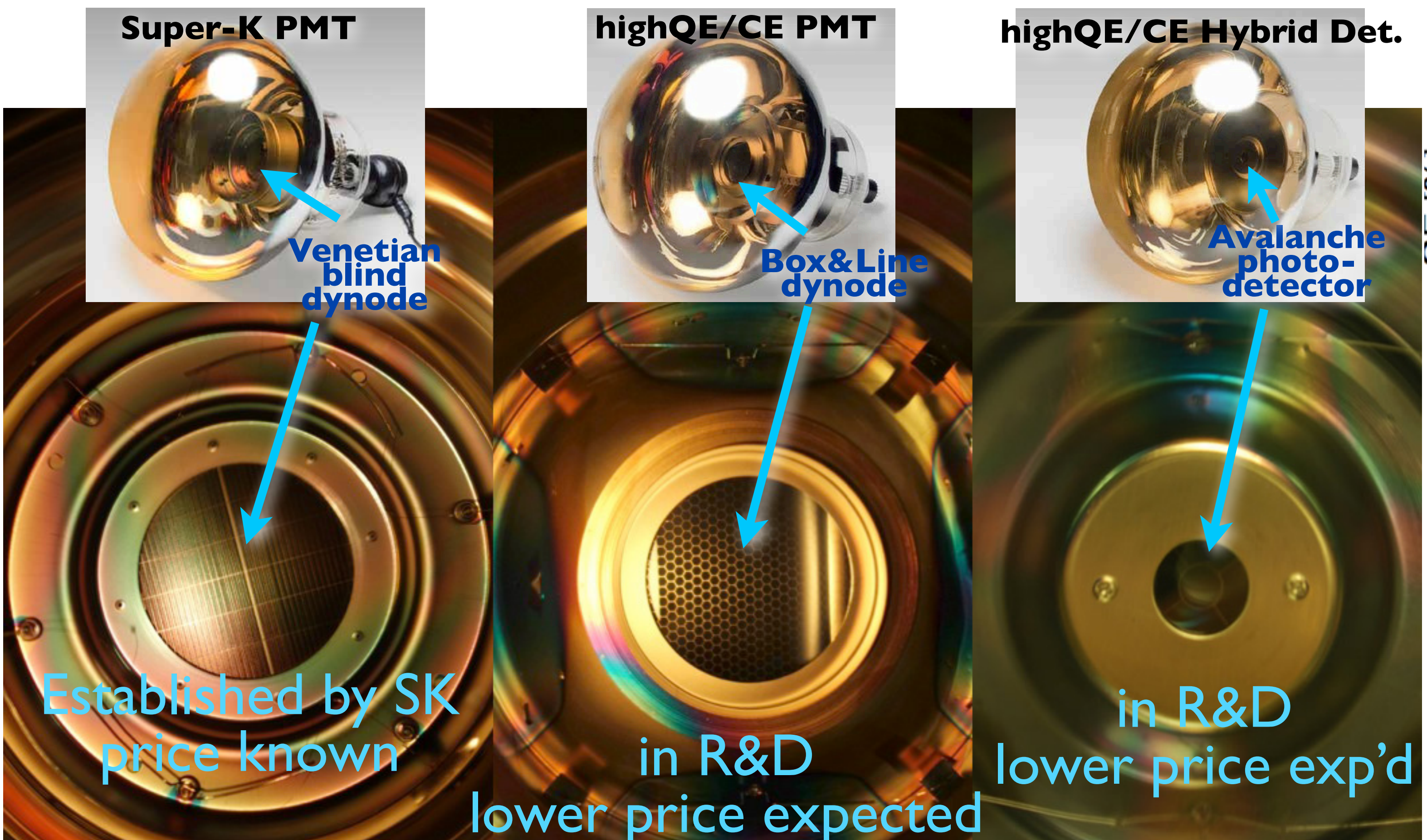
T60

Emulsion detector for <GeV neutrino with various target

Emulsion films
(vacuum packed)

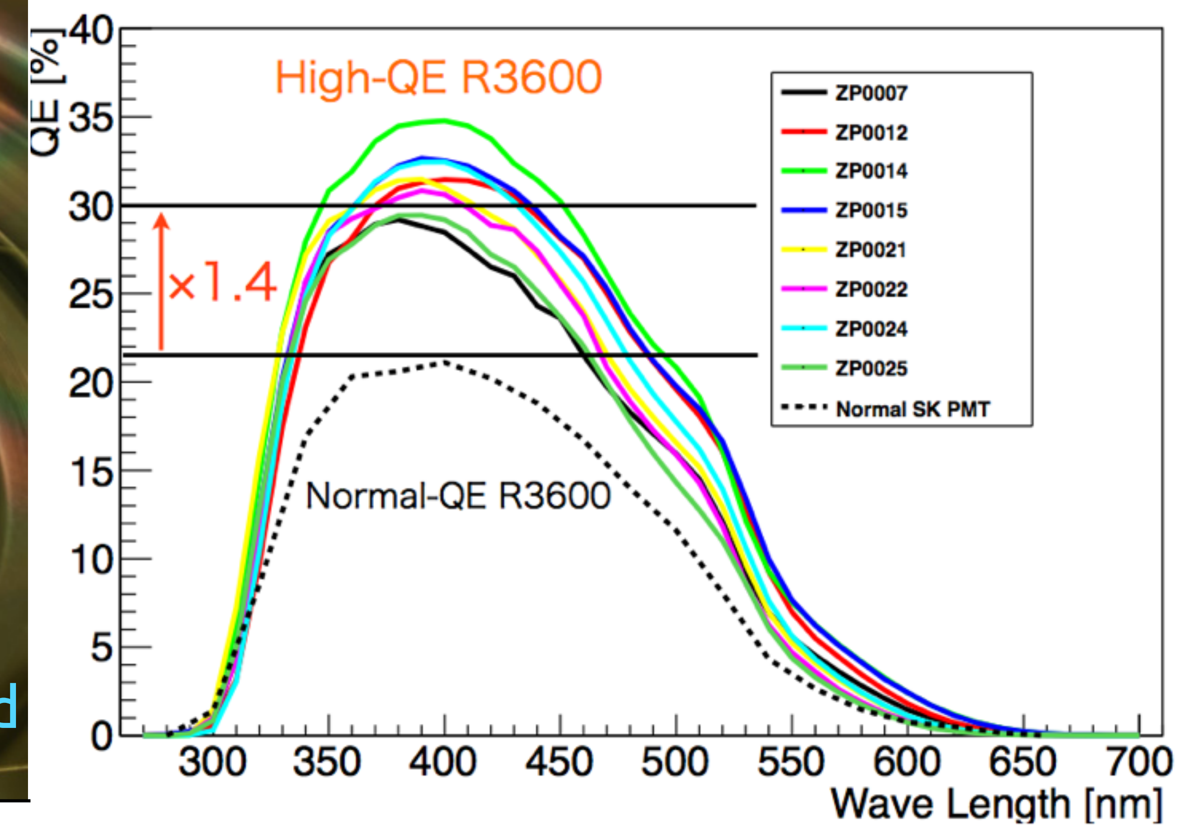


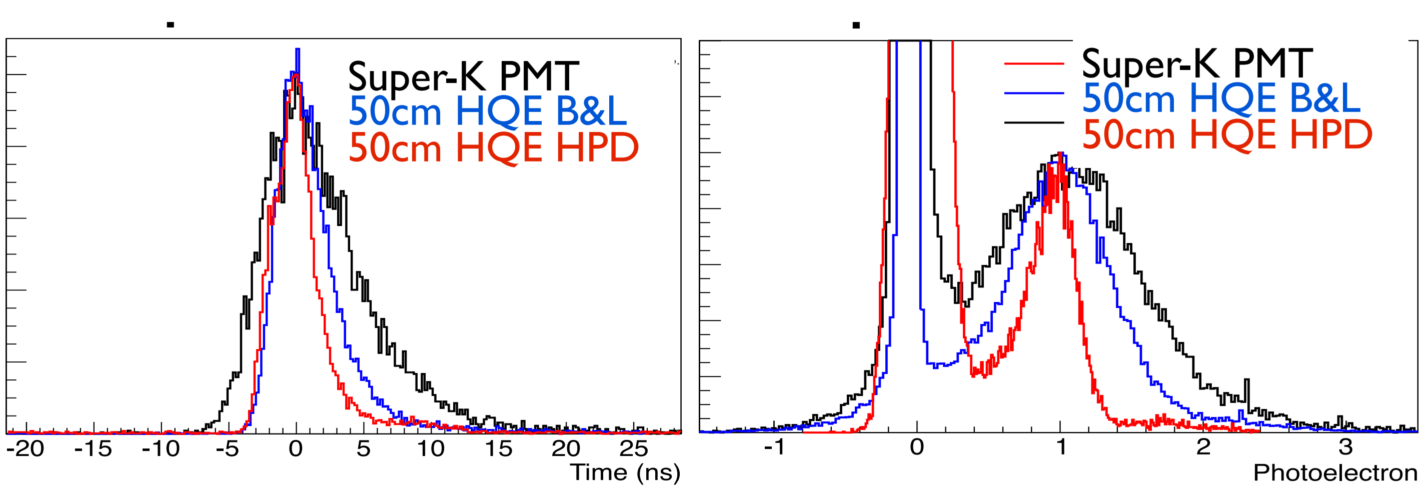
Large aperture photosensors



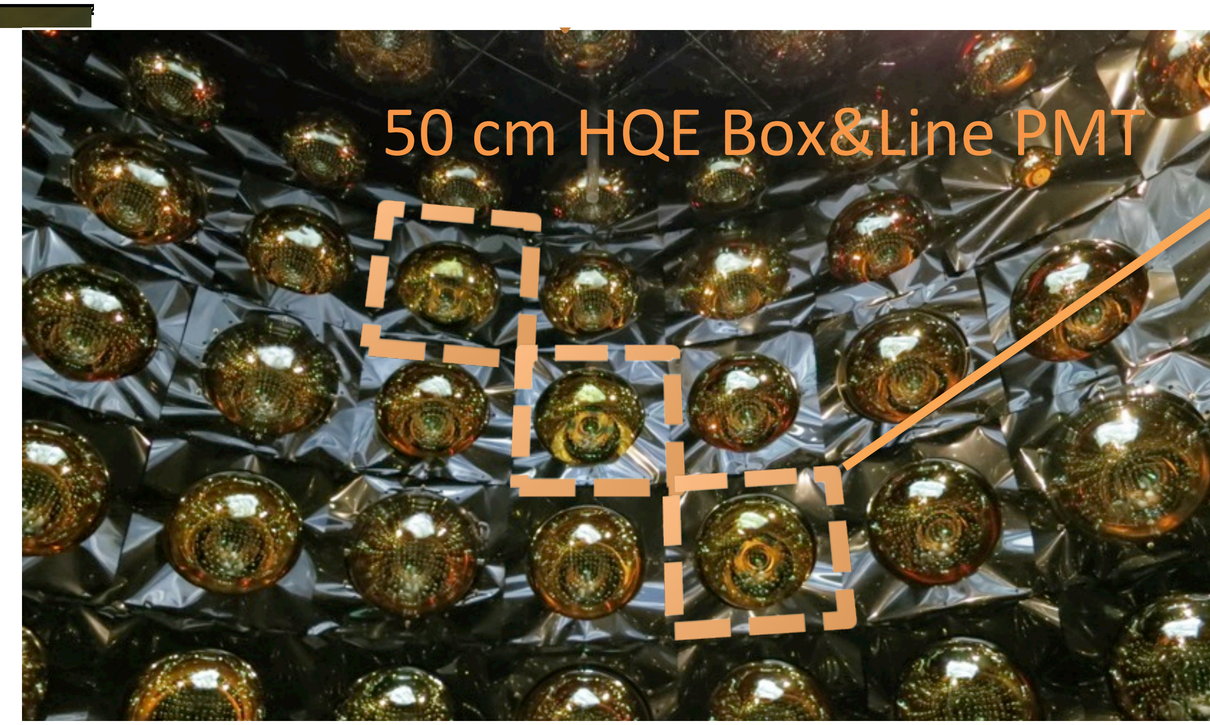
Quantum Efficiency	22%	30%	30%
Collection Efficiency	80%	93%	95%

>30% QE achieved with 50cm dia. tube

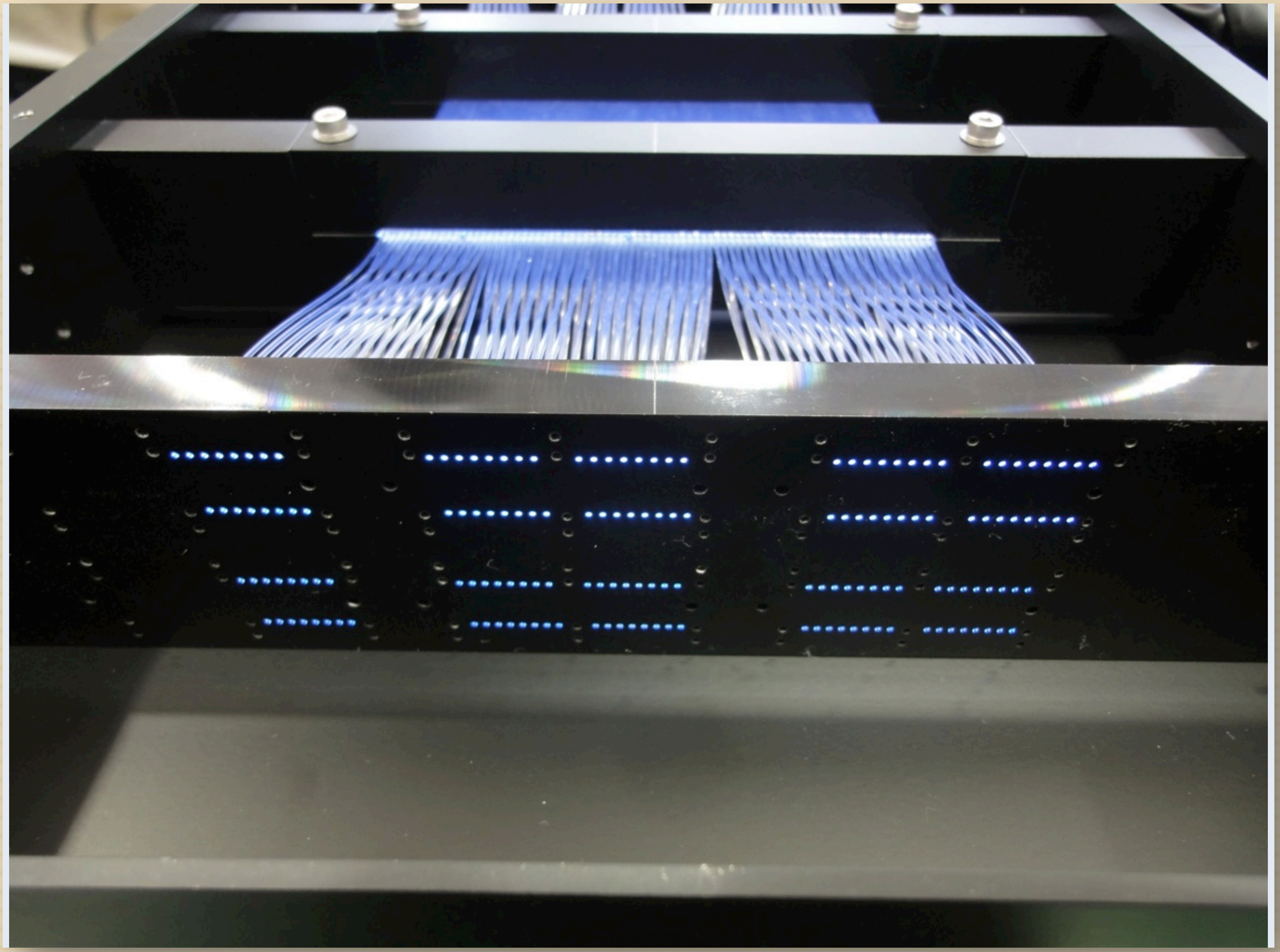




Improved timing and charge resolution



Long term test ongoing in 200ton water tank at Kamioka



E40 Preparation status

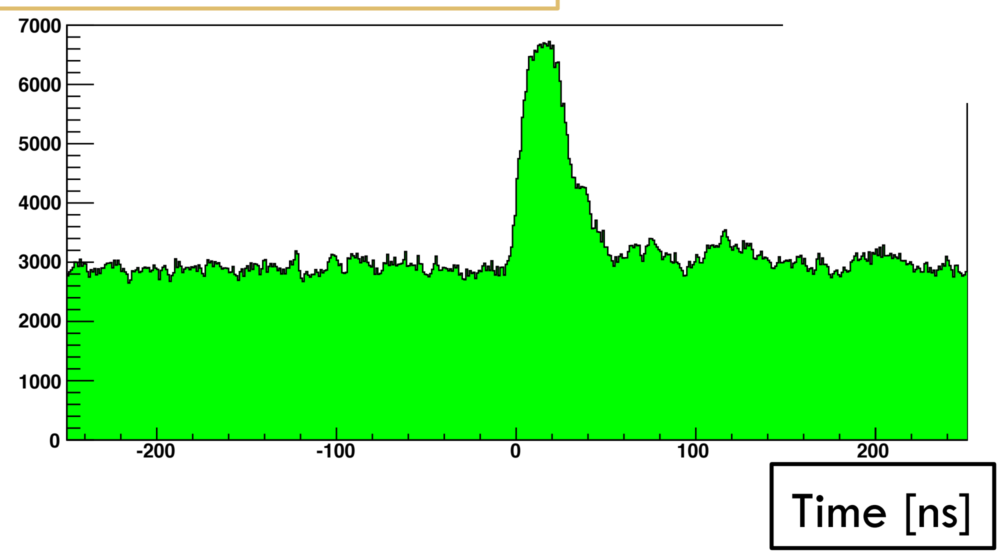
Beamline Fiber Tracker for high rate beam

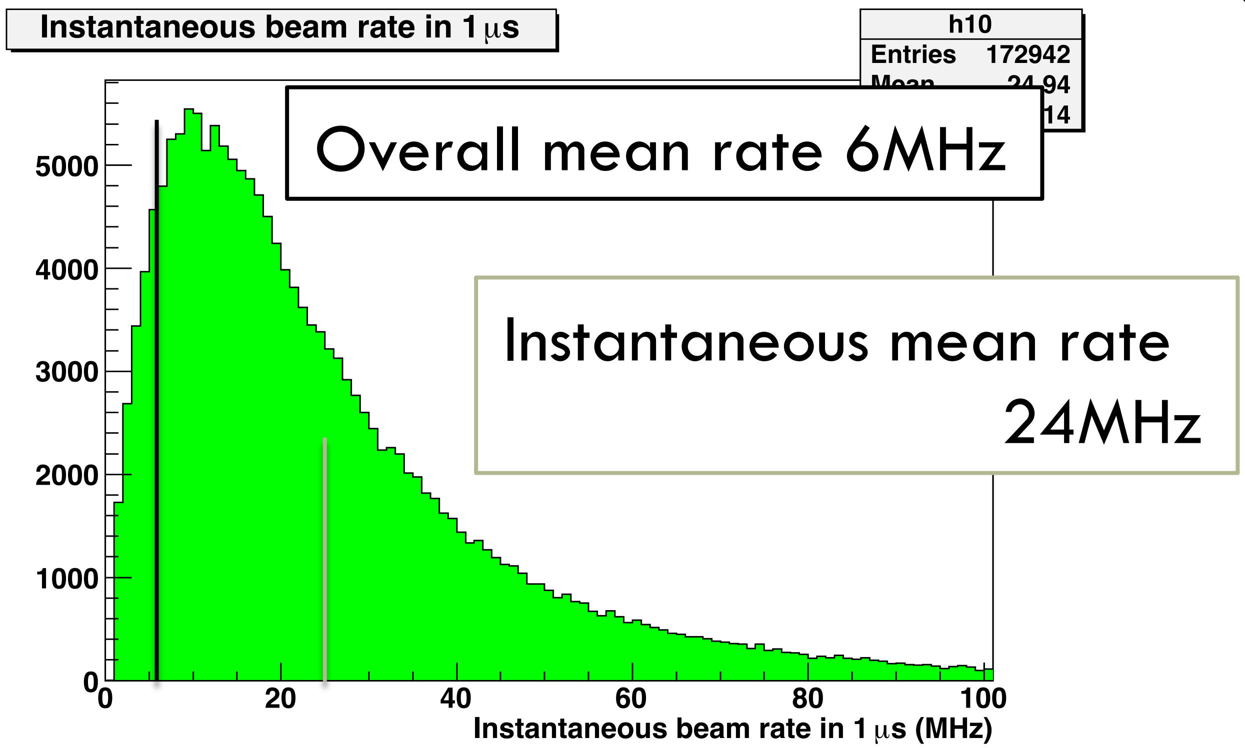
High rate π beam handling

- Σ beam is a secondary beam
  - 10^7Hz π beam is necessary for reasonable number of Σ beam
- Beam structure of J-PARC slow extraction

6 MHz beam @ E10 exp.

TDC (1.5 mm DL DC)



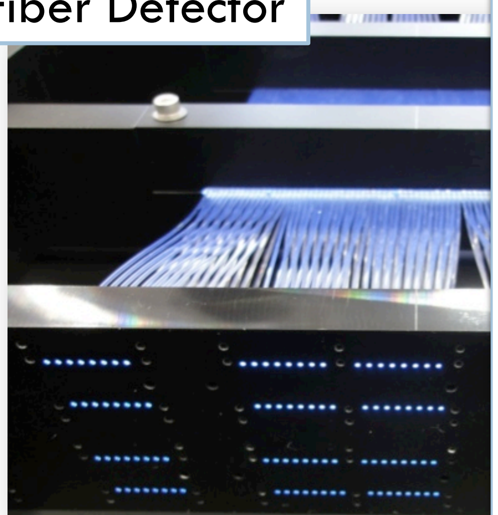


Stable operation under high intensity beam of 10^8 Hz
Good timing resolution to separate accidental background

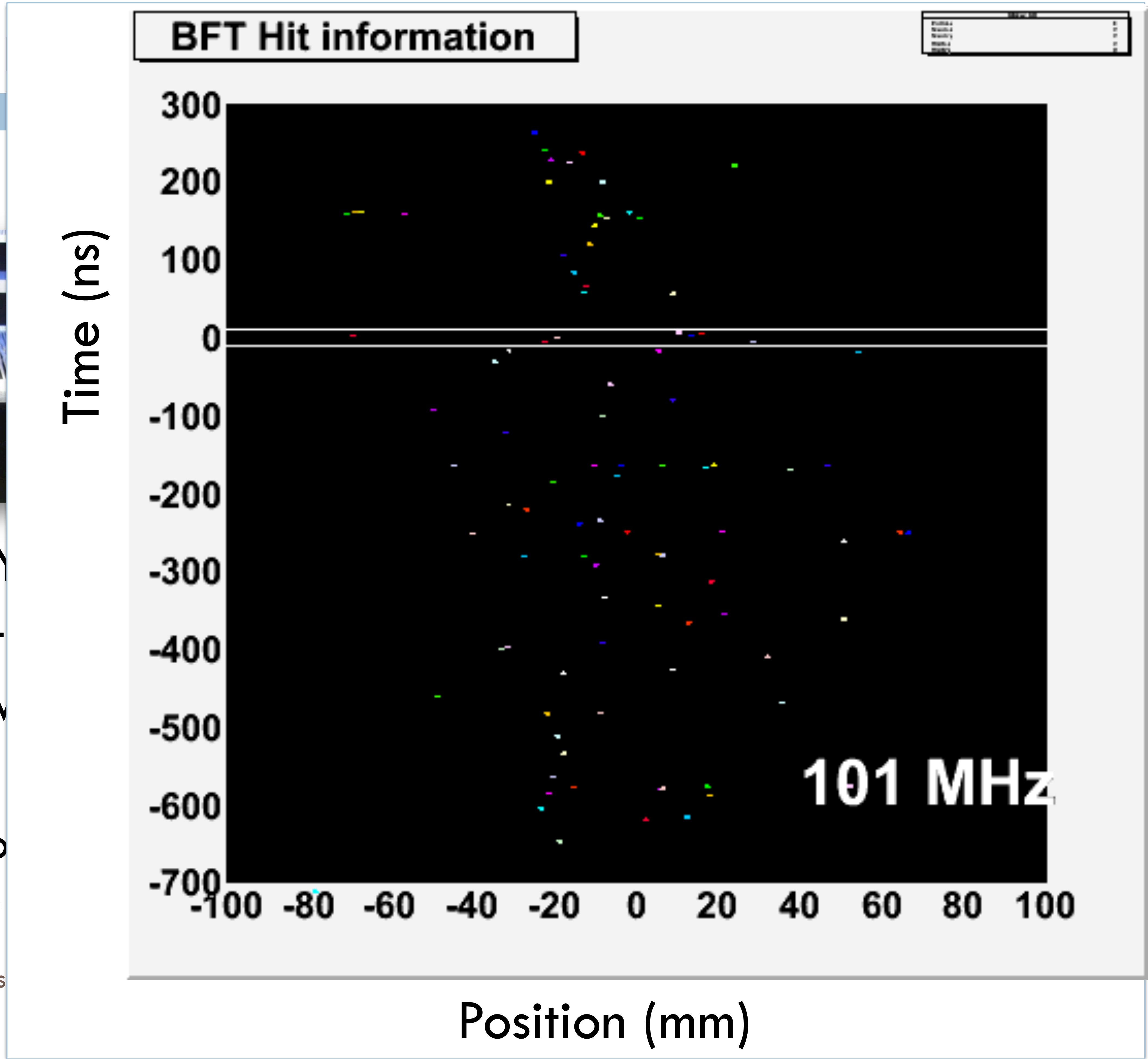
→ Fiber Tracker

Develop

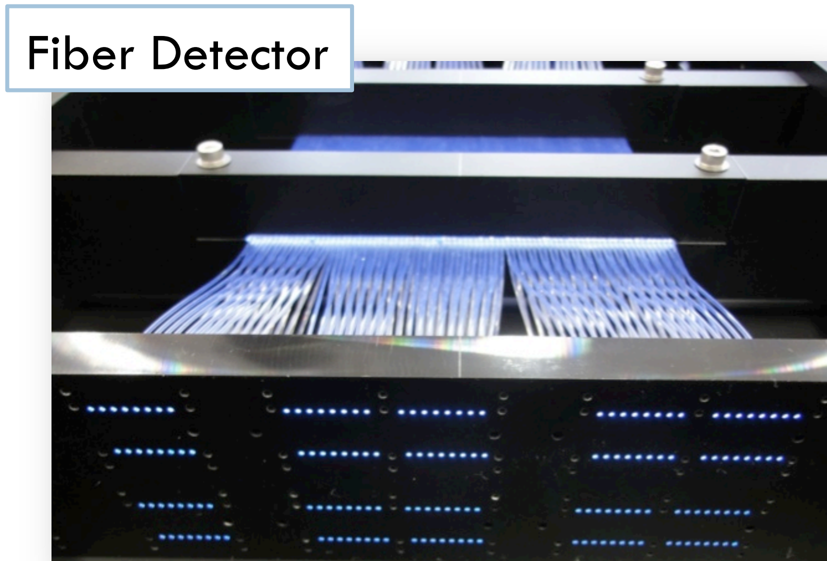
Fiber Detector

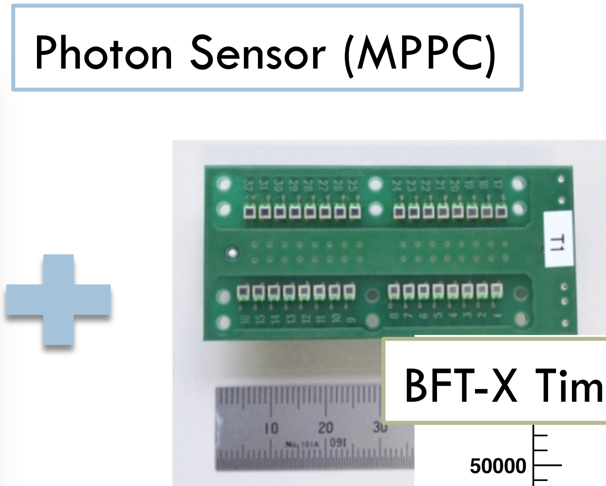


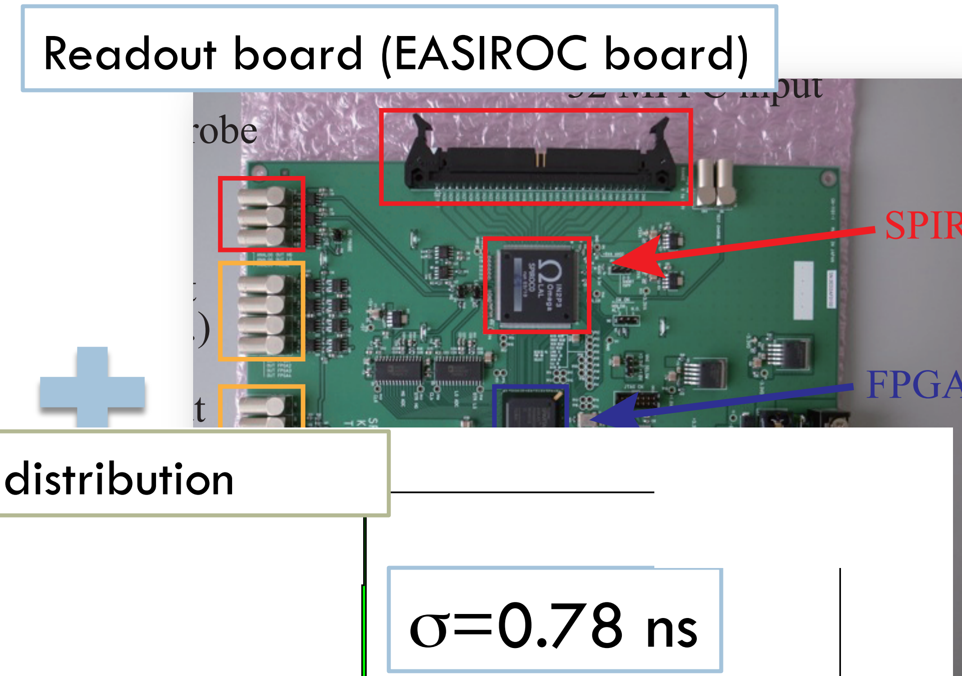
- KURARAY
- Compact
  - 32 ch M
- Readout
  - 32 ch o
  - Multihit



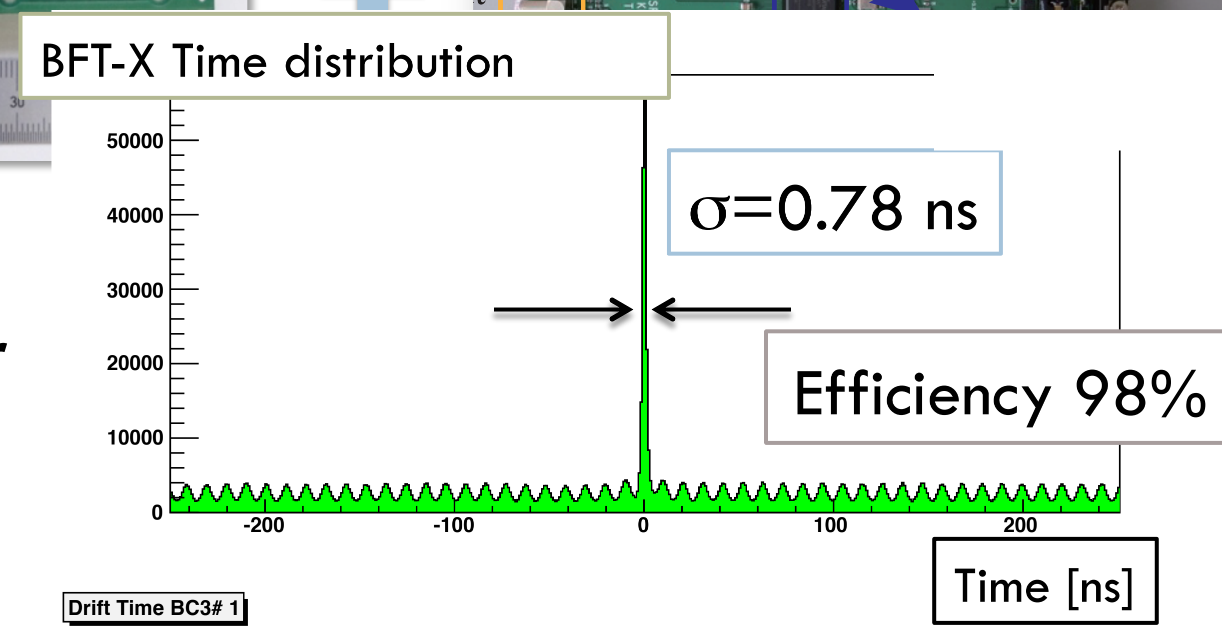
Development of Fiber Tracker

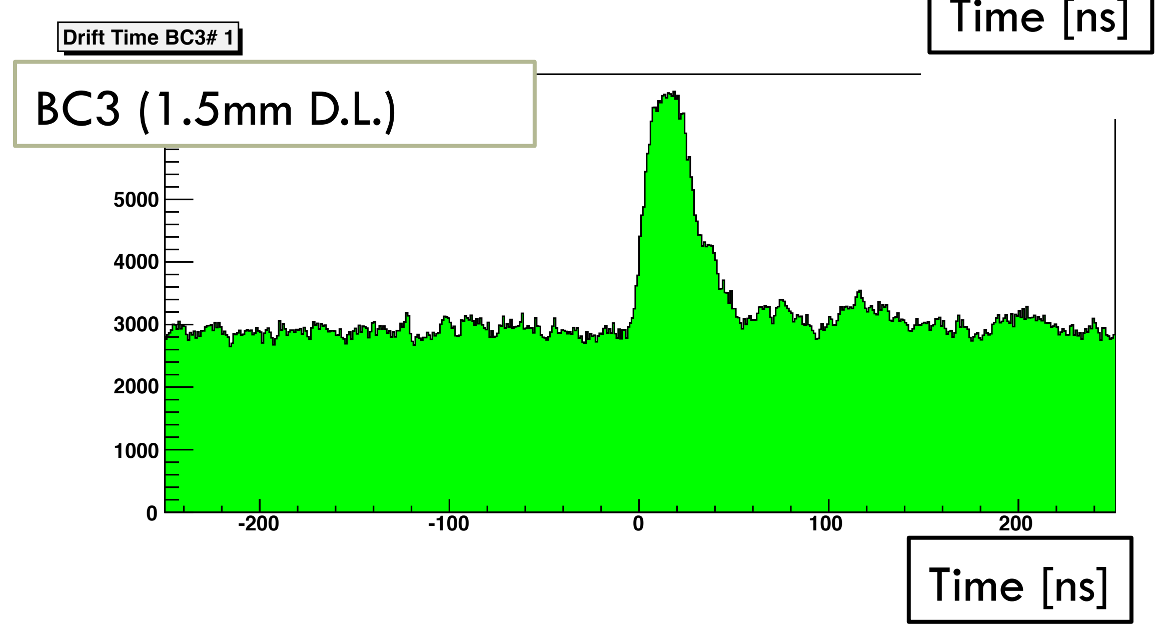




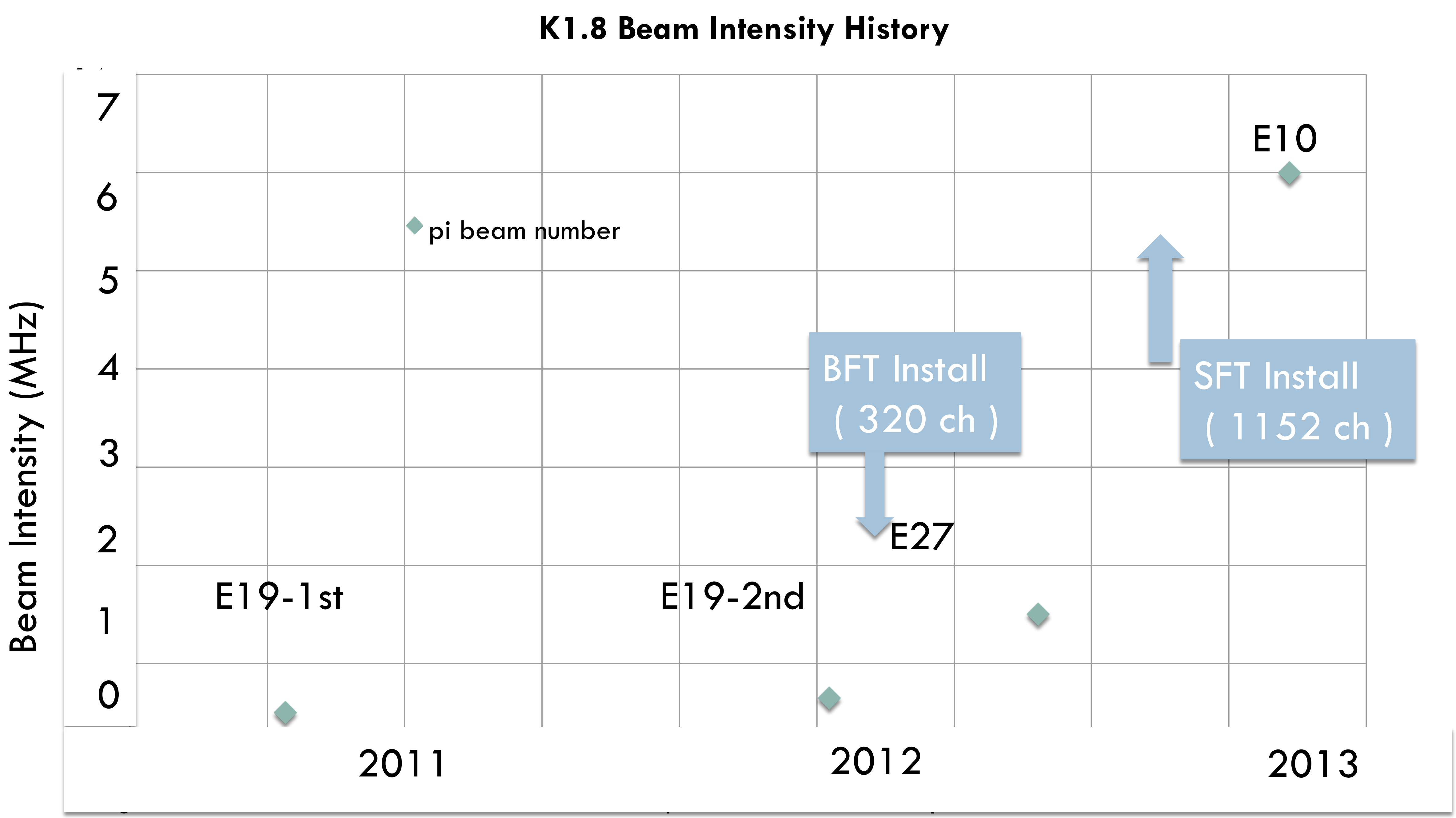


- KURARAY scintillation fiber
- Compact MPPC PCB
  - 32 ch MPPCs
- Readout board
  - 32 ch operation
  - Multihit TDC, ADC





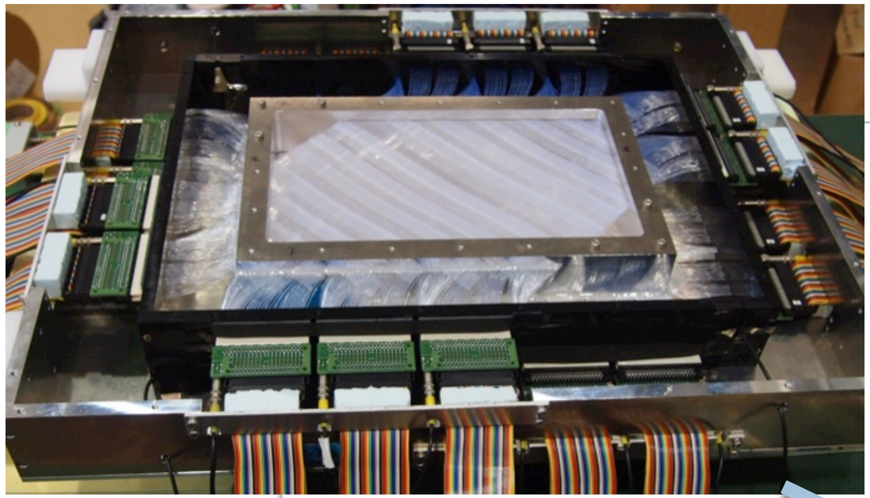
K1.8 beam intensity history



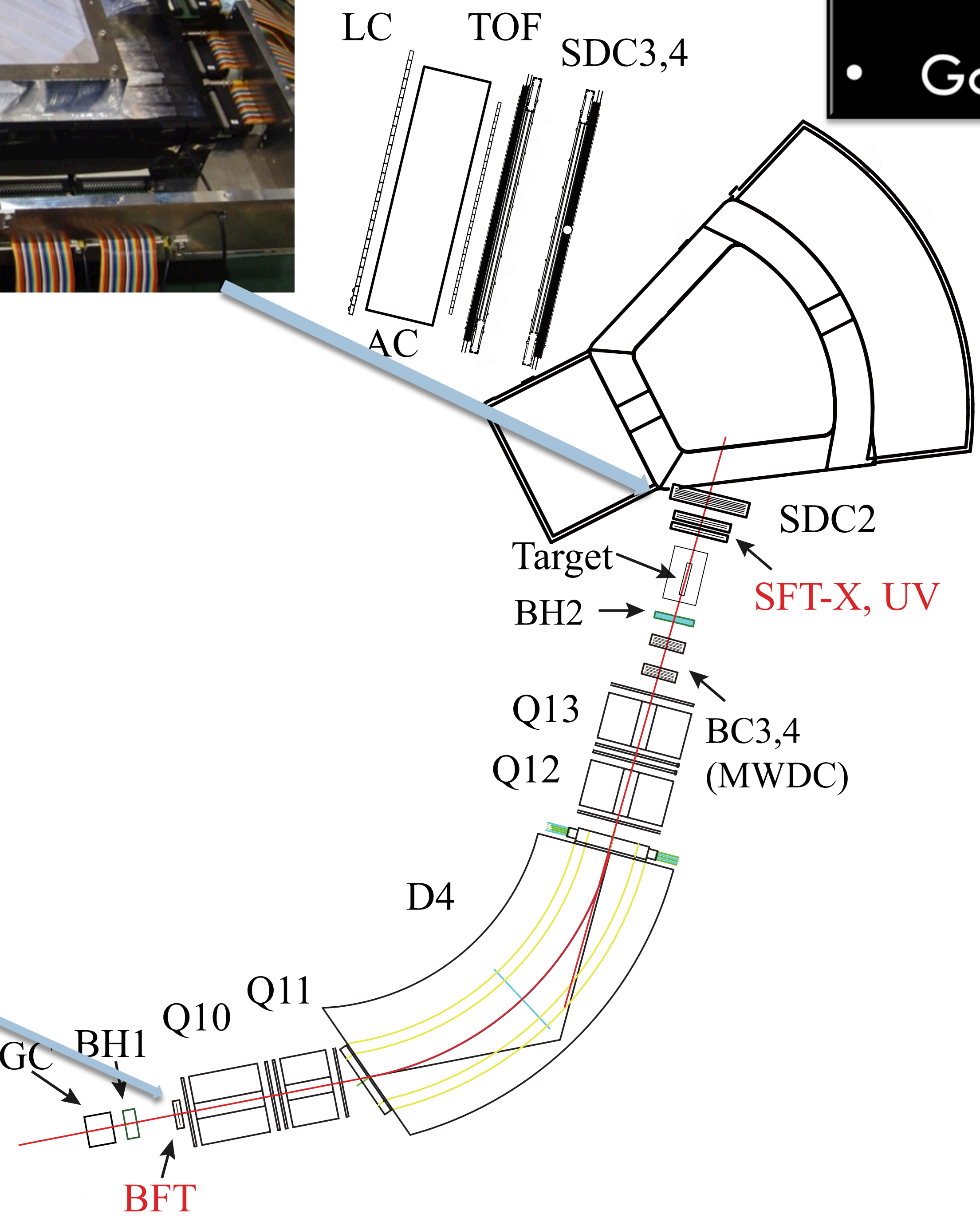
We become to use 10 times larger beam intensity.
We confirmed we can handle 10M Hz beam.

Experimental challenge

SFT

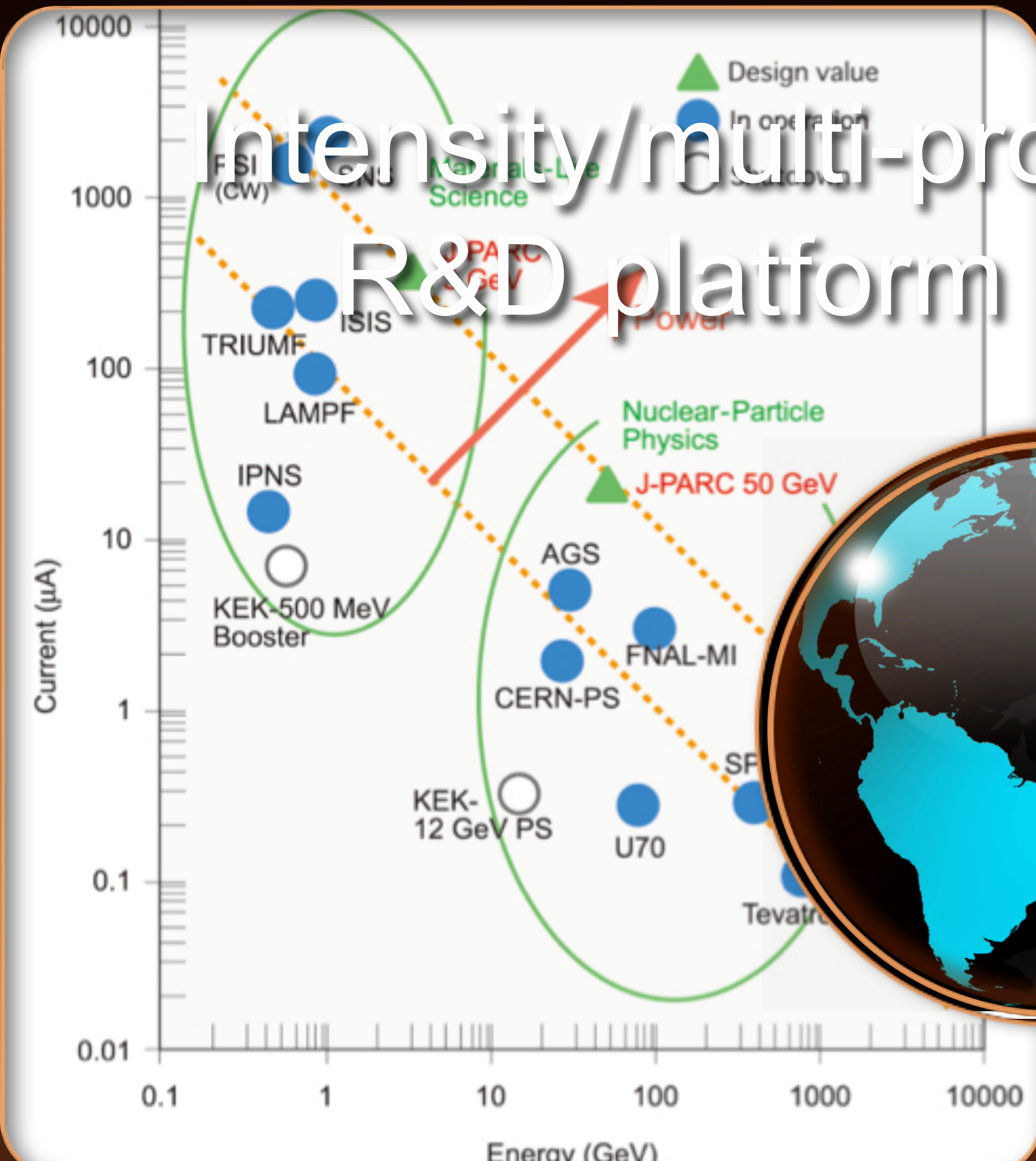


BFT



Beamline Fiber Trackers
- High efficiency for intense beam
- Good timing resolution

Intensity/multi-probes/science frontier requires technology frontier



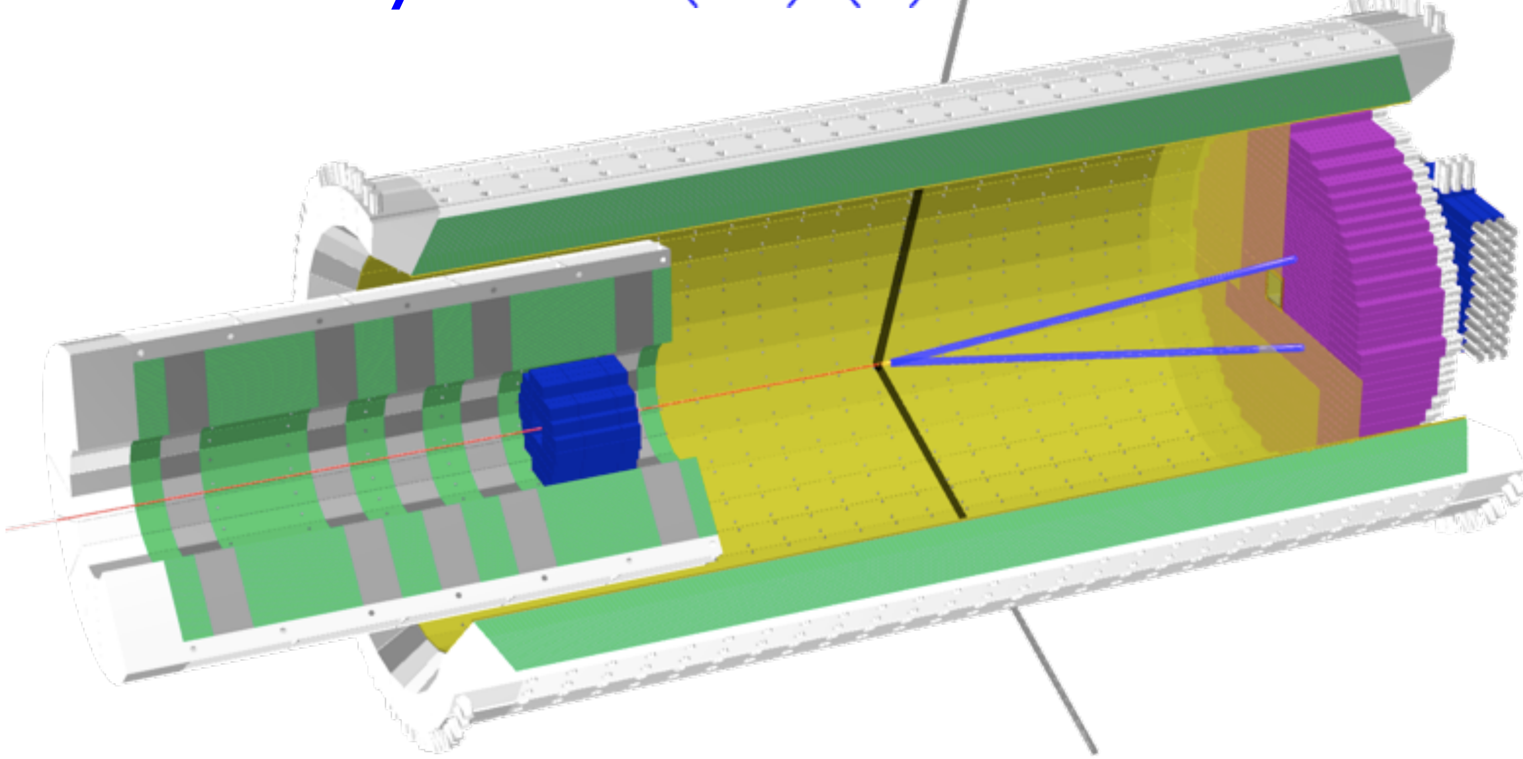
Intensity/multi-probes frontier offers R&D platform of technologies

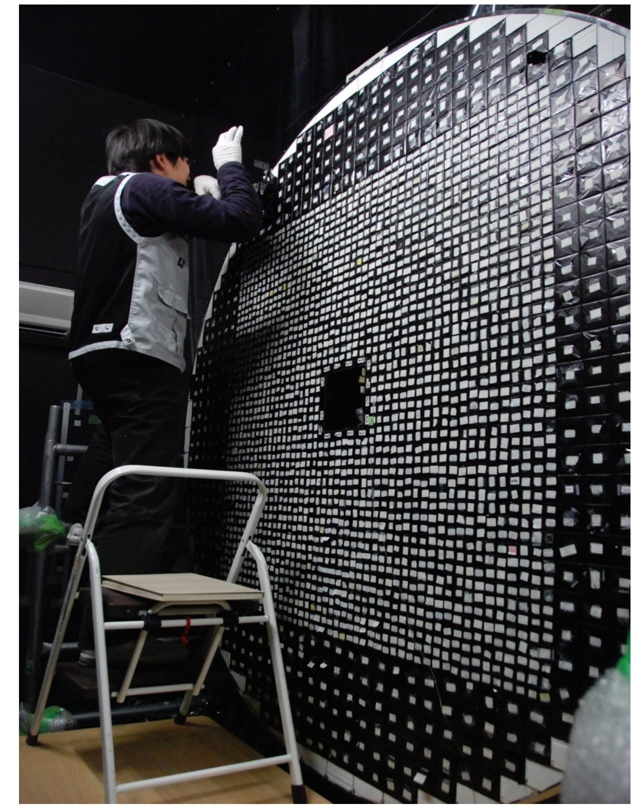
65 participants from Japan, US, Korea, Taiwan, Russia

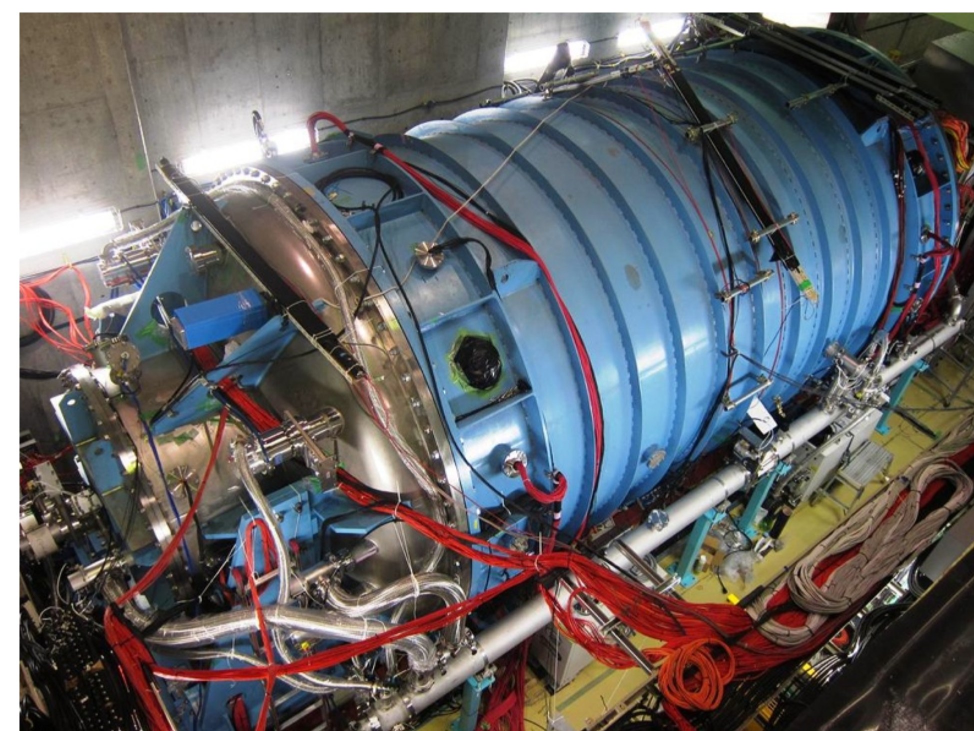
J-PARC KOTO experiment

$$K_L \rightarrow \pi^0 \nu \bar{\nu}$$

- CP symmetry breaking
- rare decay: $2.43\ (39)\ (6) \times 10^{-11}$ in the SM





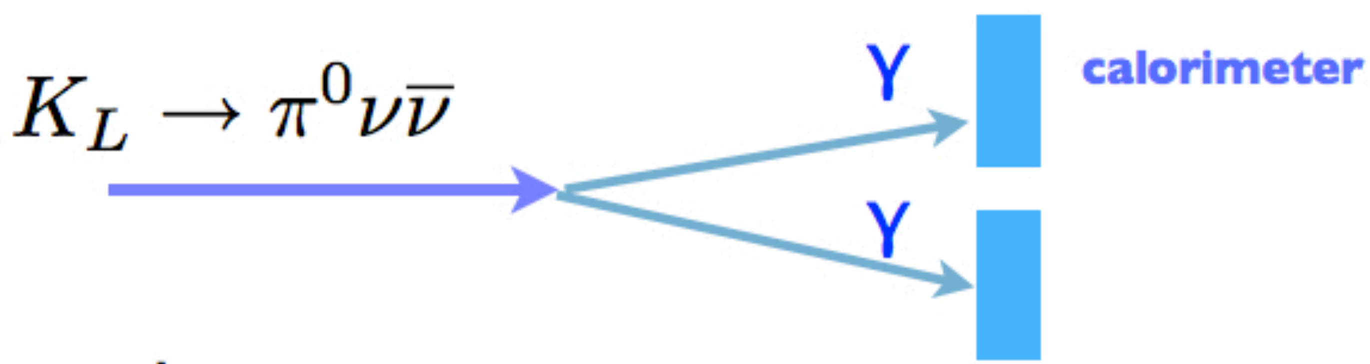


- **CsI calorimeter** to measure $\pi^0 \rightarrow \gamma\gamma$
- background rejection:
  hermetic extra-particle detection (“veto”)
- Trigger/DAQ (37k channels):
  waveform digitization (14bits, 125MHz ADC), pipeline readout

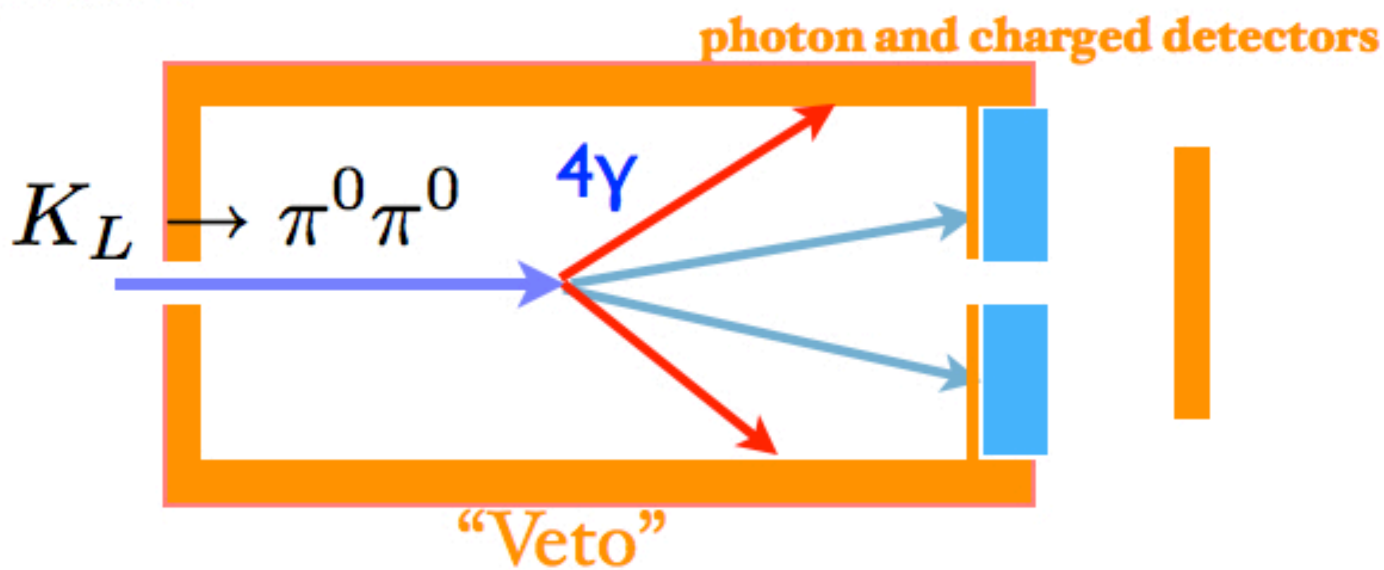
65 participants from Japan, US, Korea, Taiwan, Russia

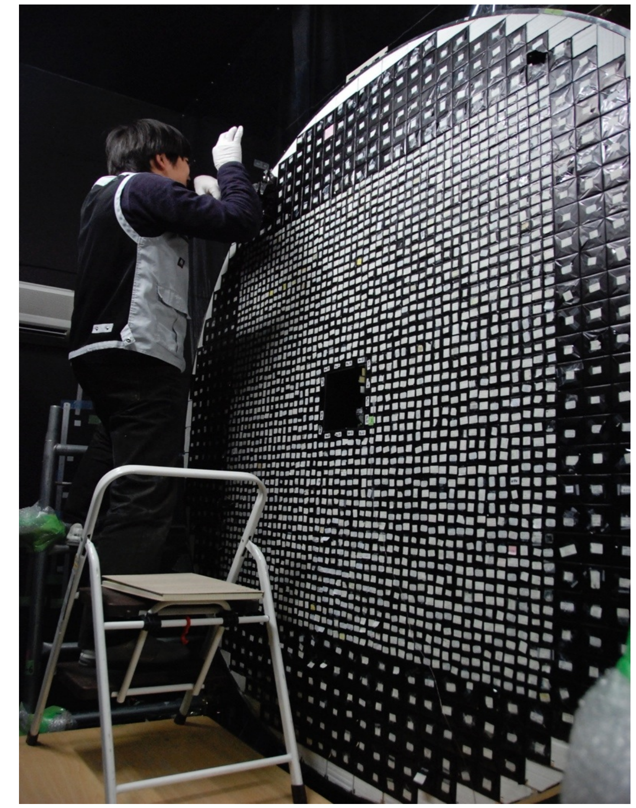
J-PARC KOTO experiment

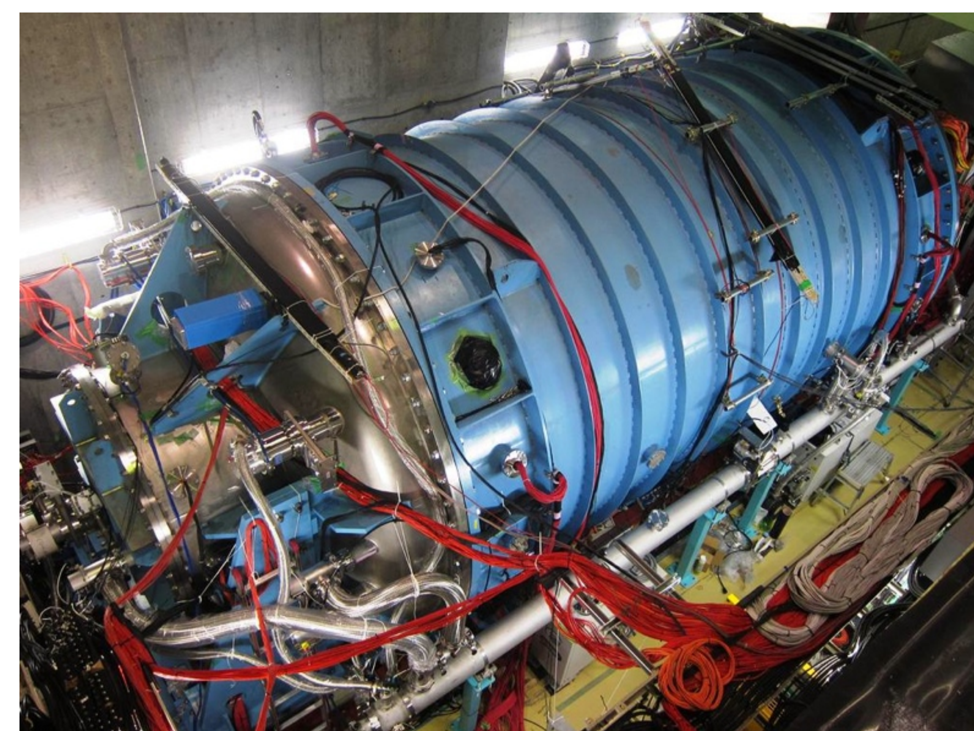
- Signal:



- Background:





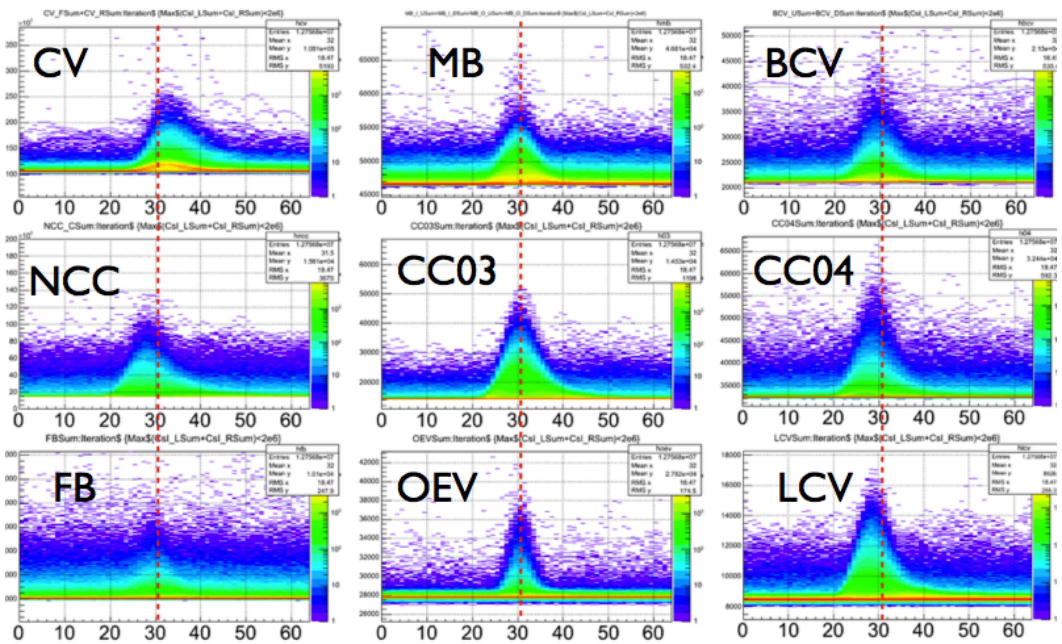


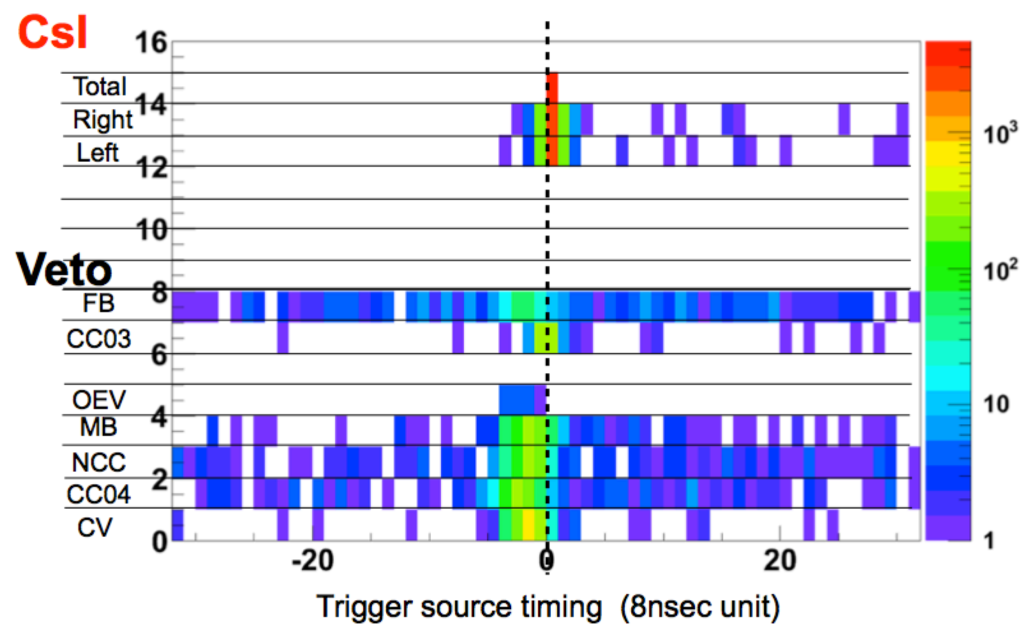
- **CsI calorimeter** to measure $\pi^0 \to \gamma\gamma$
- background rejection:
  hermetic extra-particle detection ("veto")
- Trigger/DAQ (37k channels):
  waveform digitization (14bits, 125MHz ADC), pipeline readout

65 participants from Japan, US, Korea, Taiwan, Russia

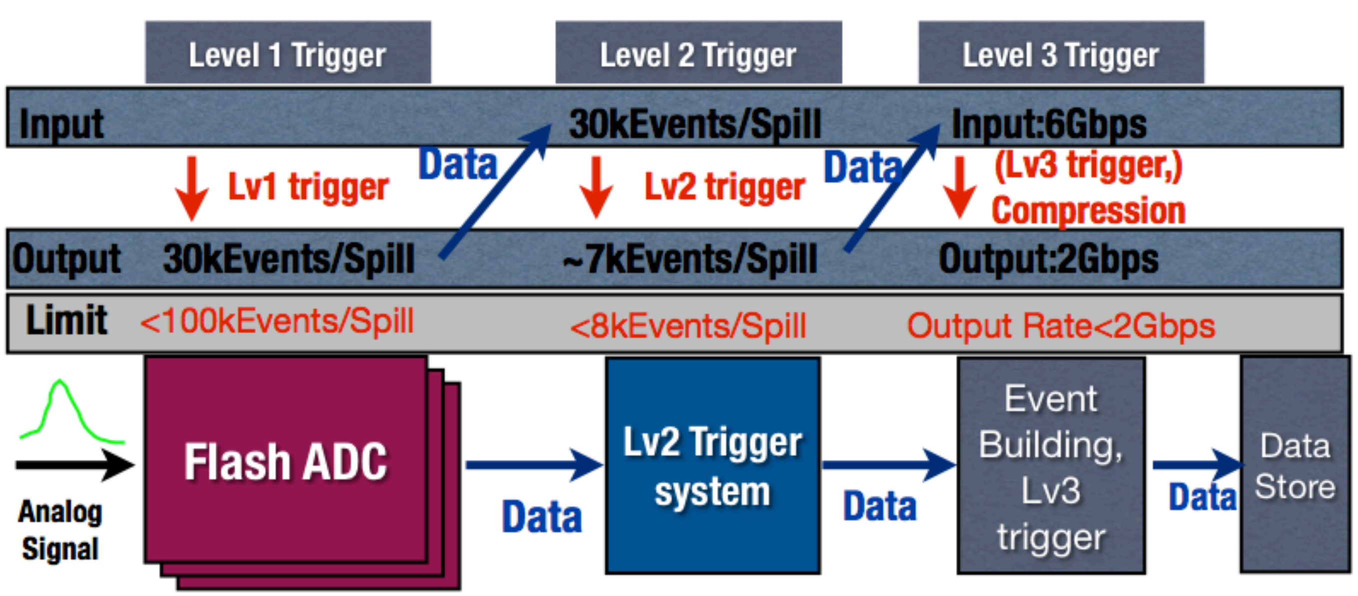
J-PARC KOTO experiment

- Trigger/DAQ (37k channels):
  waveform digitization (14bits, 125MHz ADC), pipeline readout



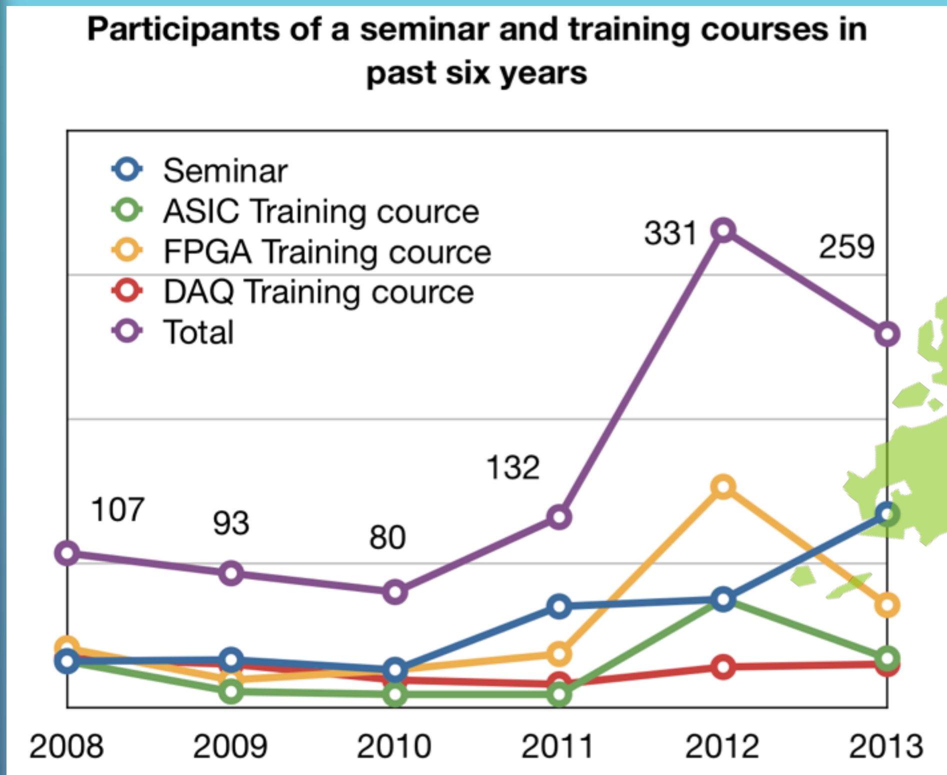


- Veto low visible-energy deposits with good timing resolution (sub-MeV, sub-nanosecond) in high counting rates (multi-hit discrimination) → waveform digitization to be 500MHz ADC

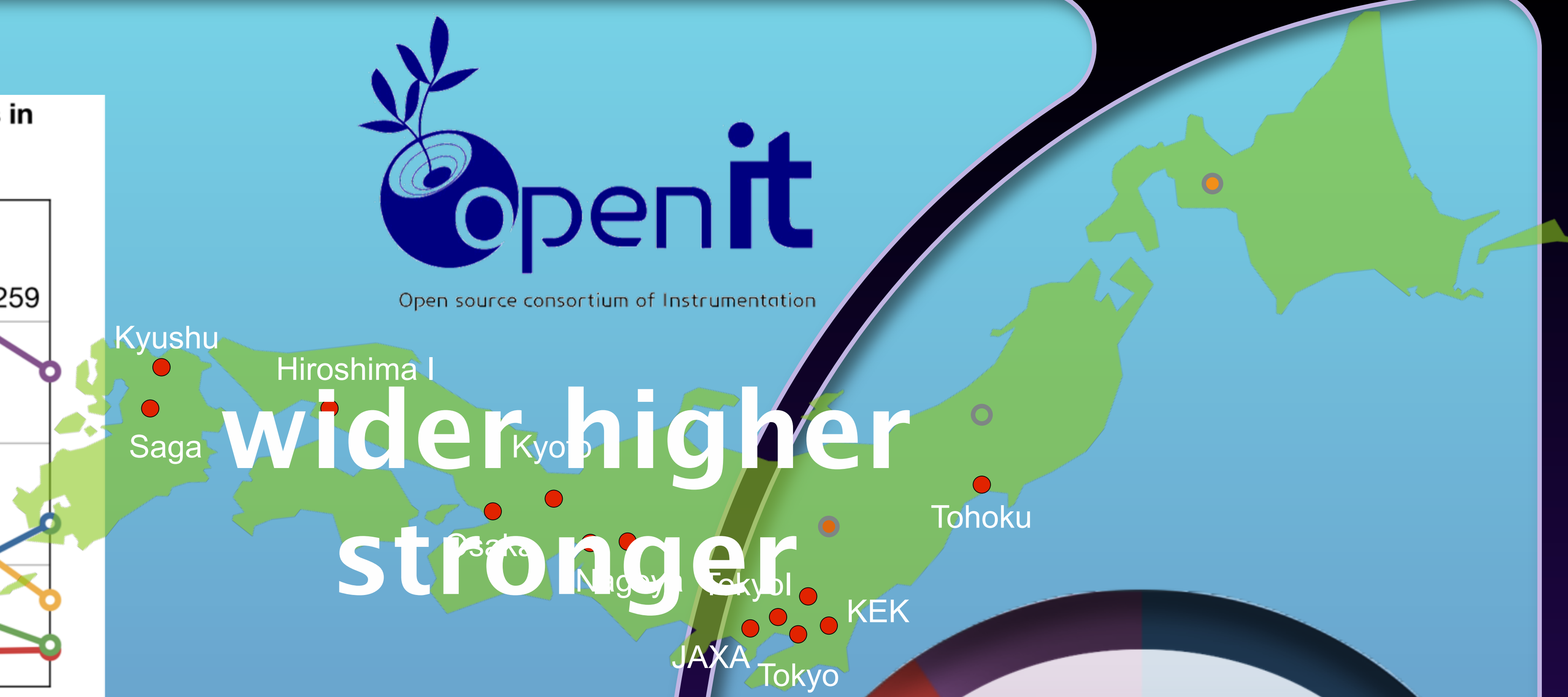


- huge amount of data to observe rare decays
  → high-speed data reduction
  and compactification

Education

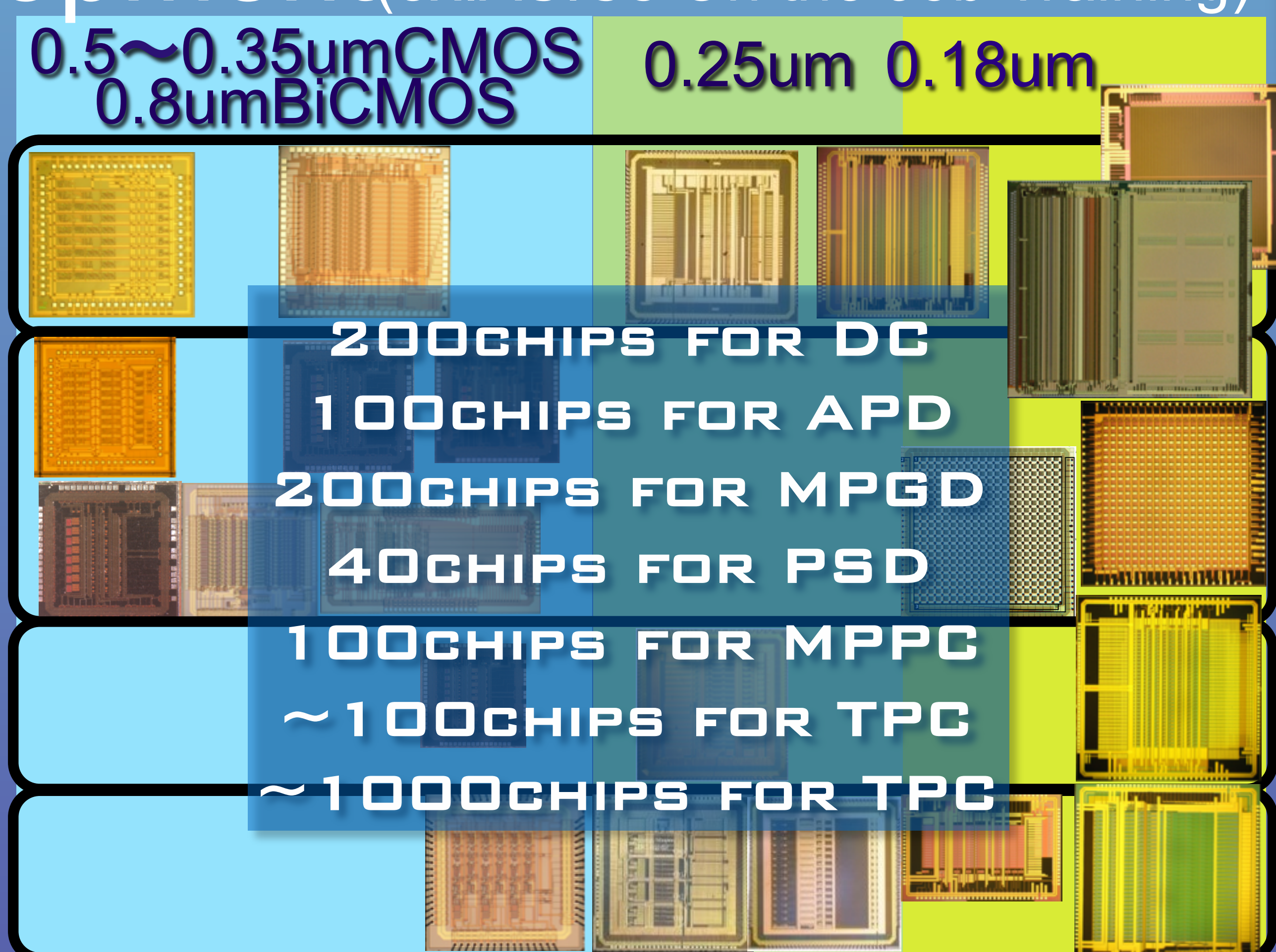


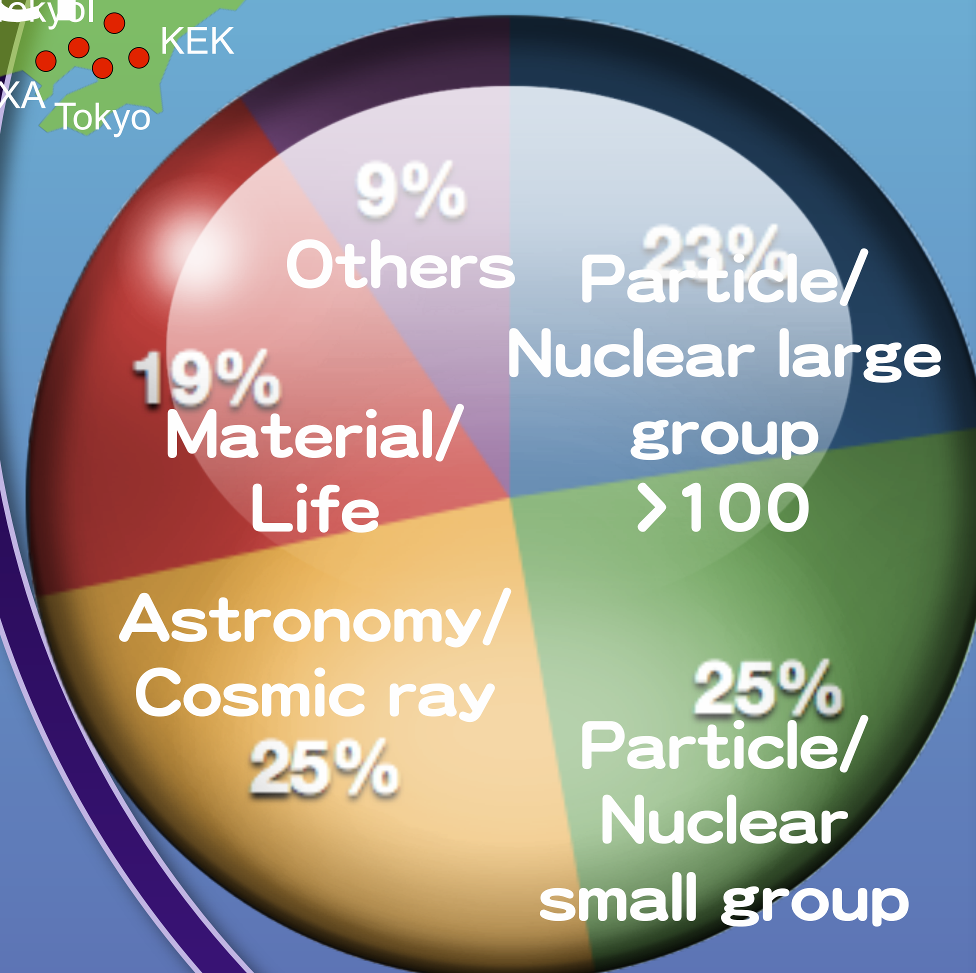
openit
Open source consortium of Instrumentation



wider higher stronger

Development(ex.ASICs On the Job Training)





OJT Projects