Particle and Nuclear physicsat J-PARC & Neutrino physiscs in Japan

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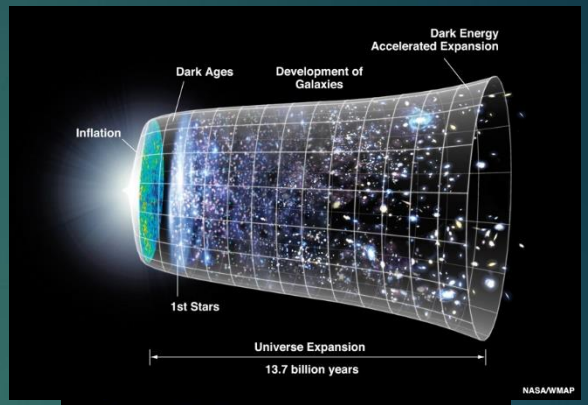
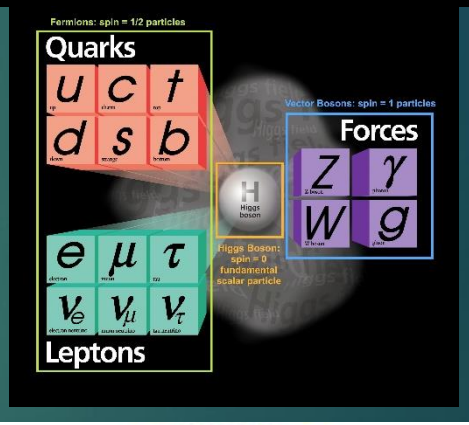
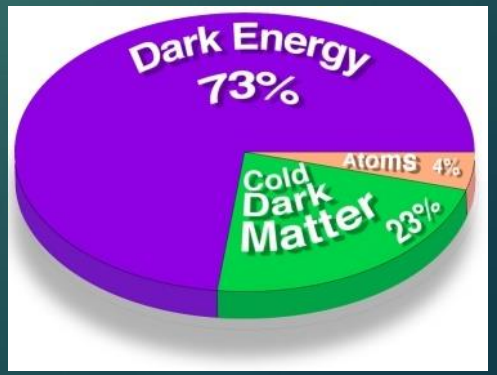
Fundamental questions in our universe

- Origin/fate of our universe
- Origin of matter
  - Where necessary CP violation comes from?
  - B-L non-conservation
- Origin of mass:
  - Higgs is really what we ordered?
- What is beyond standard model?
- Dark matter
- Dark energy

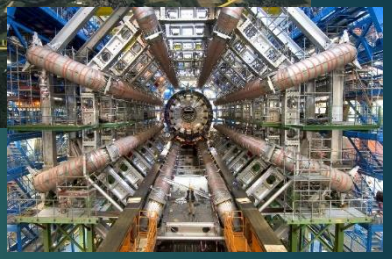




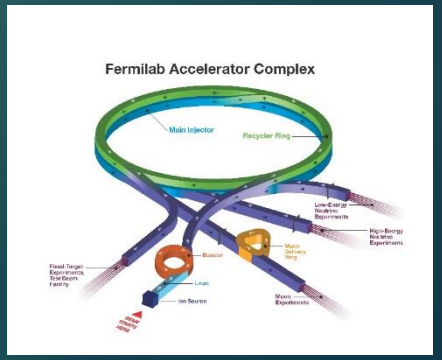


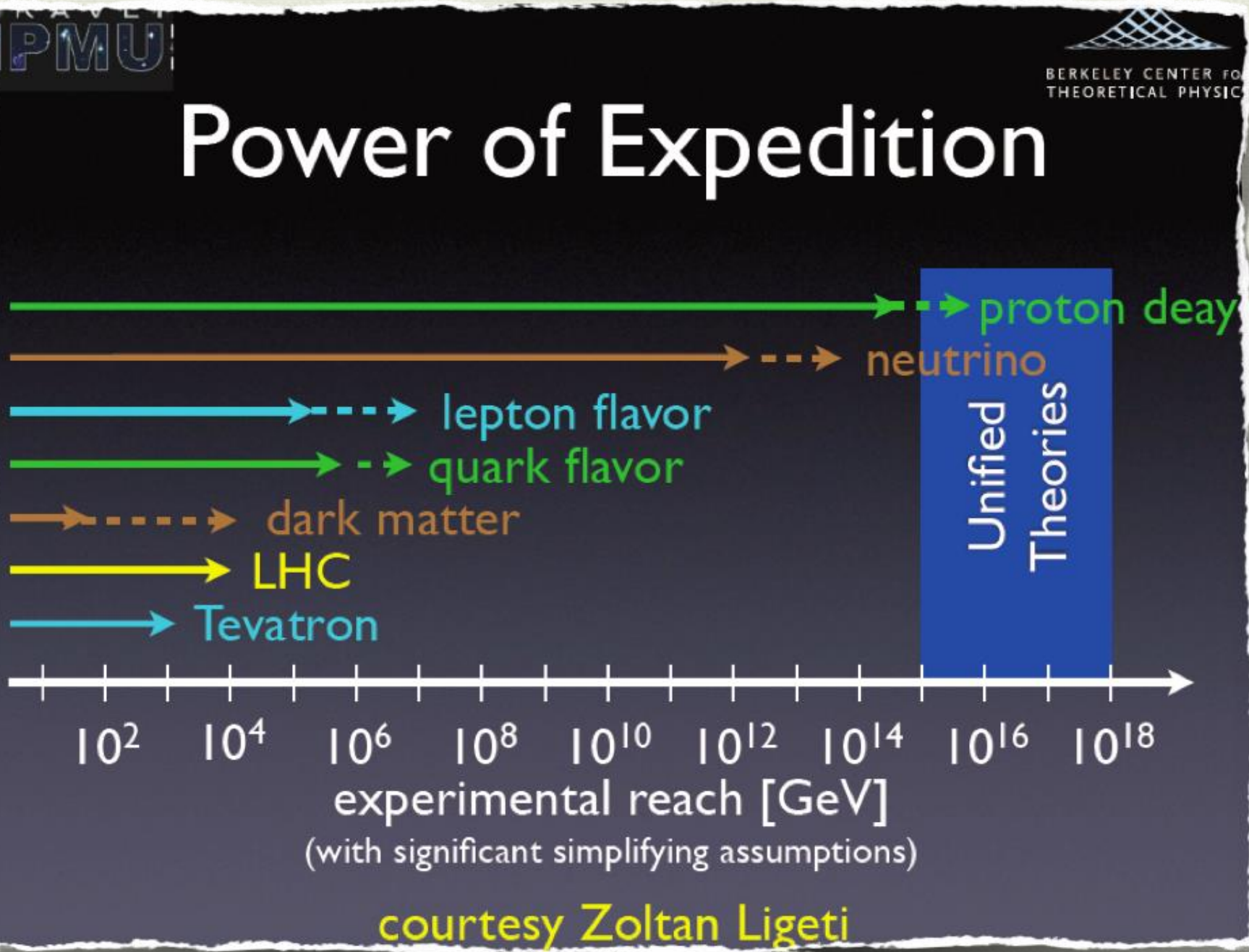
Approaches

- High energy
  - Direct search
  - Tevatron (1.9TeV)→ LHC(14TeV) → ILC → ??
- High intensity
  - Indirect search through loop diagram
  - Can probe higher mass scale than beam energy
  - KEKB,PEP-II → SuperKEKB
  - J-PARC, FNAL-MI, LNBF,



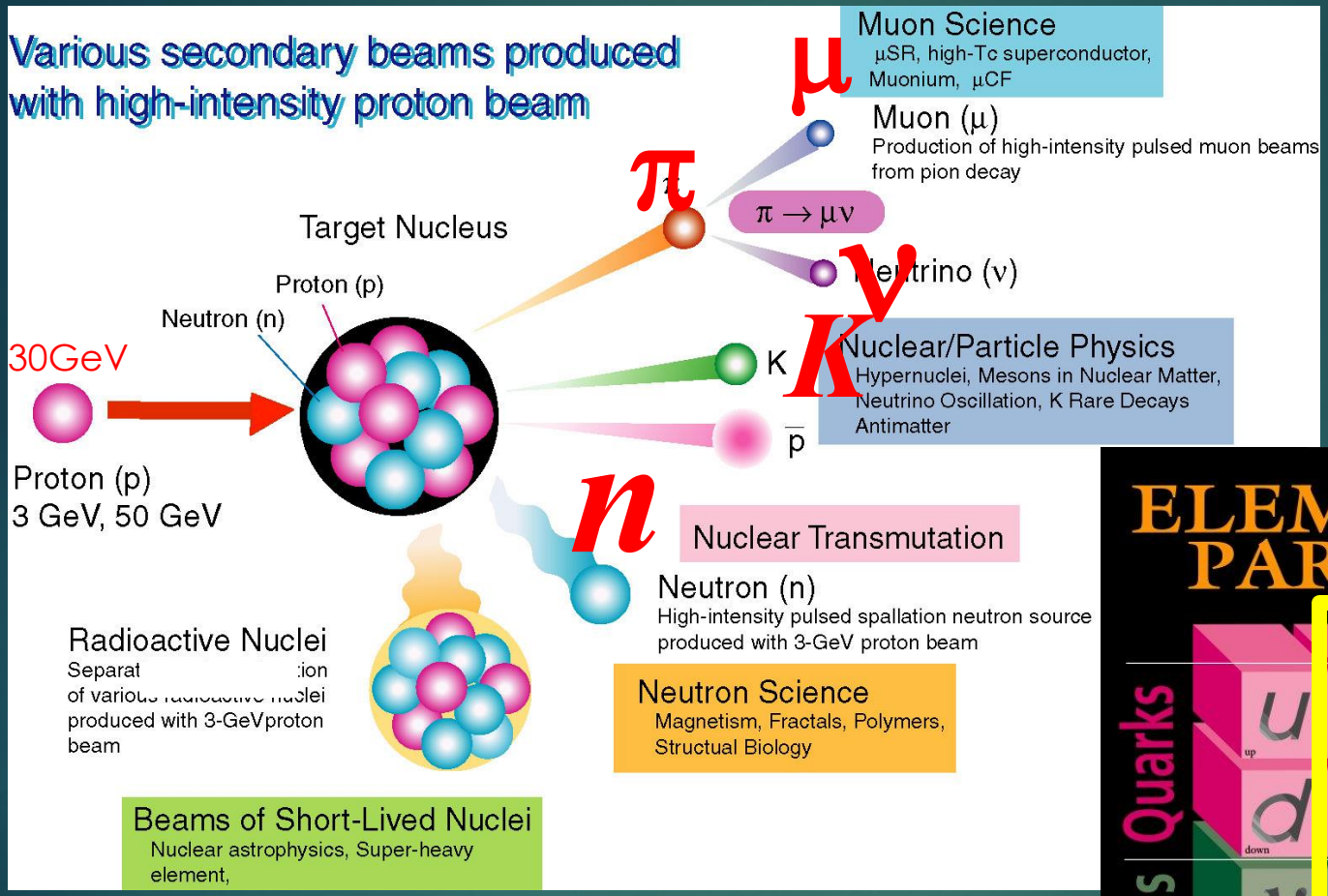
Fermilab

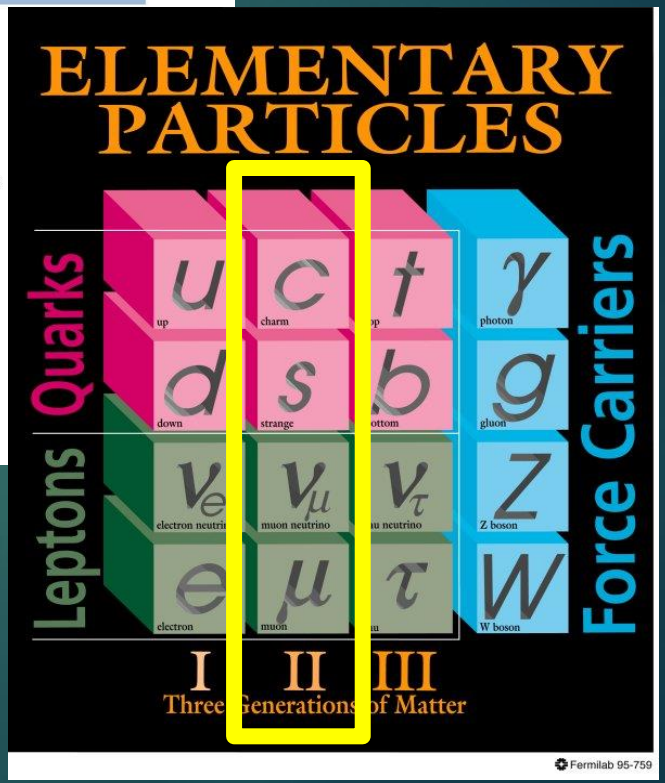




a slide by Hitoshi Murayama

Beam for Particle and Nuclear physics



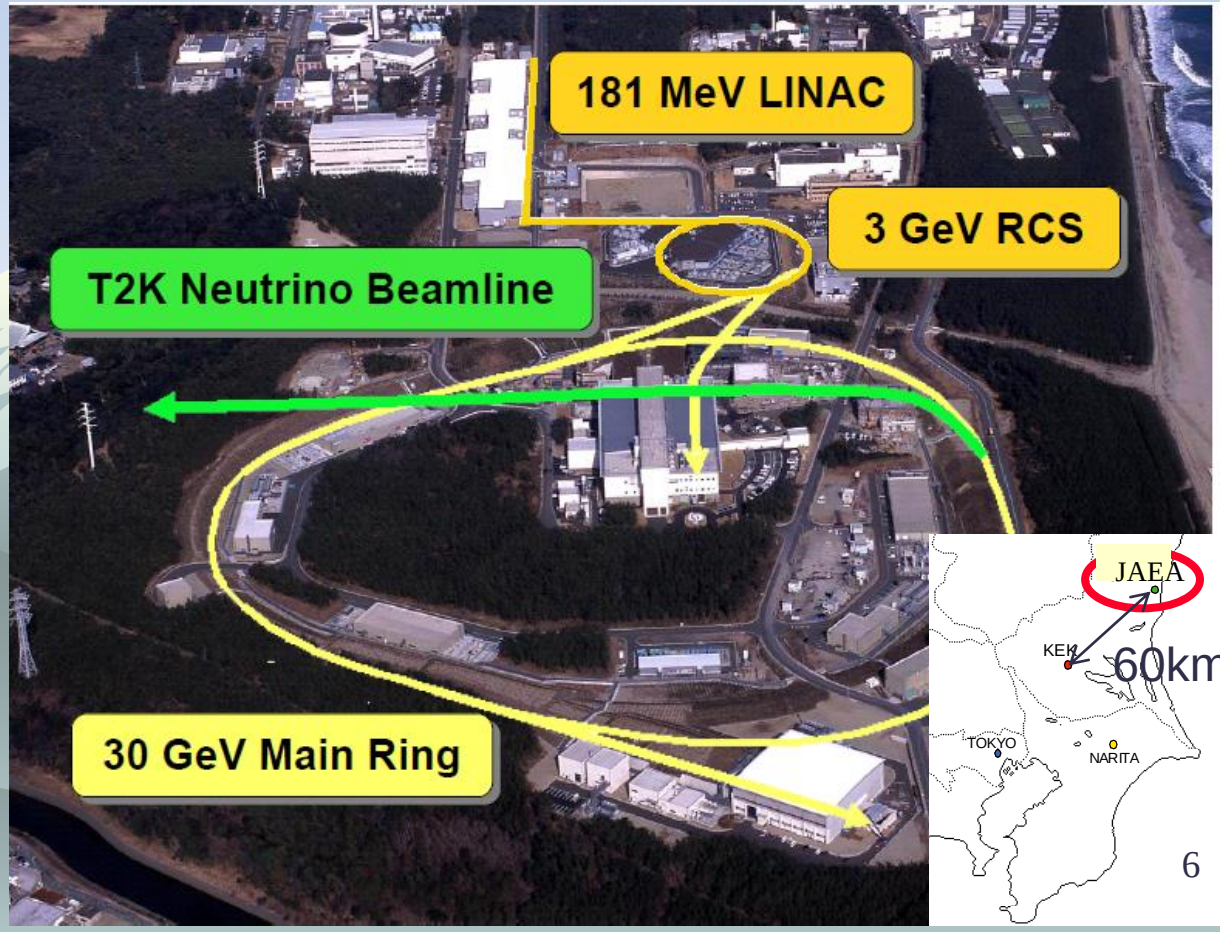


- Discover new physics by very high precision measurement with high intensity
- Primary (p)
- Secondary (pi/K/n)
- Tirtially (mu, neutrino)
- beam

J-PARC

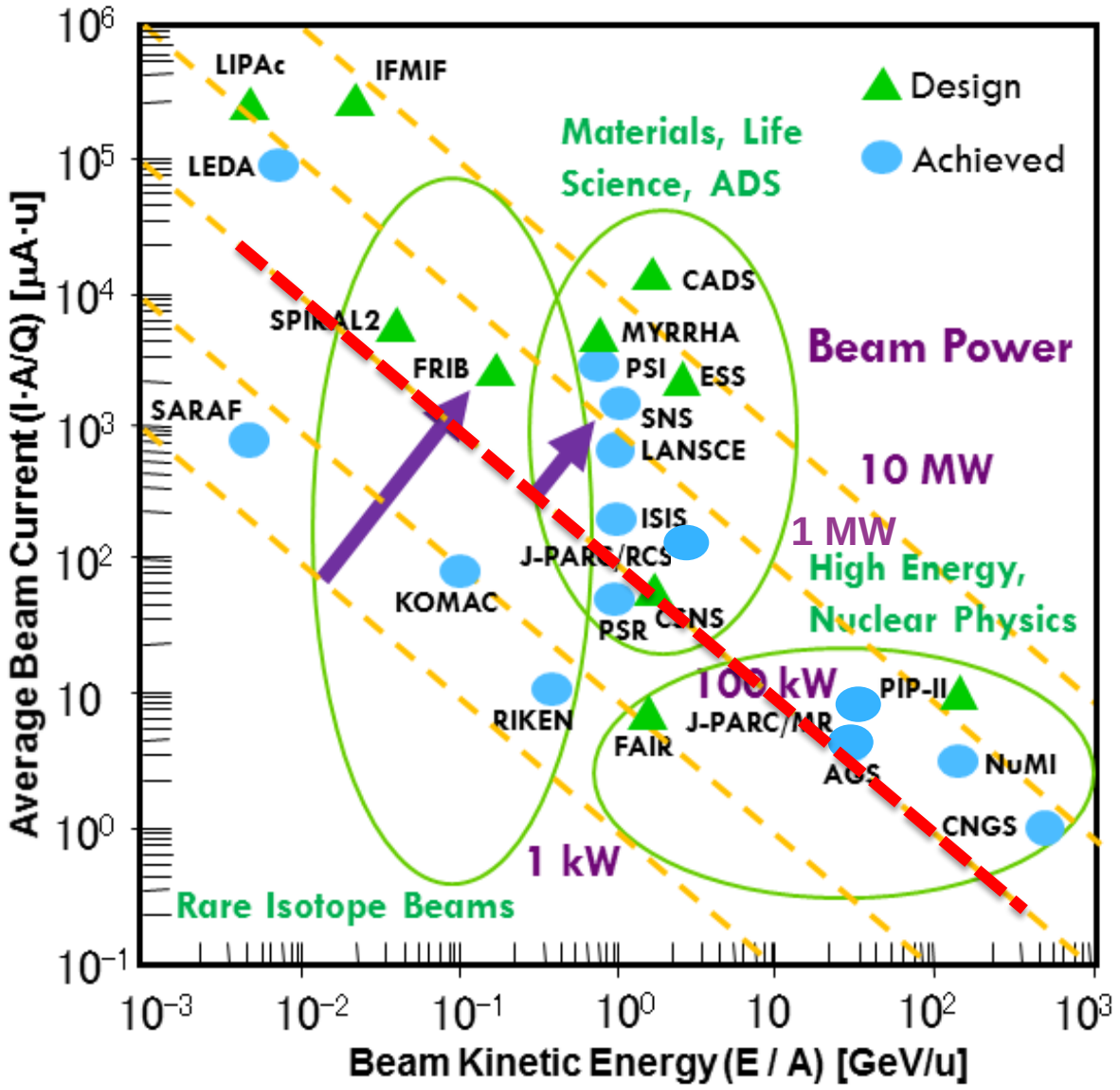
Japan Proton Accelerator Research Complex

- Located in Tokai-village, 60km N.E. of KEK
- Completed in 2009
- Design goal
  - RCS: 1MW
  - MR: 750kW



Joint project of KEK & Japan Atomic Energy Agency (JAEA)

A Quest for High Intensity



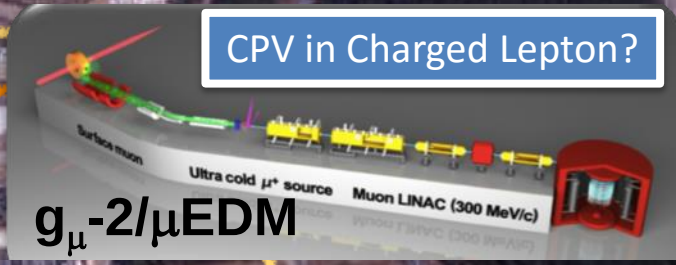
- High Intensity
- High Statistics
- More Precision
- More Rare Searches
- More Materials
- Discovery!

Particle and Nuclear Physics @ J-PARC

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

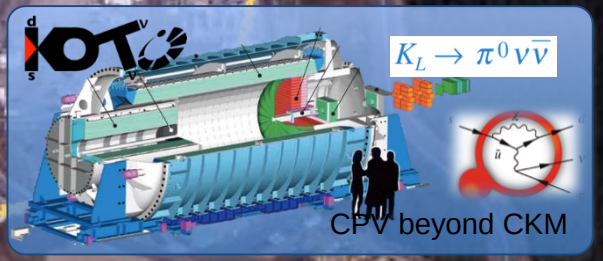
3GeV RCS

FX beam



new particle ν_s?

MLF

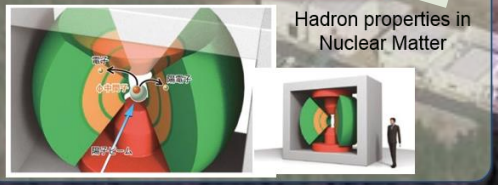


Hyper-nuclear physics

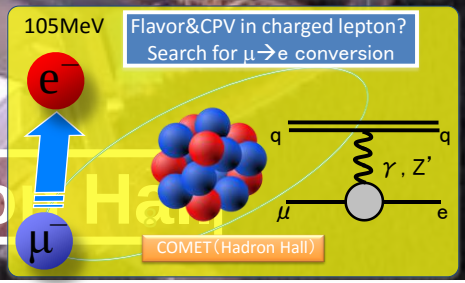
Strangeness in Nuclei

Role of strange quark in extreme high density matter?

Hadron Experiments
～CP beyond CKM; Mass modification～



Hadro

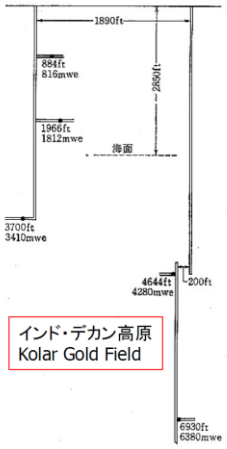



Neutrino Program

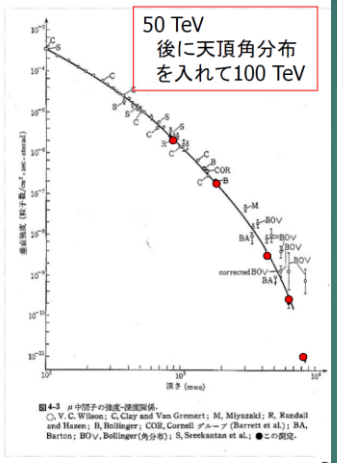
Long history of India-Japan international collaboration on cosmic-ray experiment

KGF(OCU三宅グループ and Tata Inst.)
1960 ～ 1980

三宅三郎

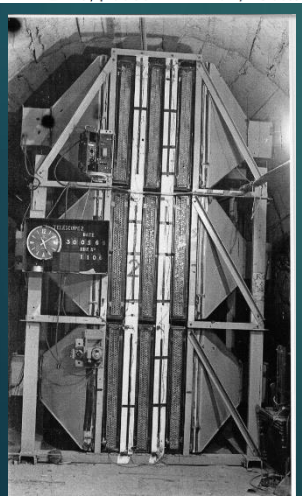


インド・デカン高原
Kolar Gold Field



三宅三郎; μ中間子とニュートリノ,「宇宙線研究」(武谷三男編, 岩波書店)(1970)137

- First detection of atm-ν by India&Japan
- n osc & mass in Japan → Nobel prize
- Lepton CPV together again?



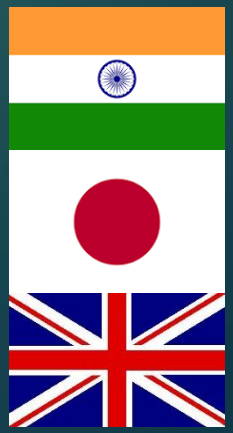
DETECTION OF MUONS PRODUCED BY COSMIC RAY NEUTRINOS DEEP UNDERGROUND

C. V. ACHAR, M. G. K. MENON, V. S. NARASIMHAM, P. V. RAMANA MURTHY and B. V. SREEKANTAN,
Tata Institute of Fundamental Research, Colaba, Bombay

K. HINOTANI and S. MIYAKE,
Osaka City University, Osaka, Japan

D. R. CREED, J. L. OSBORNE, J. B. M. PATTISON and A. W. WOLFENDALE
University of Durham, Durham, U.K.

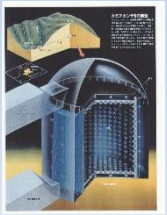
Received 12 July 1965 Reines's paper: 26 July 1965



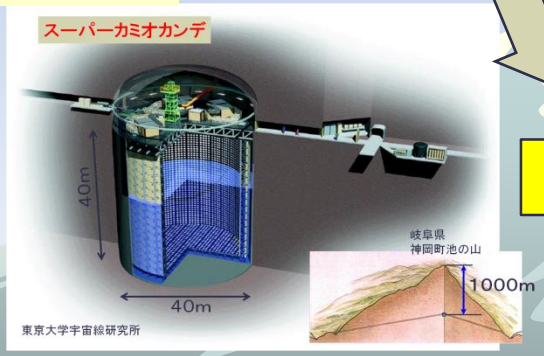
Neutrino experiments in Japan

’80s ’90s ’00s

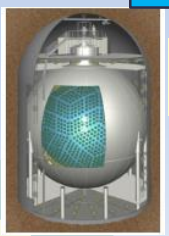
Kamiokande (1983~1996)



3000ton Water



KamLAND (2002~)



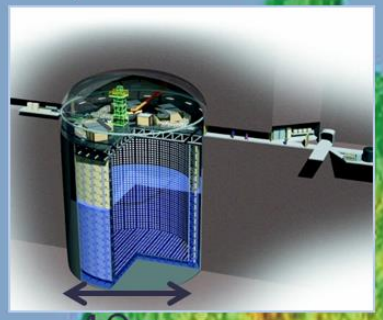
1000ton pure oil Liq Scint.

Super-Kamiokande (1996~)

50,000ton Water

World first accelerator-based long baseline experiment

Super-Kamiokande



K2K
(1999~2004)

T2K実験(2009~)

295 km

東海村

神岡

250km

KEK

J-PARC
@JAEA

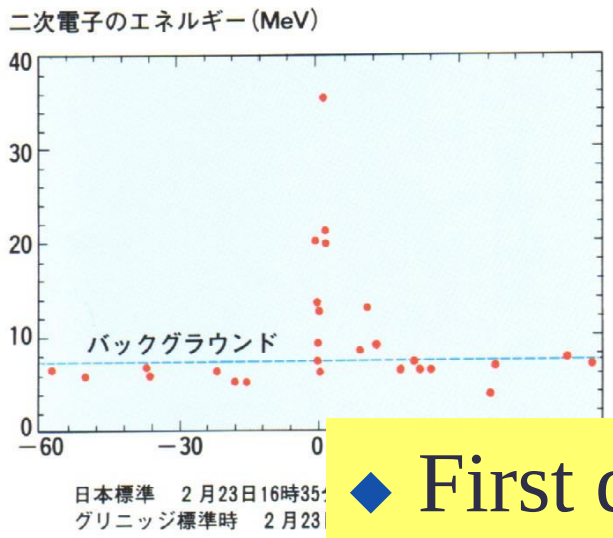
K2K (1999~2004)

T2K(2009~)

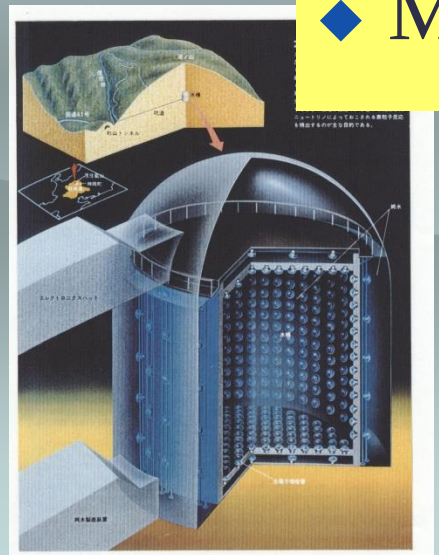
2nd gen. LBL experiment w/ ~MW beam (~100xK2K)

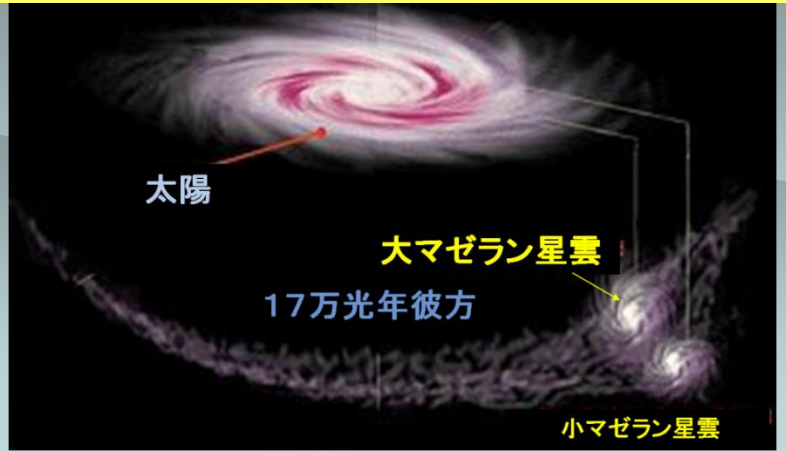
Kamiokande

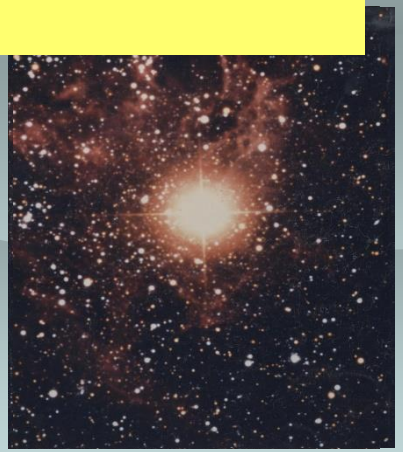
"for pioneering contributions to astrophysics, in particular for the detection of cosmic neutrinos"



- First detection of Supernova neutrino
- Measurement of Solar neutrino







Japanese Neutrino Detectors

Super-Kamiokande

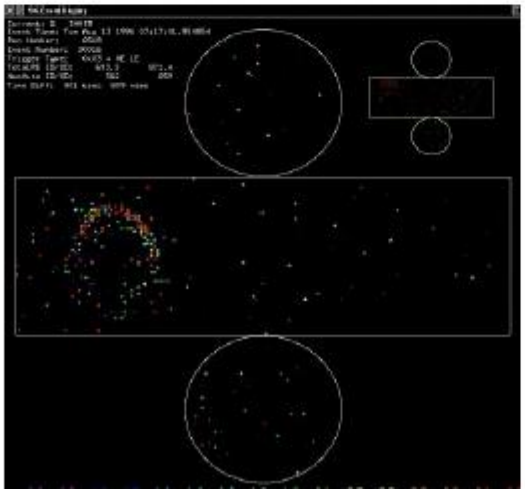
50,000 ton pure water
Cherenkov detector

photon yield 6 p.e./MeV

Energy threshold ~5 MeV

Physics target

- Solar neutrino
- Atmospheric neutrino
- Supernova neutrino
- proton decay
- etc.



KamLAND

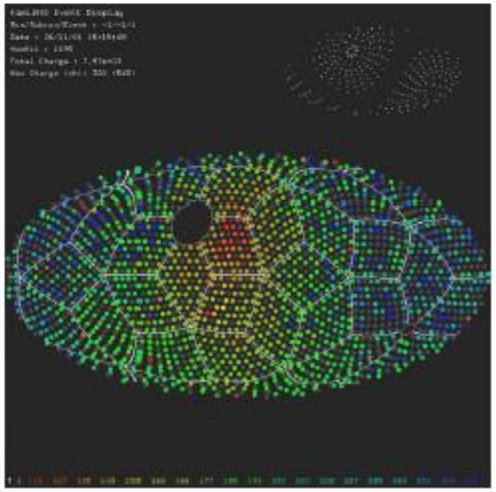
1,000 ton ultra pure oil
Scitillation detector

photon yield 500 p.e./MeV

Energy threshold 0.25~0.4 MeV

Physics target

- reactor neutrino
- geo-neutrino
- low energy solar neutrino
- nucleon decay
- etc.



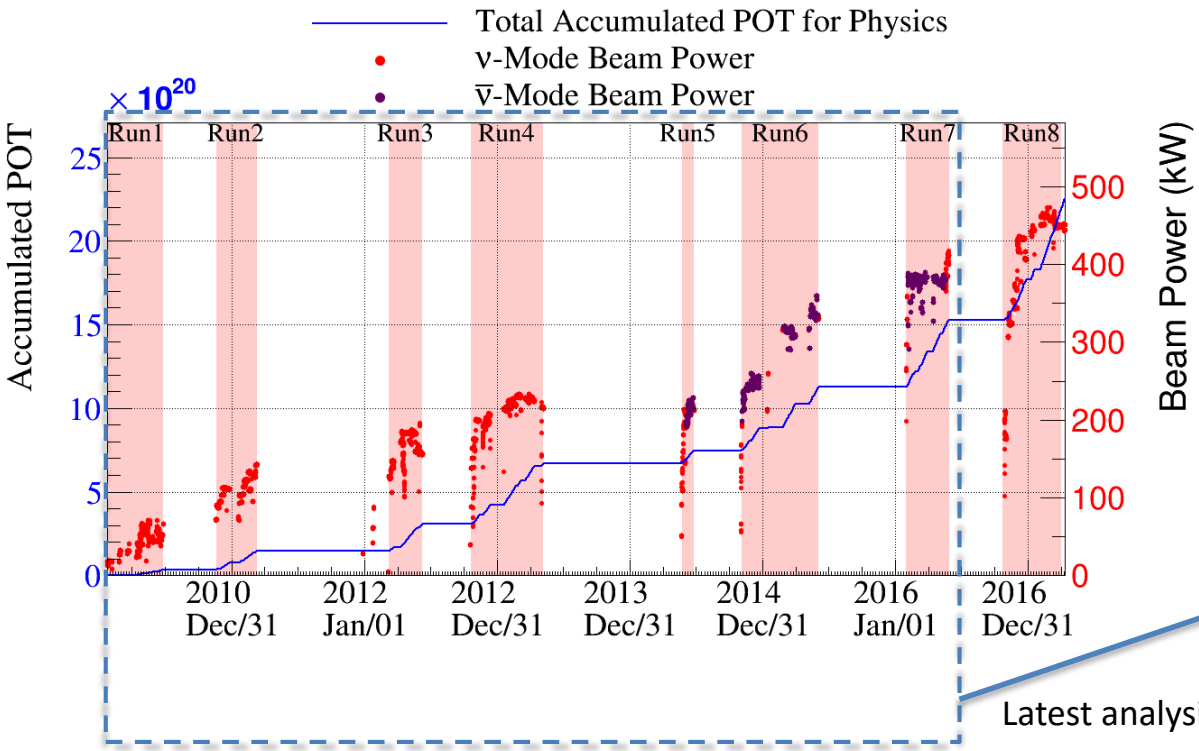
T2K (Tokai to Kamioka) experiment

- High intensity ν_μ beam from J-PARC MR to Super-Kamiokande
- Evidence → Observation of $\nu_\mu \rightarrow \nu_e$ (2011-2013)
- Updated goals
  - Precise measurement of ν_e appearance
  - Precise meas. of ν_μ disappearance

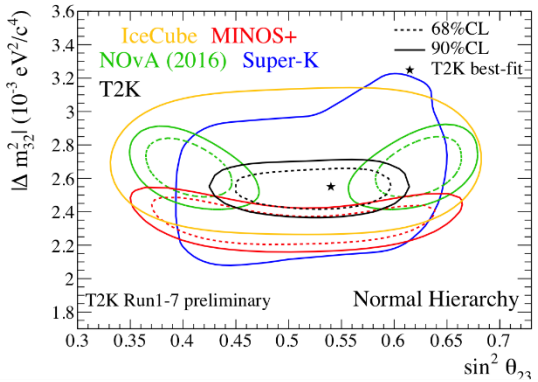
  → Measure CPV phase, contribution to mass hier. determ.

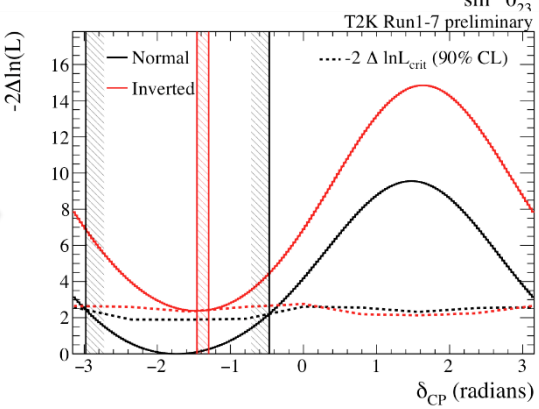
T2K: Current status

- Accumulated POT: *15.3 ×10²⁰ (2016 Oct.)*→ **22.5 × 10²⁰ (2017 Apr.)**
  - ν-beam: *7.7 ×10²⁰ (2016 Oct.)*→ **14.9 × 10²⁰ (2017 Apr.)**
  - $\bar{\nu}$-beam: 7.6 × 10²⁰
- J-PARC MR achieved continuous 470kW beam delivery to NU beam-line.
  - Trial of 510kW beam extraction to NU beam in Apr. 2017
- The results of ν oscillation analysis using the data until 2016 may had been published.
  - Phys. Rev. Lett. 118, 151801
- Preliminary results of improved analysis with new event selection was relased 2017 Feb.
  - Best measurement of the neutrino oscillation between 2nd-3rd generation.
  - The CP conservation hypothesis (δ_{CP}=0, π) is excluded at >90% C.L.
- New results with doubled ν-beam data will be released in 2017 Summer.



Latest analysis results





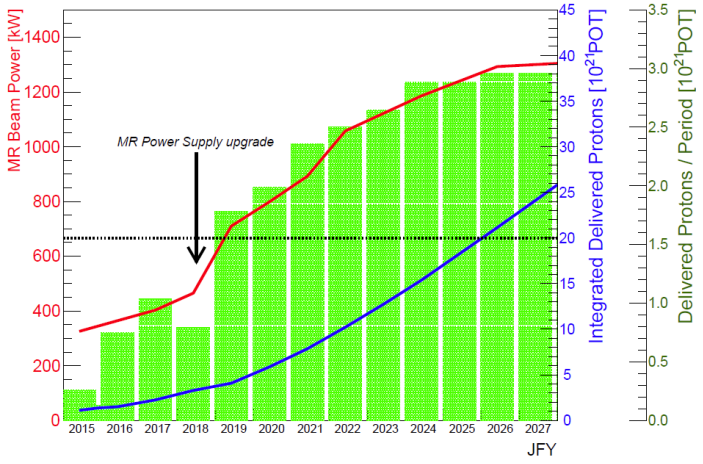
T2K: Future prospects

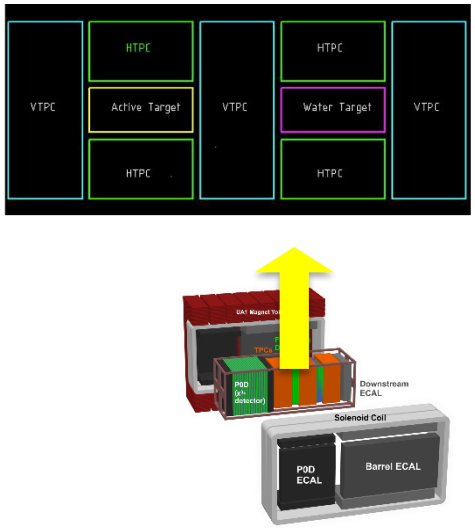
- T2K proposes to collect 20×10^{21} POT data to search for evidence of CP violation in the lepton sector with 3σ sensitivity. (arXiv:1609.04111 [hep-ex])
  - J-PARC PAC recognizes the scientific merit and gave stage-1 status in 2016.
- Upgrade plans
  - Beam improvement
    - 750kW→1.3MW, horn 250kA→320kA.
  - Far Detector analysis update
    - Enlarge fiducial volume, etc.

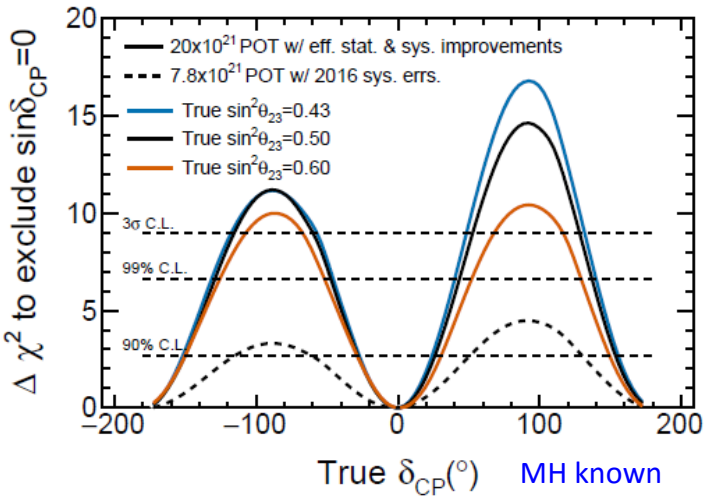
Aiming ×1.5 signal/POT
356.3 $\nu_\mu \rightarrow \nu_e$ sig. expected in ν-beam
73.6 $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ sig. expected in $\bar{\nu}$-beam
(ν-beam:$\bar{\nu}$-beam=50:50, NH, δ_{CP}=0 is assumed)

  - Near detector upgrade:
    - Widen angular acceptance, etc

Aiming to reduce systematic uncertainty:
ex. Expectation of $\nu_\mu \rightarrow \nu_e$ sig.: ~7% → ~4%

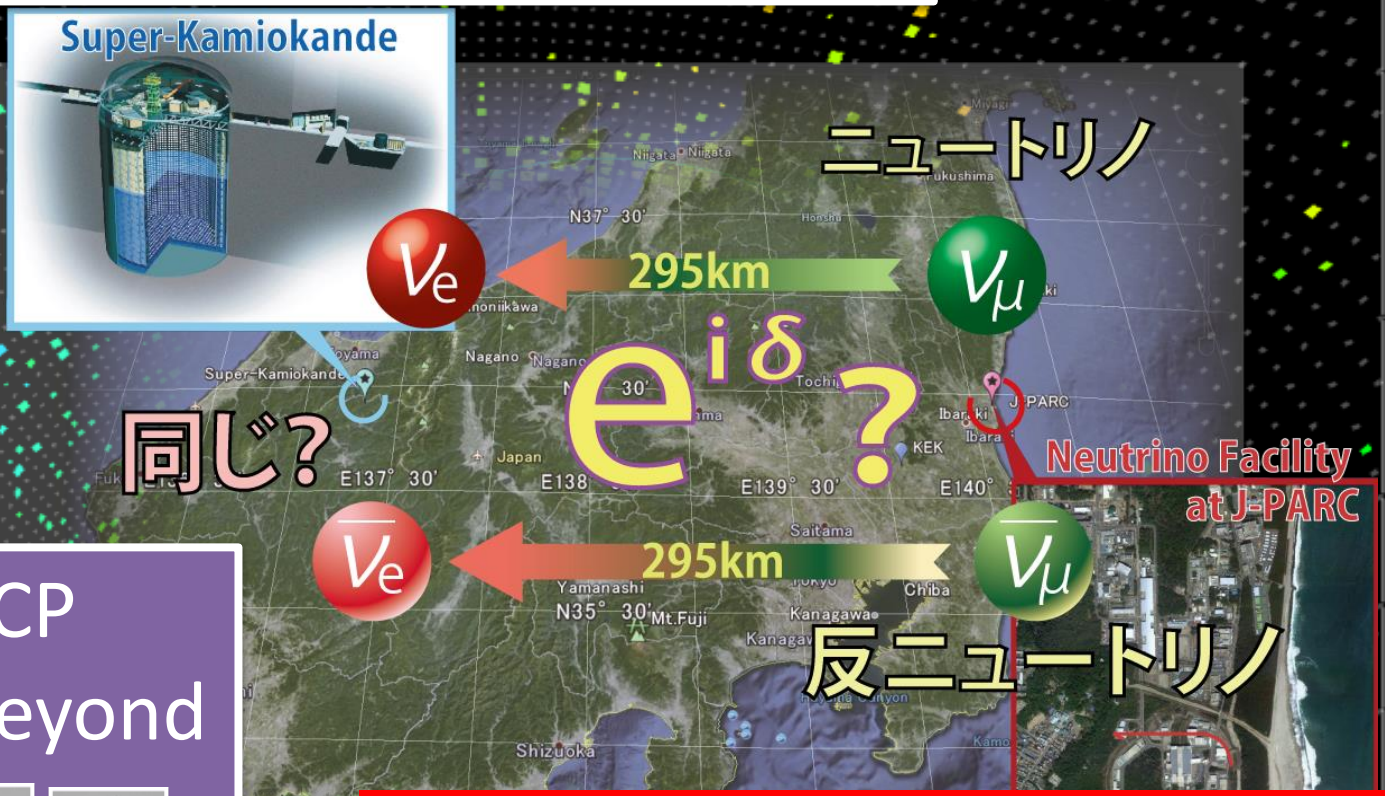






Next goal of T2K

Neutrino and anti-neutrino behave same?

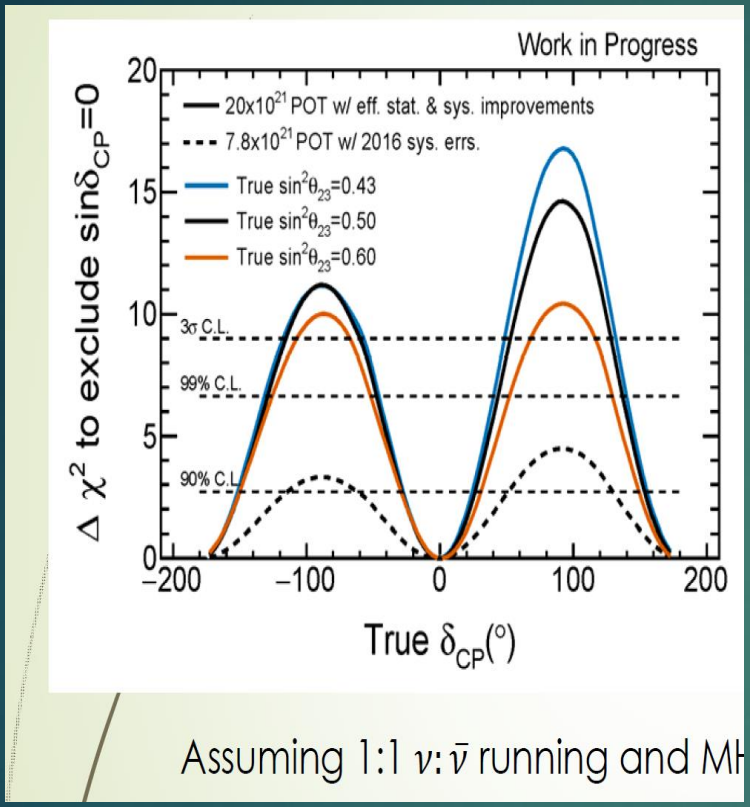


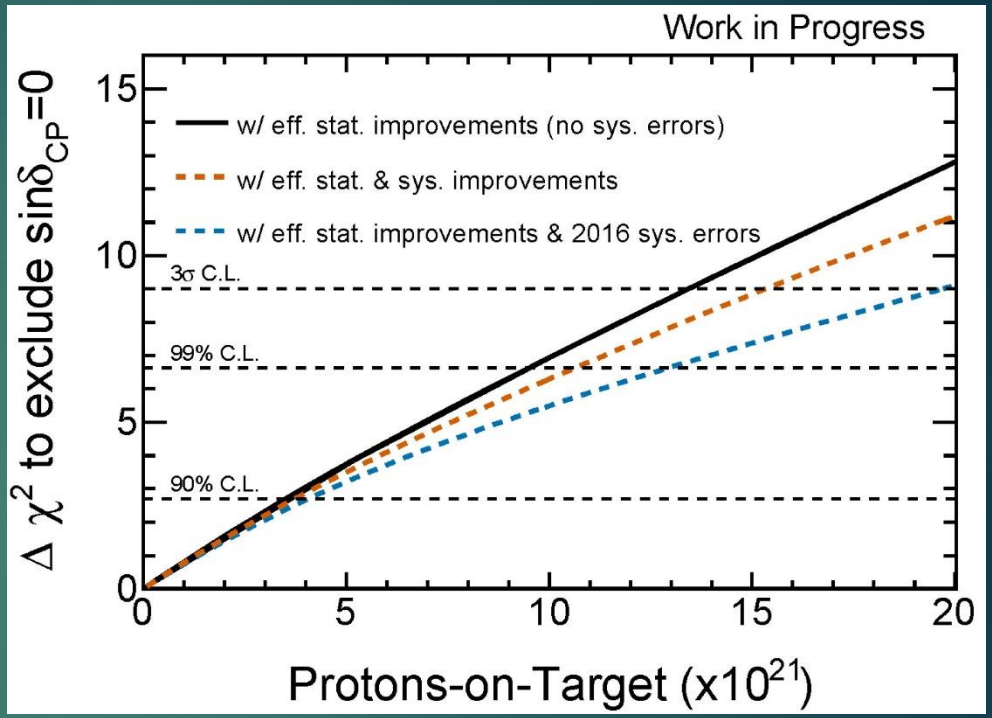
Search for CP Violation beyond CKM

Origin of Matter

Discovery of CPV at > 3sigma
With 10 times more proton beam & 1.3MW beam

T2K-II (T2K extention)

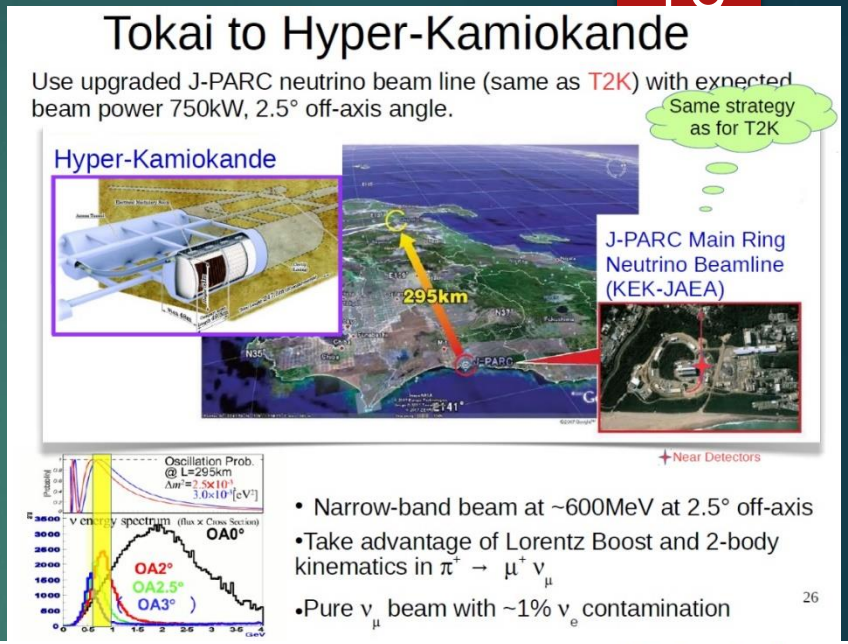


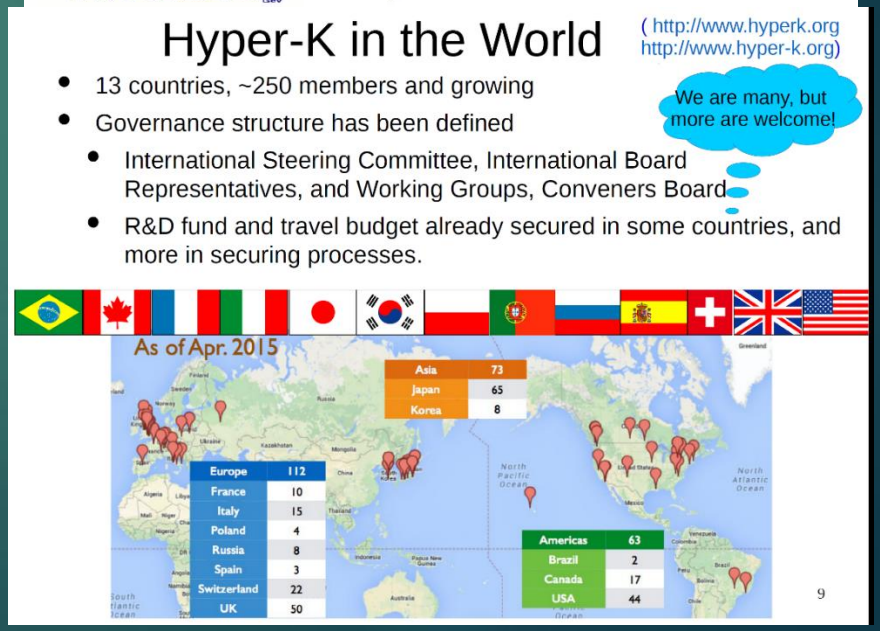


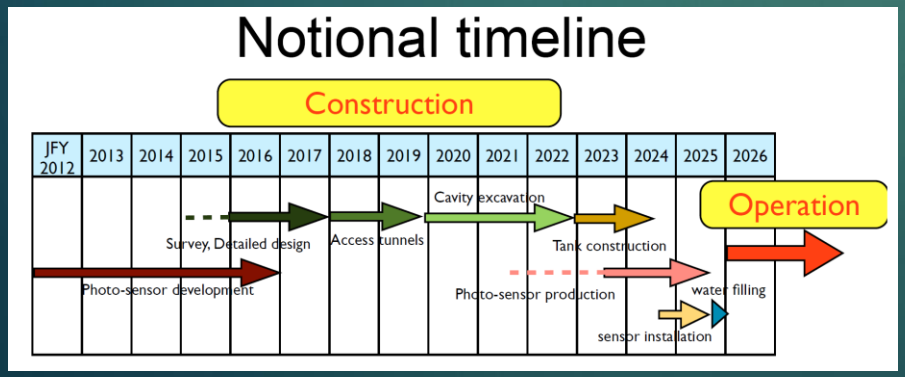
- Aim to reach ~1.3MW and accumulate ~2e22POT x ~1.5(ana. imp. + 320kA horn)
- > 3 sigma CPV sensitivity
- EoI submitted

Next gen.:Hyper-Kamiokande

- >10 times SK Water Cherenkov with 1.3MW J-PARC
- Physics
  - Neutrino oscillation
    - Accelerator based LBL
    - Atmospheric nu
    - Solar nu
    - ..
  - Proton decay
  - Astrophysics neutrinos
    - Supernova, SRN, dark matter, etc





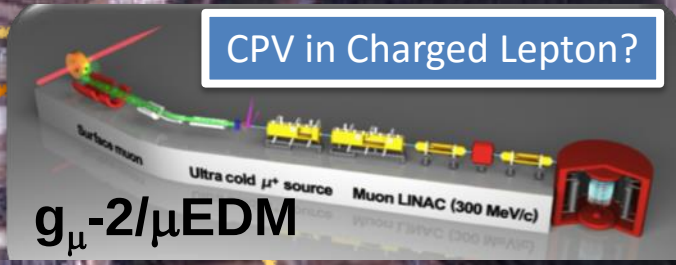


Particle and Nuclear Physics @ J-PARC

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

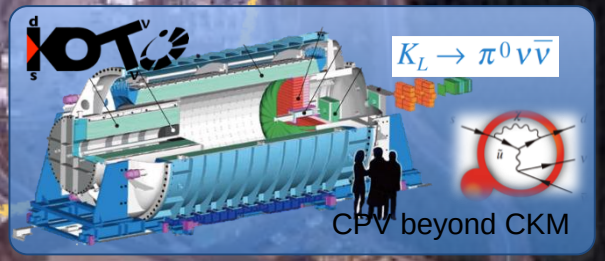
3GeV RCS

FX beam



new particle ν_s?

MLF



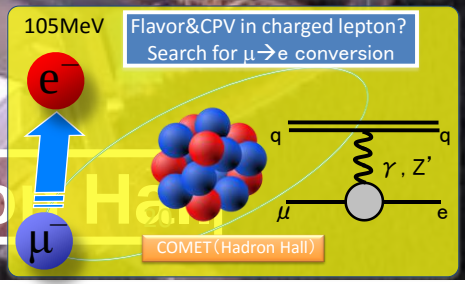
Hyper-nuclear physics

Strangeness in Nuclei

Role of strange quark in extreme high density matter?

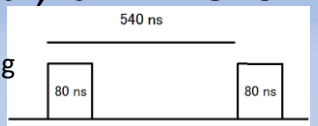
Hadron Experiments
～CP beyond CKM; Mass modification～

Hadro



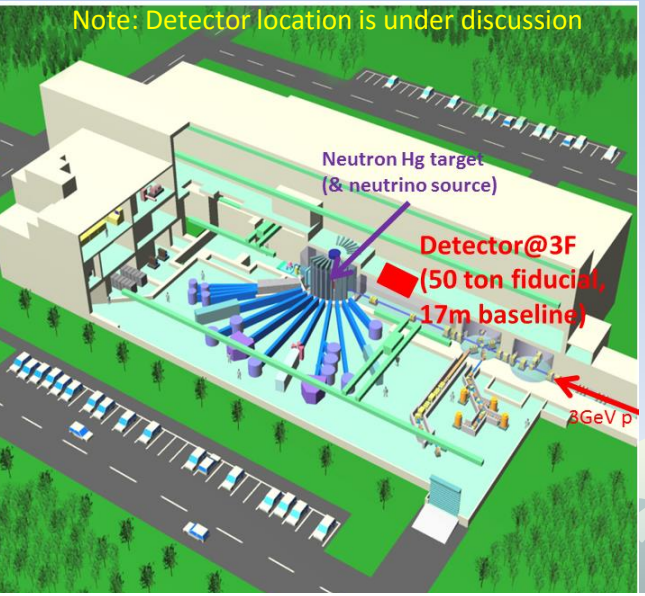
New proposal: Sterile neutrino search @ MLF (P56)

M. Harada *et al*, arXiv:1310.1437 [physics.ins-det]

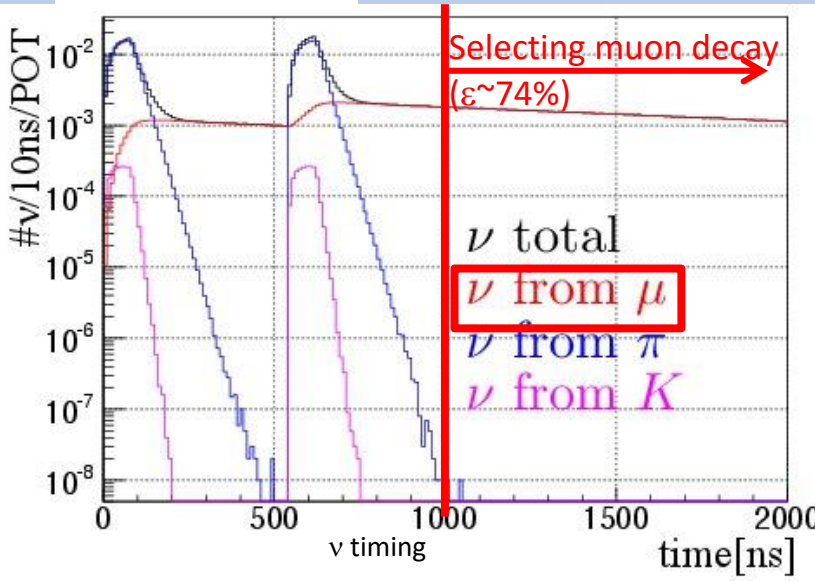


p timing

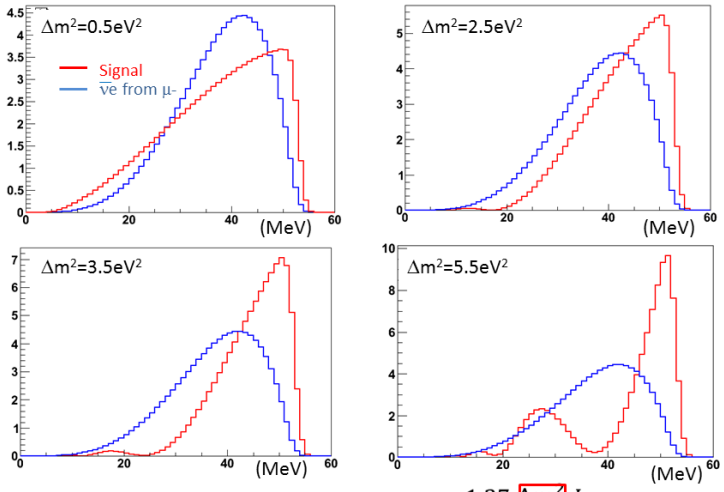
Next beam is 40ms later\



- J-PARC P56 aims to measure the neutrino oscillation with sterile neutrino ($\mu^+ \rightarrow \overline{\nu}_\mu \rightarrow \overline{\nu}_e$)
- With gating the time we can use ultra-pure neutrinos from μ^+ (top-right)
- Energy distortion is seen if sterile νs exist (bottom-left)
- Sensitivity of P56 (right); blue 5σ, green 3σ. We conclude LSND region (brown (90%CL) & green (99%) within 4 years
- will measure BKG rate at 3F with 1 ton detector soon

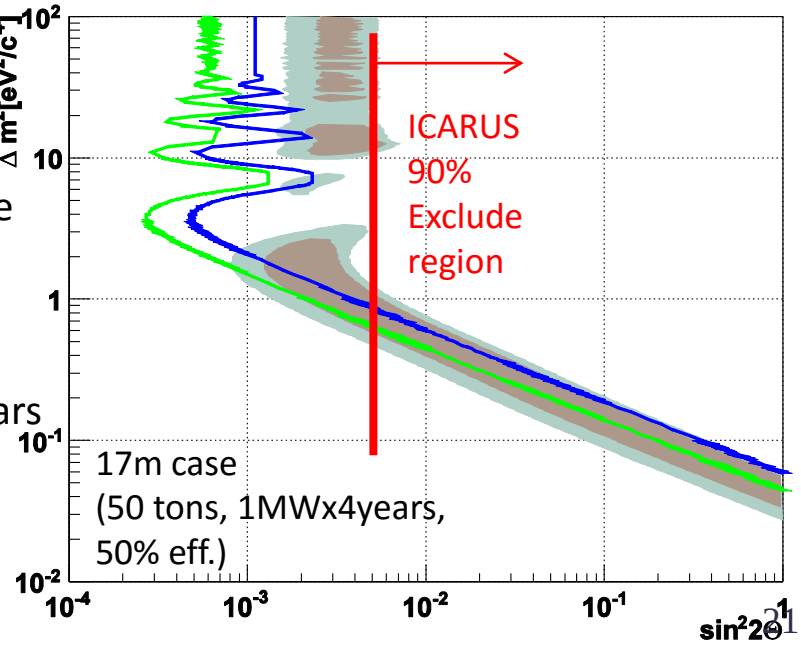


Energy distribution of events (L=17m)



$$P(\nu_\mu \rightarrow \nu_e) = \sin^2 2\theta \cdot \sin^2\left(\frac{1.27 \cdot \Delta m^2 \cdot L}{E_\nu}\right)$$

- Energy is smeared by 15%/sqrt(E) (detector E resolution)

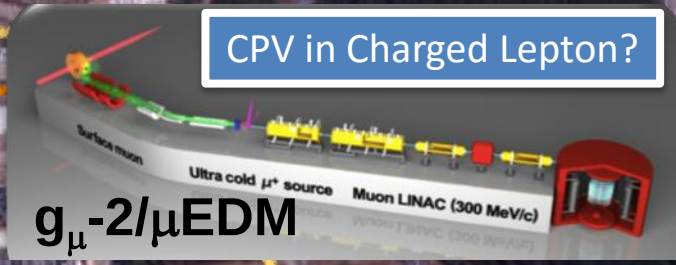


Particle and Nuclear Physics @ J-PARC

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

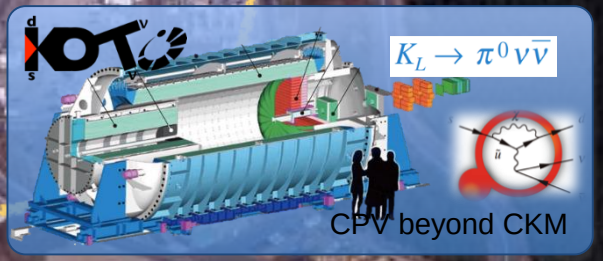
3GeV RCS

FX beam



new particle ν_s?

MLF



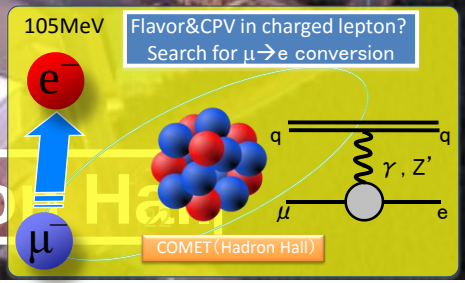
Hyper-nuclear physics

Strangeness in Nuclei

Role of strange quark in extreme high density matter?

Hadron Experiments
～CP beyond CKM; Mass modification～

Hadro



Physics at J-PARC Hadron Hall

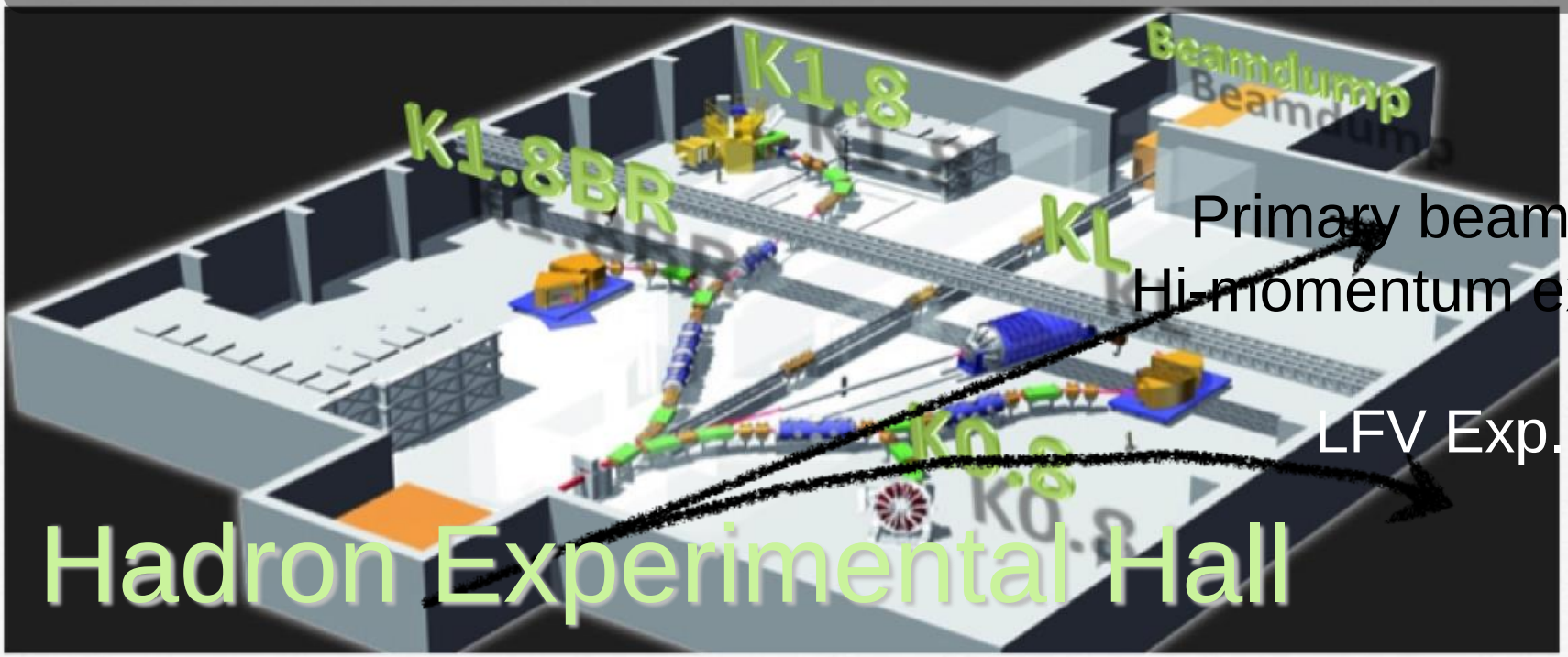
Strong Interaction

CP Violation・T-Violation

Quark and Lepton Sectors

Lepton Flavor Violation

⇒Origin of Matter




Kaon Program

J-PARC E14

KOTO

= K^0 at TOkai

Arizona State
Chicago
Michigan

KEK, Kyoto, NDA, Osaka,
Okayama, Saga, Yamagata

Chonbuk, Hanyang,
Jeju, JINR, NTU,
Pusan

Kaon program

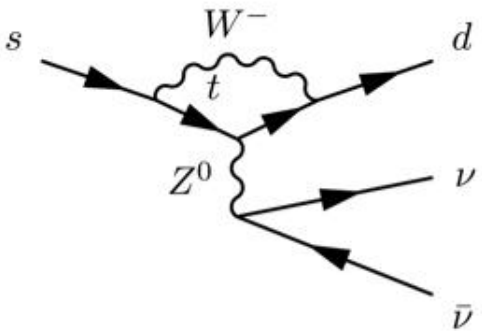
KOTO : Study on $K_L \rightarrow \pi^0 \nu\nu$

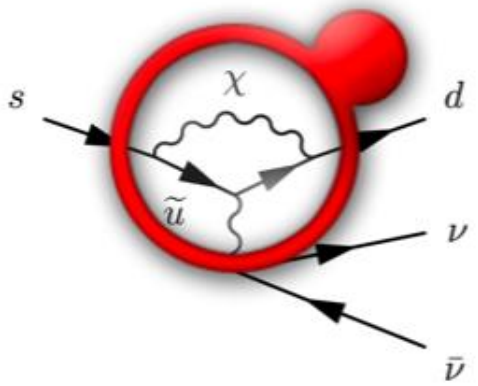
Collaboration photo at KEK, October 2014

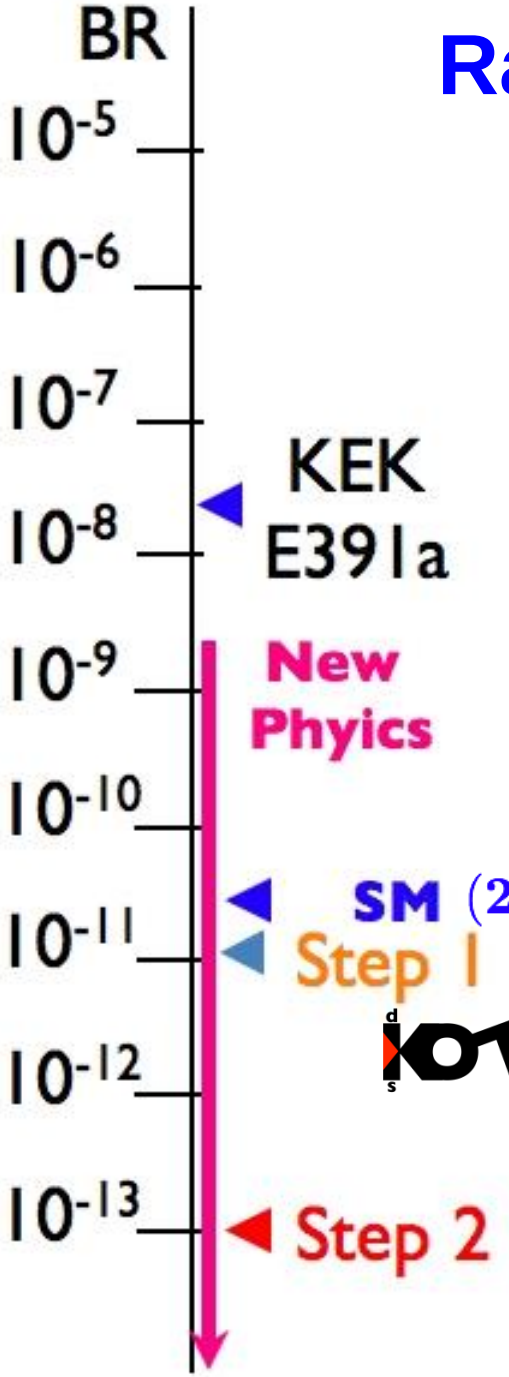
Taking data

Slide by T. Nomura

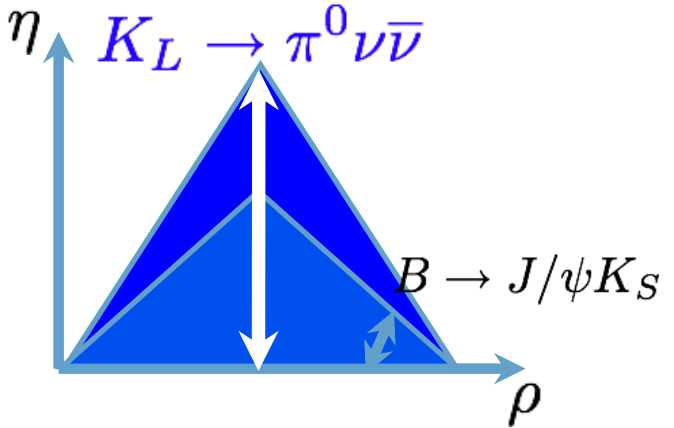
Rare Kaon Decay $K_L^0 \to \pi^0 \nu\bar{\nu}$







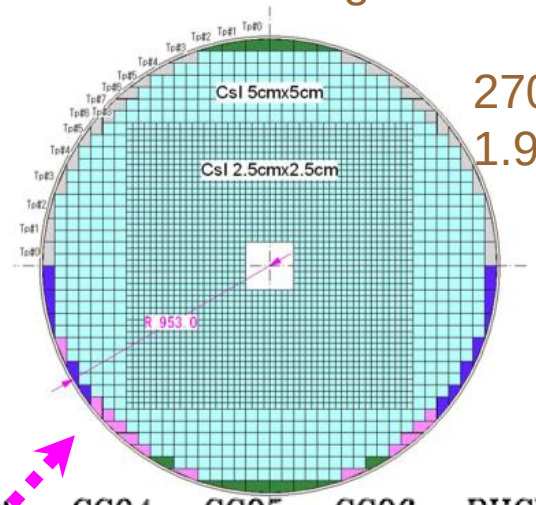
- Not yet discovered
- SM prediction is very small ~2.4e-11 but precise
- Discovery beyond SM prediction = Discovery of New Physics



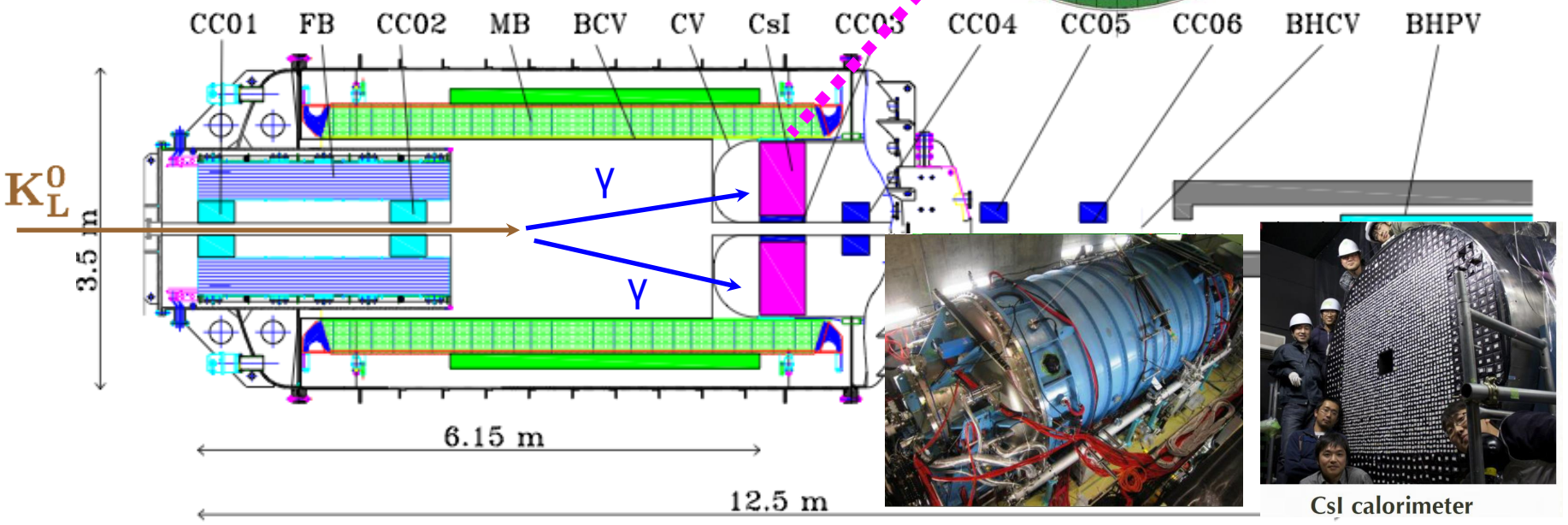
E14: K0 at TOkai for $K_L \to \pi^0 \nu\bar{\nu}$

- **new beamline**
- **Move and modify E391a detector**
  - **CsI calorimeter (KTeV crystals)**
  - **readout: waveform digitization**
  - **photon veto in the beam**

a long Japanese musical instrument (zither) with thirteen strings



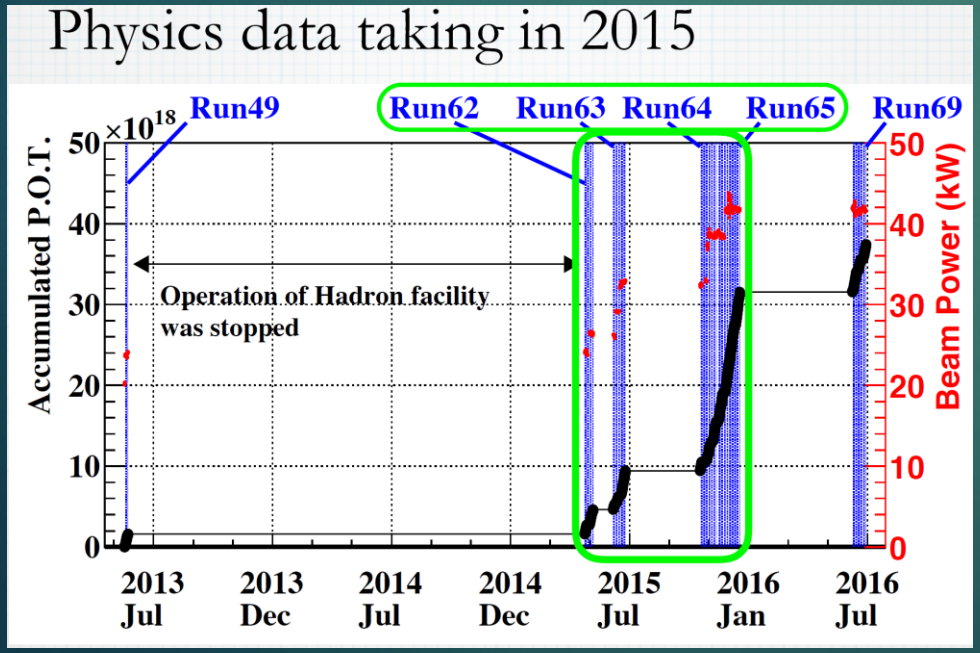
2700 CsI crystals
1.9m diameter

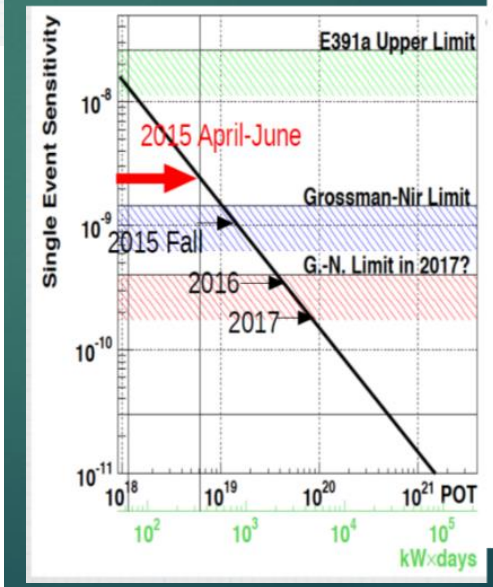


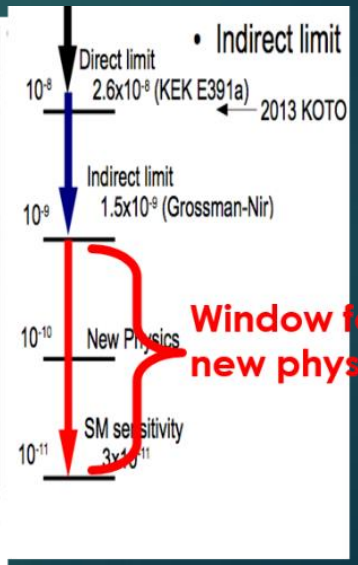
CsI calorimeter

KOTO status

- Started to probe new physics!







Completed

Kaon program

E36: Lepton universality in K^+ decay

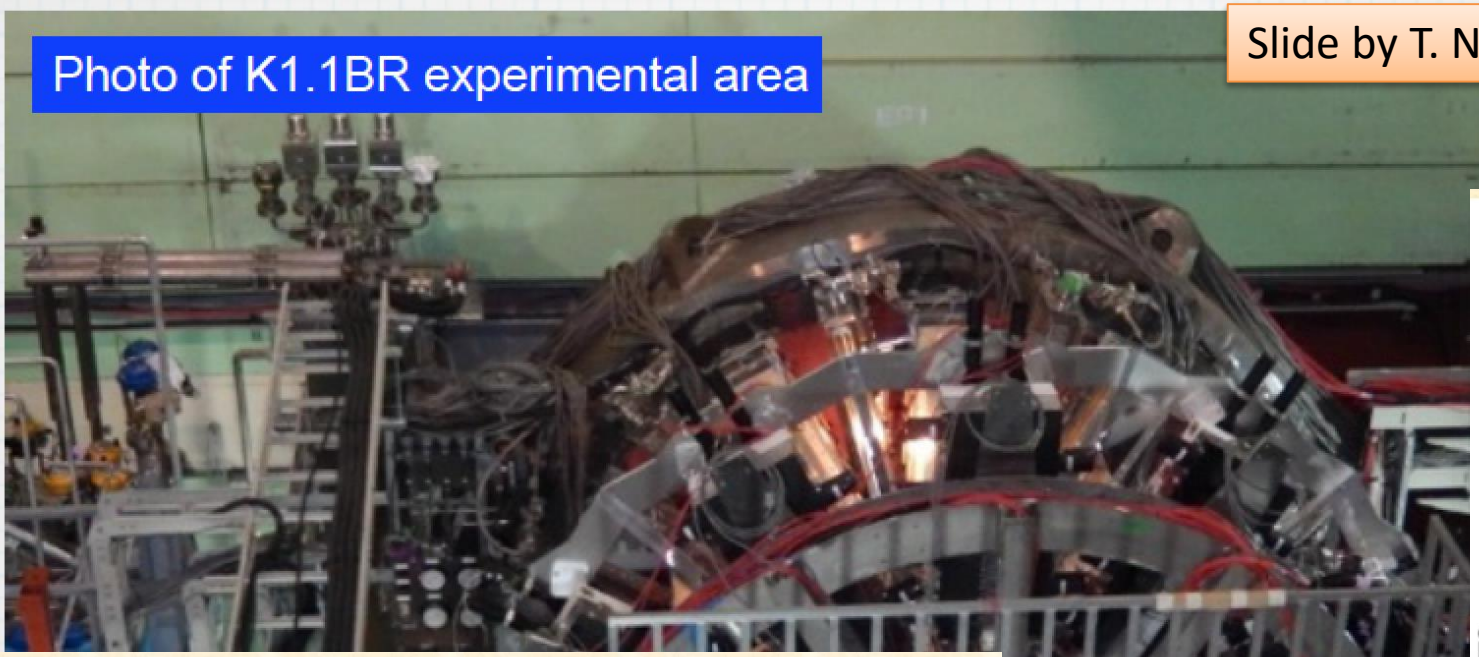
- ~20 collaborators from Japan, US, Canada, and Russia
- Search for New Physics via:

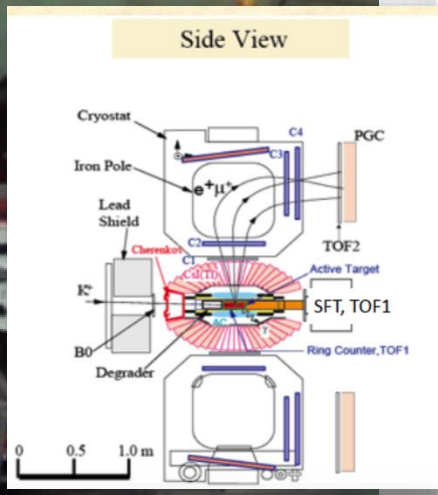
$$R_K = \frac{\Gamma(K^+ \to e^+\nu(\gamma))}{\Gamma(K^+ \to \mu^+\nu(\gamma)}$$

Slide by T. Nomura

E36

Photo of K1.1BR experimental area



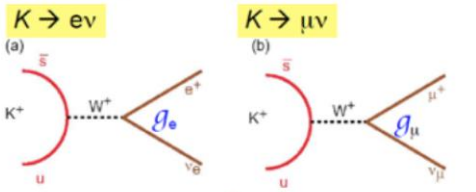


Lepton universality in K_{l2} decay

- Precise measurement of decay width ratio

$$R_K^{exp} = \frac{\Gamma(K^+ \to e^+\nu)}{\Gamma(K^+ \to \mu^+\nu)}$$

$g_e = g_\mu$?

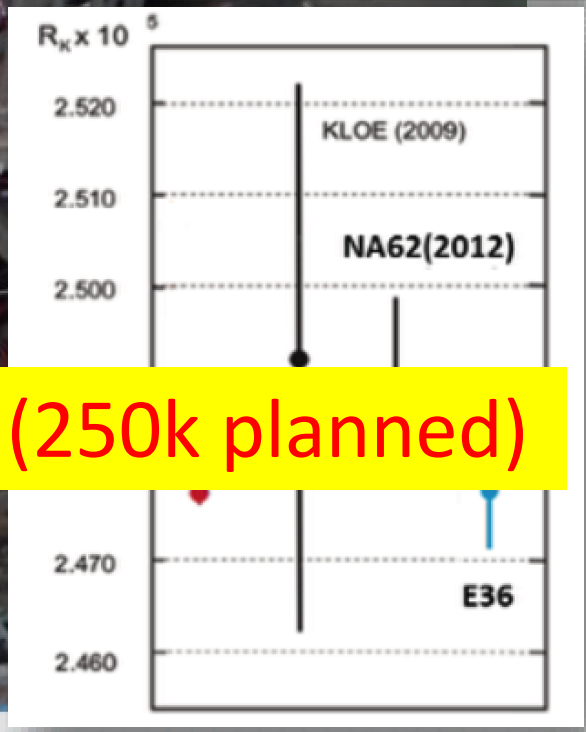


$$\Gamma(K_{l2}) = g_l^2 \, (G^2/8\pi) \, f_K^2 m_K m_l^2 \{1-(m_l^2/m_K^2)\}^2$$

$$R_K^{SM} = \frac{m_e^2}{m_\mu^2}\left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)(1+\delta_r) \qquad R_K^{SM}=(2.477\pm0.001)\times10^{-5}$$

SM uncertainty is $\Delta R_K/R_K \sim 0.04\%$

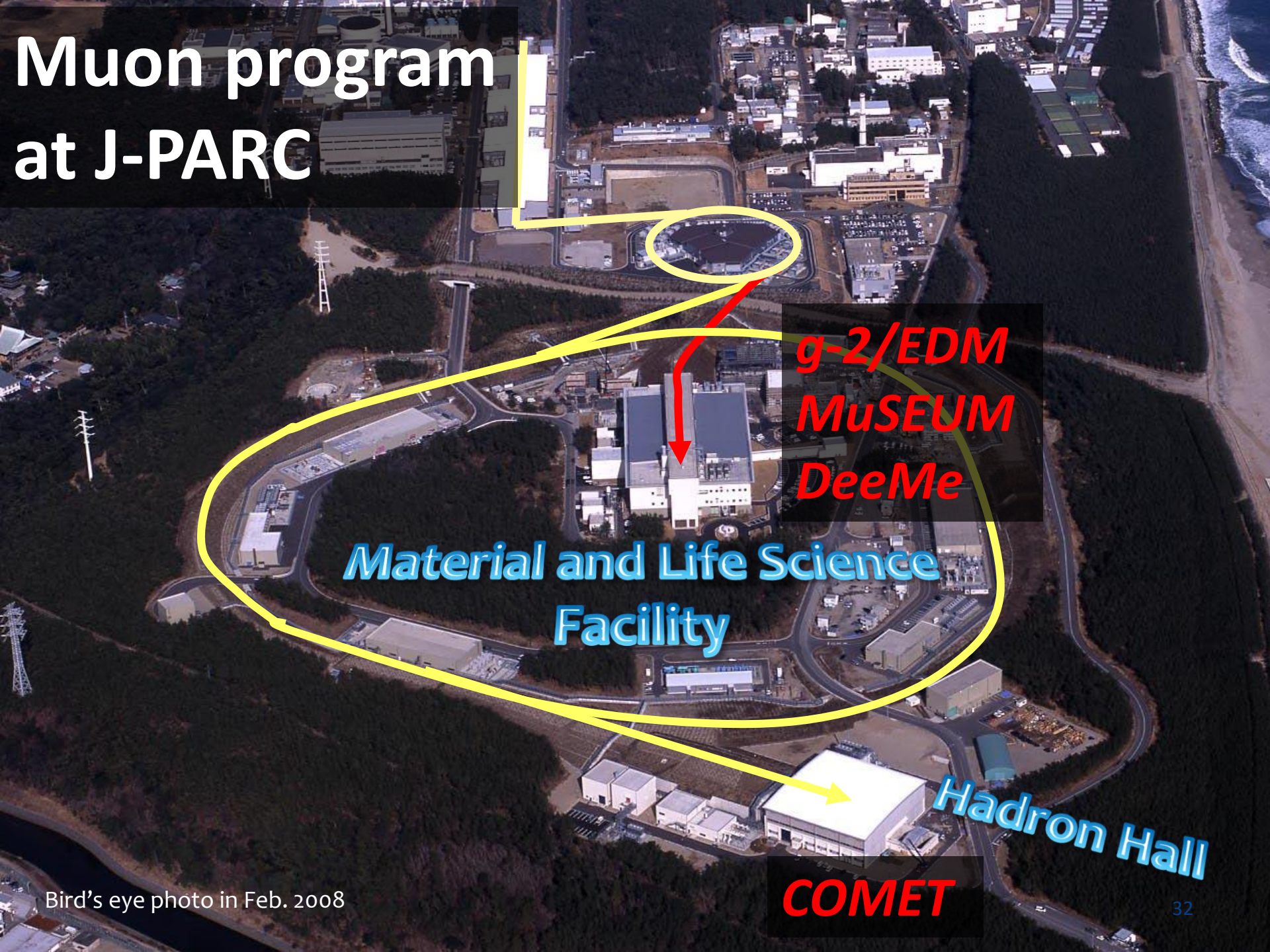
- Deviation of the experimental R_K from the SM prediction indicates lepton universality violation, which arises from New Physics



Completed in Dec.2015 with 40k Ke2 (250k planned)


Muon Program

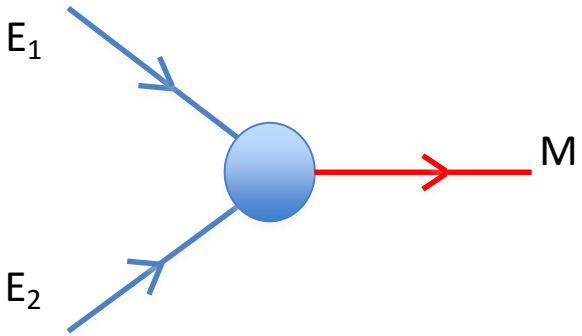
Muon program at J-PARC



Bird's eye photo in Feb. 2008

Role of low-energy charged lepton physics in LHC/ILC era

- Direct search
- (Energy Frontier)

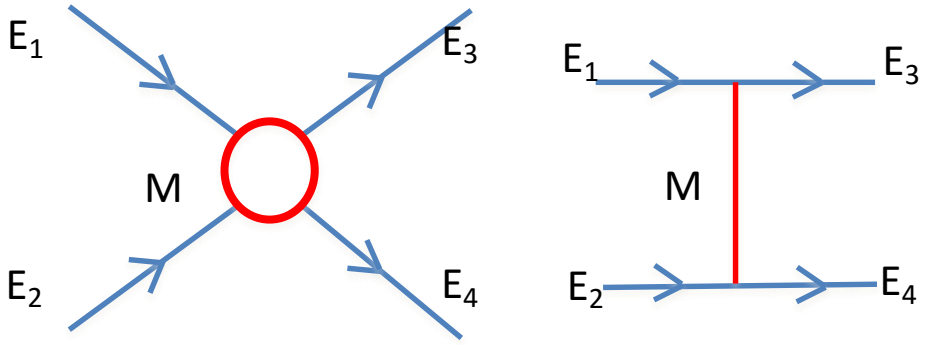


$E_1+E_2 > M \sim O(>100GeV)$

- LHC, ILC
  - Higher energy for heavier new particle

- Indirect search

(Intensity Frontier)



$E_1+E_2=E_3+E_4 < M$

- Charged LFV/g_μ-2

$L = L_{SM} + L_{BSM}$

"Slight" difference from SM prediction

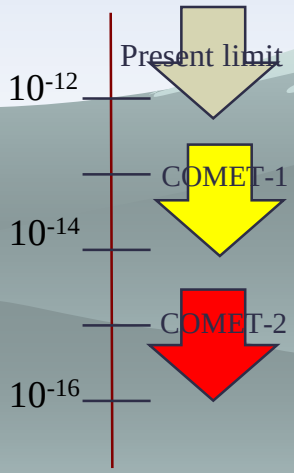
Muon physics program

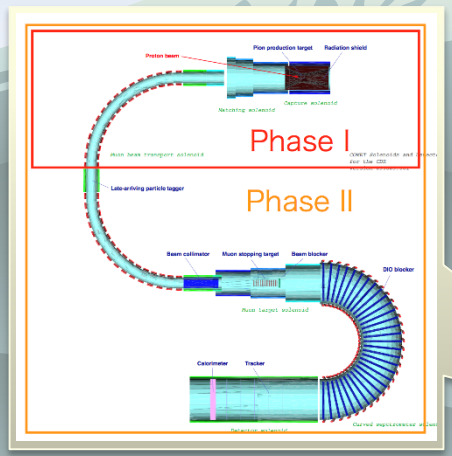
COMET in hadron hall

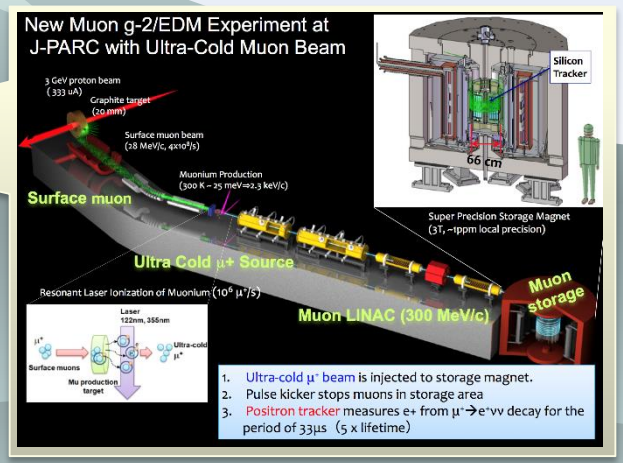
- μ→e conversion search
  - $\mu^- + (A,Z) \rightarrow e^- + (A,Z)$
  - Delayed 105MeV e^-
  - Present upper limit ~10^{-12}
- Phased approach
  - Phase-I: Beam study & Search < 10^{-14}
  - Phase-II: Search <10^{-16}
- Construction started!!

g-2/EDM in MLF

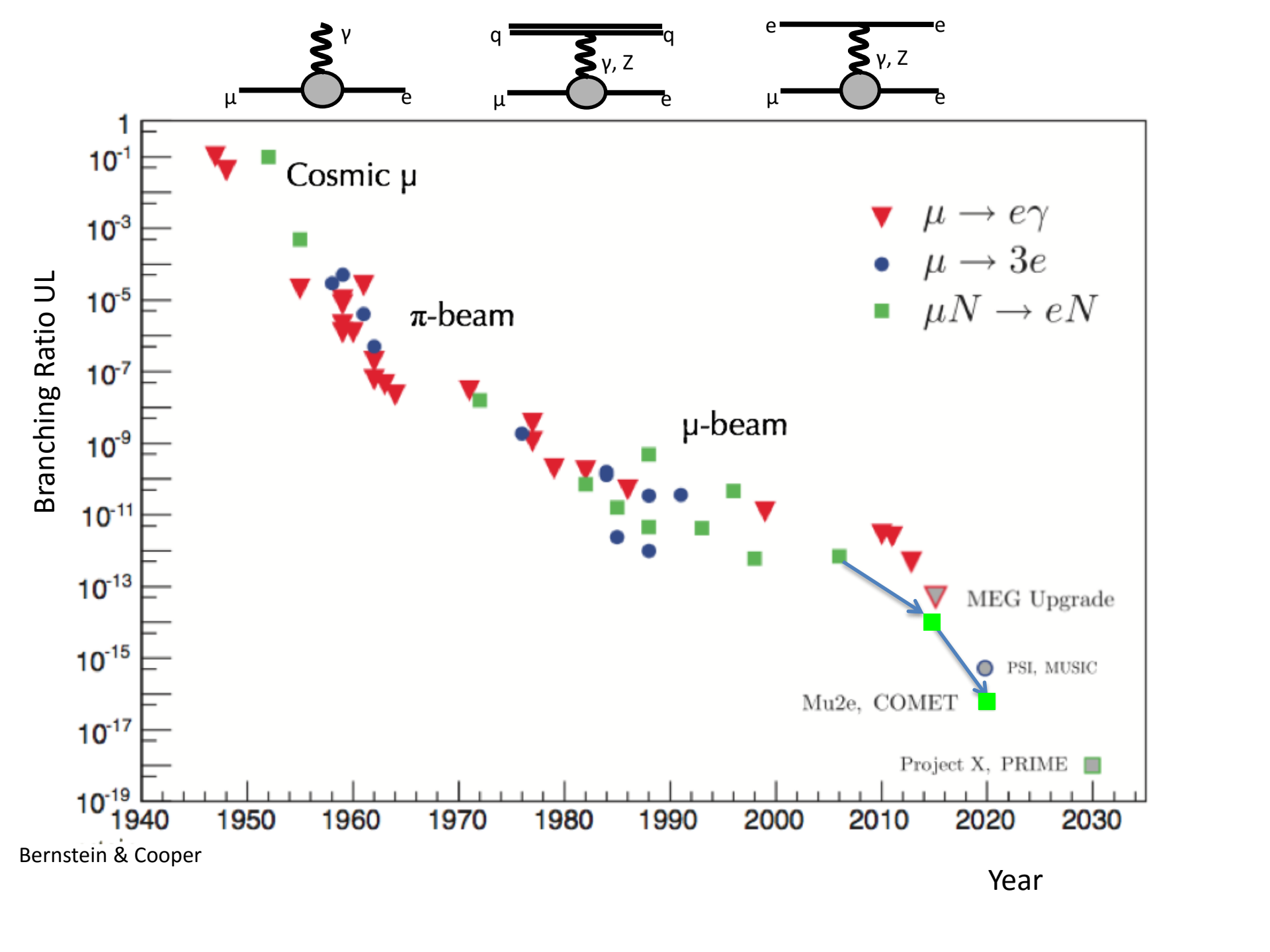
- New idea to avoid "magic" momentum by eliminating electric field
- Ultra cold μ^+ accelerated to 300MeV/c
- Goals
  - g-2 : 3 σ deviation from the SM
    - 0.5 ppm → 0.1 ppm
  - EDM: CP violation in the lepton sector?
    - < 1.8 x 10^{-19} e cm → 2 x 10^{-21} e cm
- Extensive R&D on-going
  - Beam intensity to test BNL g-2 results can be realized







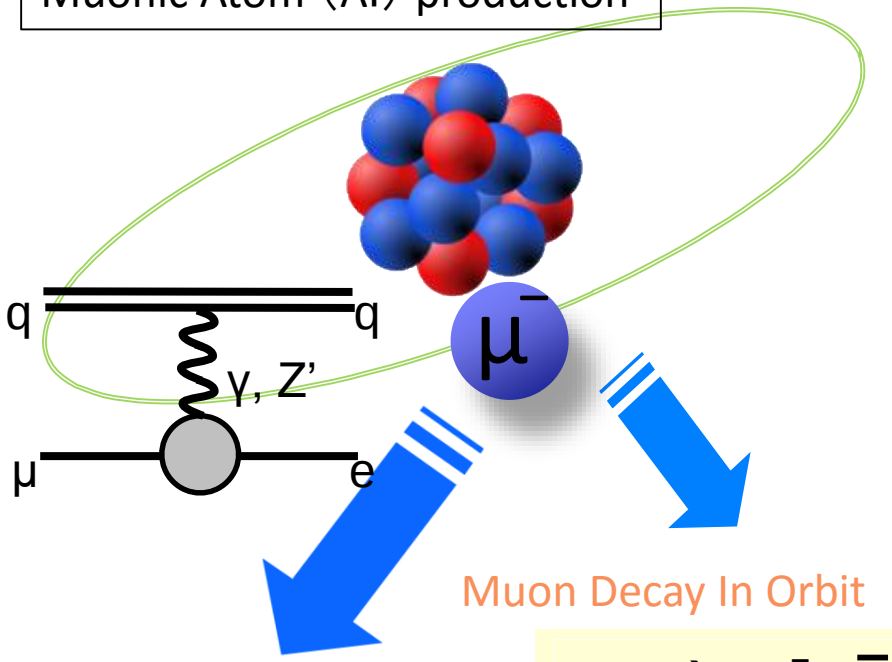
Opportunities to find New Physics "TOMMOROW"!



Bernstein & Cooper

COMET Experiment at J-PARC

Muonic Atom（Al）production



Muon Decay In Orbit

$$\mu^- \rightarrow e^- \nu \bar{\nu}$$

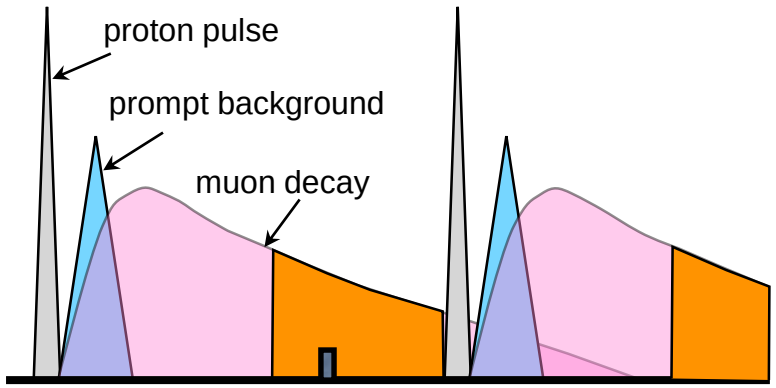
nuclear muon capture

$$\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)$$

μ-e conversion

$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$

- $E_{\mu e(Al)} \sim m_\mu - B_\mu = 105\text{MeV}$
  - B_μ: binding energy of the 1s muonic atom



$\pi^- + (A,Z) \rightarrow (A,Z-1)^*$, $(A,Z-1)^* \rightarrow \gamma + (A,Z-1)$, $\gamma \rightarrow e^+ e^-$

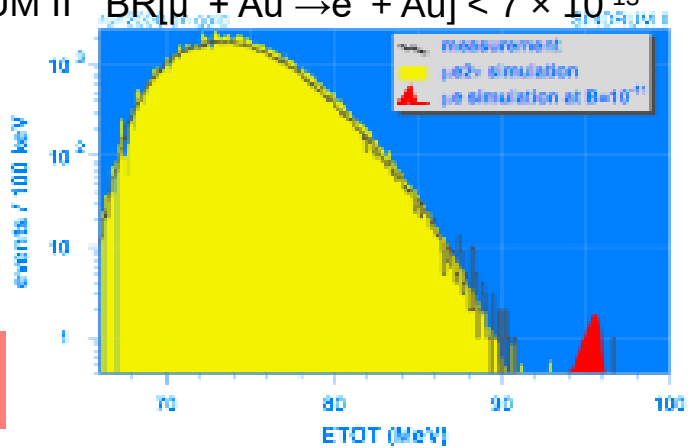
Prompt timing

Other sources

μ^- decay-in-flight, e^- scattering, neutron streaming

$$R_{ext} = \frac{\text{number of proton between pulses}}{\text{number of proton in a pulse}} < 10^{-9}$$

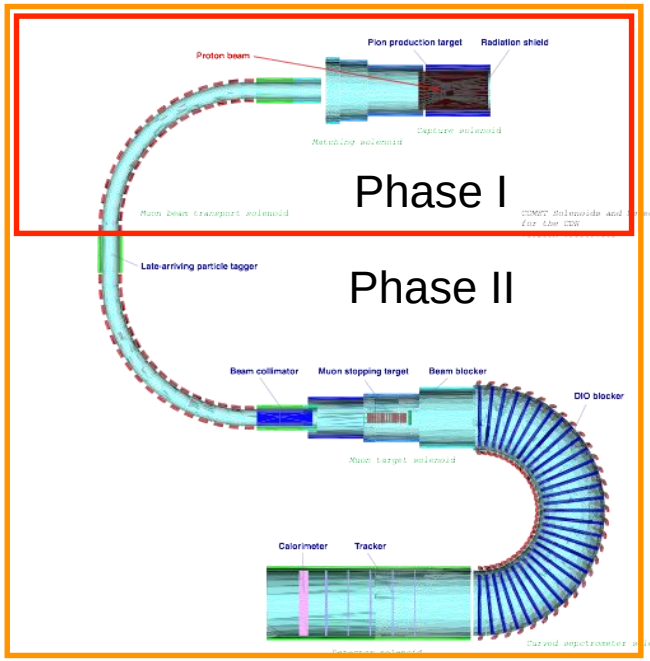
SINDRUM II $BR[\mu^- + Au \rightarrow e^- + Au] < 7 \times 10^{-13}$

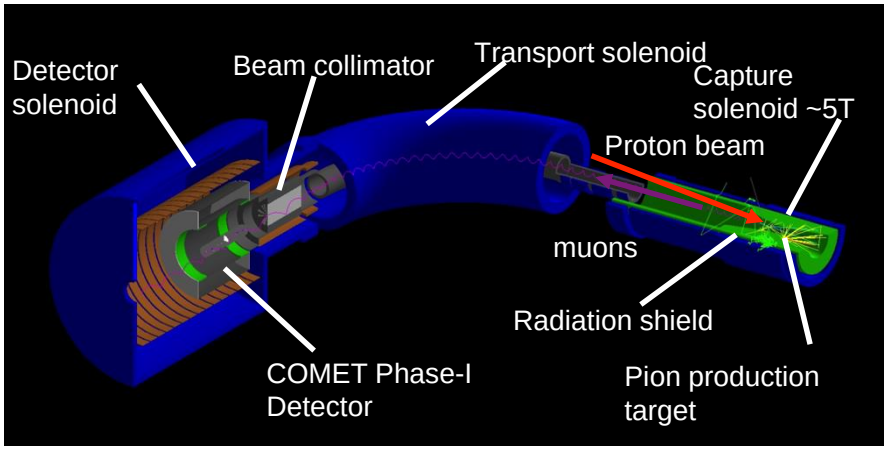


Slide by S. Mihara

COMET Phase I & II

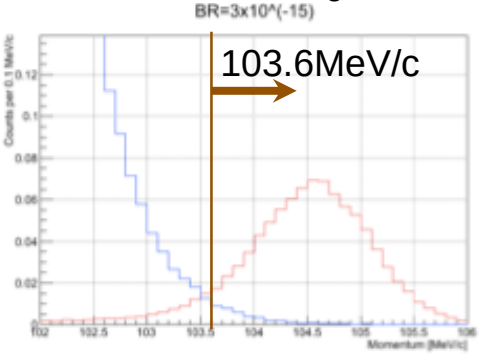
- Phase I
  - beam background
  - achieving the sensitivity of < 10^{-14} (100 better than the current limit)
  - **8GeV, 3.2kW beam, ~100-days DAQ (Graphite as a primary target)**
- Phase II
  - 8GeV, 56kW beam, 1-year DAQ (Tungsten as a primary target)
  - COMET final goal Sensitivity < 10^{-16}
- Proton beam extinction (w/o extraction) of 10^{-12} has already been achieved (Req. < $10^{-9\sim10}$)





Phase I background

0.024 BG expected
In 9.5x10^6 sec running time

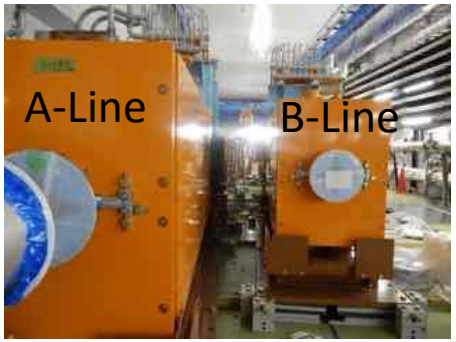


175 researchers from 33 institutes in 15 countries

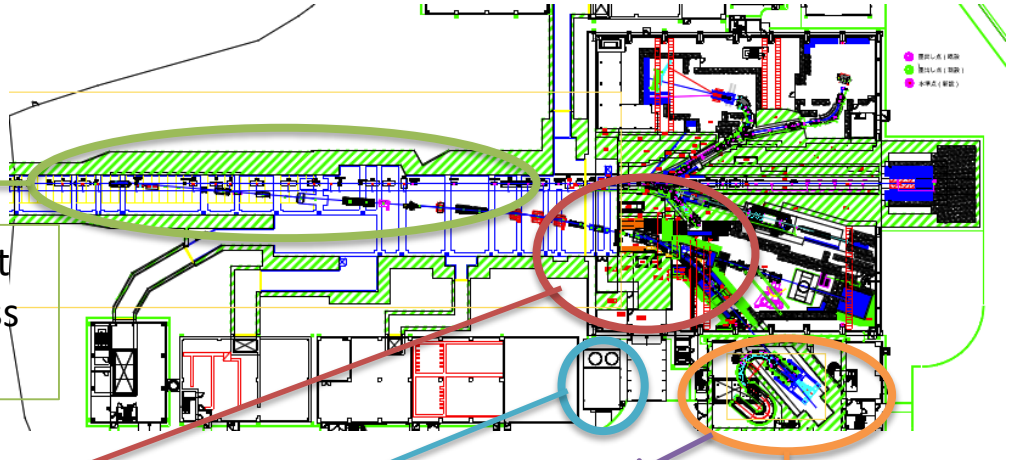
- **KAIST, Technical Univ. of Dresden and Lyon-IN2P3** have jointed in 2015

Status of COMET Experiment Facility

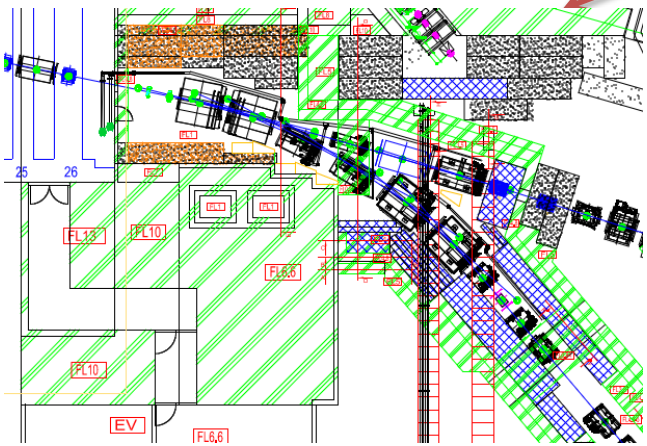
Switch Yard Beamline Elements



Beam line component installation in progress in SY since 2014



Beam transport line in HD hall



Significant construction work 2016 Summer to connect SY and Hall along the B-Line

SC magnets

He compressor used for E36 will be reused for COMET

90 deg. Transport Solenoid installed in Spring 2015 & Refrigerator in 2016

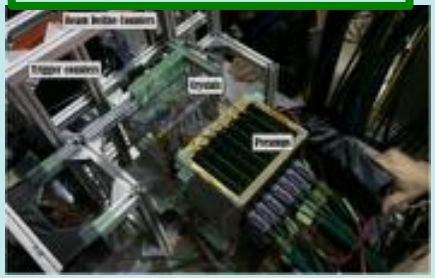
Hall construction

COMET Hall ready in Spring 2015

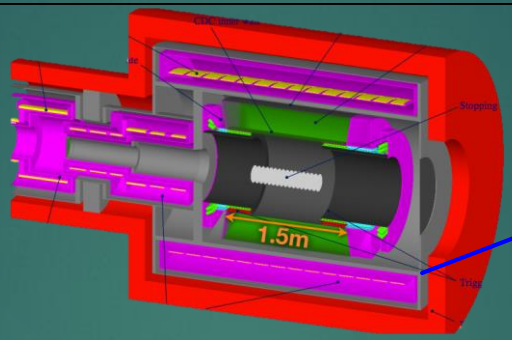
Status of Detector Preparation

Straw tracker (operational in vacuum) prototype

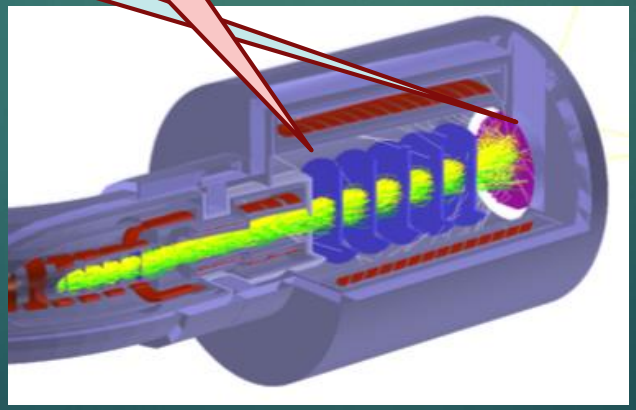
ECal (LYSO) R&D using prototypes



For physics measurement in Phase I



Detector for beam BG measurement in Phase I and physics measurement in Phase II



CDC : the main detector of COMET Phase-I Physics

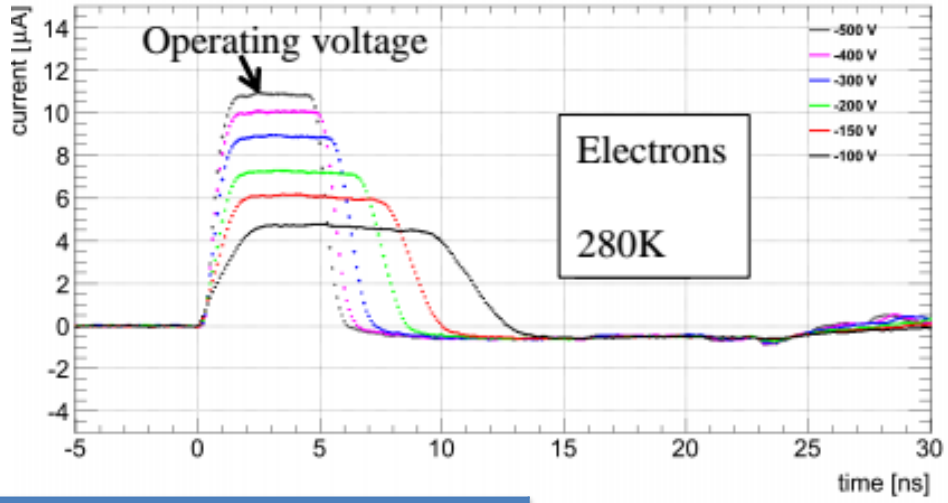
Total ~20,000 wire stringing completed in Nov. 2015 at KEK

CDC Read Out Electronics RECBE production at IHEP

Slide by S. Miha

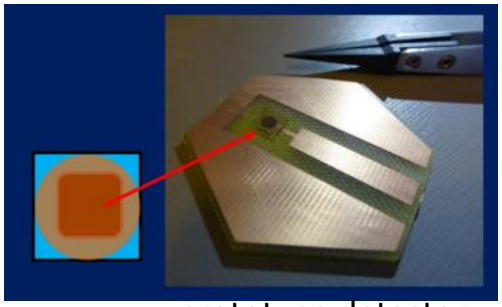
Indian Contribution to COMET at J-PARC

- Proposal by the IIT-Bombay group to use diamond detectors for monitoring proton beam.
  - First response
  - Good S/N
  - Radiation hard
  - Reasonable construction cost
  - Collaboration with J-PARC Acc. Monitor group
- Members
  - P. Sarin & S. Umasankar
- Supported by DST-JSPS bilateral research program



	Silicon	Diamond
Bandgap	1.12 eV	5.5 eV
Average Energy to create e-h	3.6 eV	13 eV
electron mobility	1450	4500
Hole mobility	480	3800

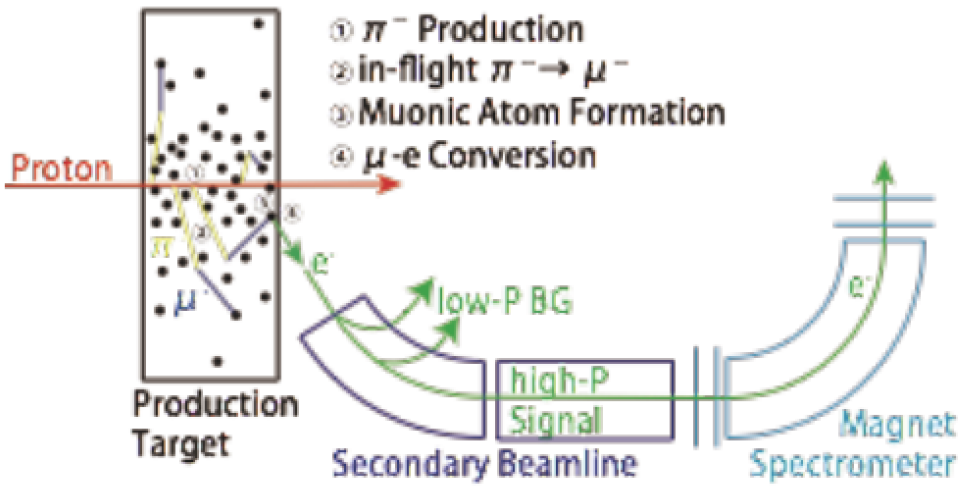
mobility in $cm^2/Vsec$



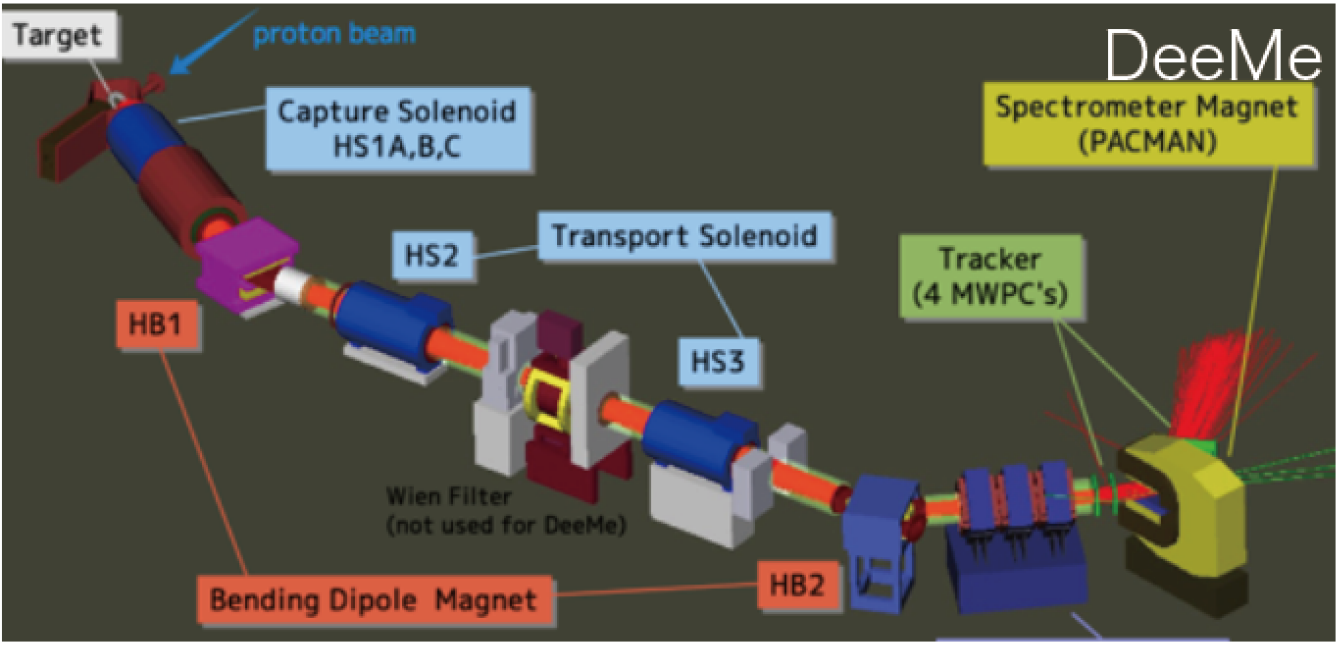
prototype detector

P. Sarin's visit to J-PARC MR accelerator tunnel in Feb. 2016

DeeMe: Search for μ-e Conversion



- **IMSS/Muon PAC: Stage-2 Approved**
- **J-PARC/RCS**: High-Power High-Purity Pulsed Proton Beam.
- **Production Target as μ-stopping target**.
- **H-Line/MLF**: Large-Acceptance Beam line.
- **State-of-the-Art MWPC** Technology
- **S.E.S. — BR~5 x 10^{-15}**
  (8 x 10^7 sec of data taking with SiC target)
- Start the physics run with graphite target
  - S.E.S. — 1 x 10^{-13} (2 x 10^7 sec)
- Aiming to start the engineering run in **2015**.



Magnet leased from TRIUMF is waiting for the installation at MLF

Muon Program

Muon g-2/EDM measurement

@ MLF H-line

100+ collaborators from 26 institutions

Slide by T. Nomura

muon g-2/EDM measurements

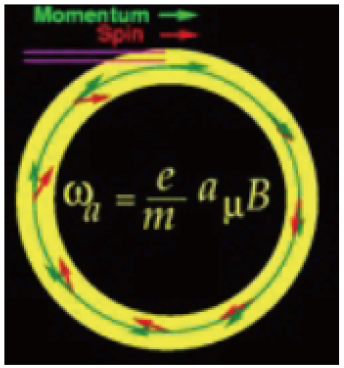
Anomalous magnetic moment (g-2)

$a_\mu = (g-2)/2$ = 11 659 208.9 (6.3) x 10^{-10} (BNL E821 exp) 0.5 ppm

11 659 182.8 (4.9) x 10^{-10} (standard model)

Δa_μ = Exp - SM = 26.1 (8.0) x 10^{-10} 3σ anomaly

In uniform magnetic field, muon spin rotates ahead of momentum due to g-2 ≠ 0



general form of spin precession vector:

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} - \left(a_\mu - \frac{1}{\gamma^2 - 1}\right)\frac{\vec{\beta}\times\vec{E}}{c} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B} + \frac{\vec{E}}{c}\right)\right]$$

BNL E821 approach
γ=30 (P=3 GeV/c)

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B} + \frac{\vec{E}}{c}\right)\right]$$

Continuation at FNAL with 0.1ppm precision

J-PARC approach
E = 0 at any γ

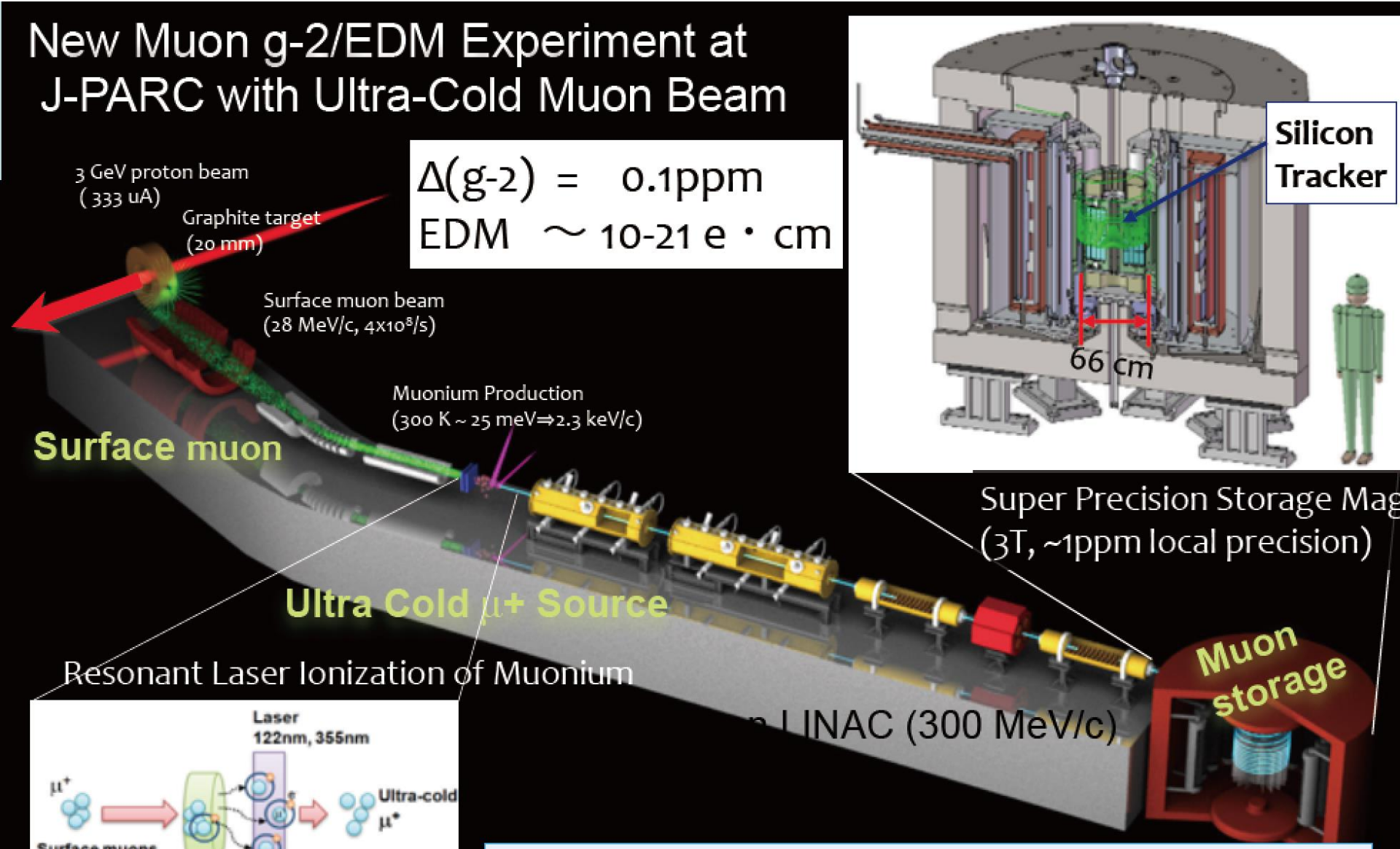
$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B}\right)\right]$$

Proposed at J-PARC with 0.1ppm precision

New Muon g-2/EDM Experiment at J-PARC with Ultra-Cold Muon Beam

$\Delta(g-2) = 0.1\text{ppm}$

EDM $\sim 10\text{-}21\ e \cdot cm$

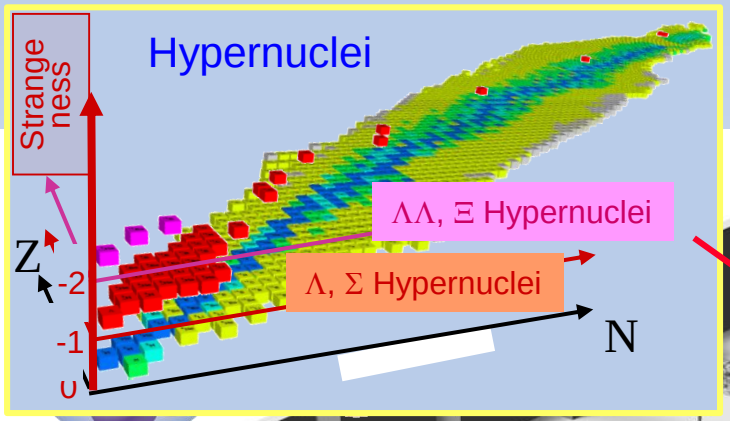


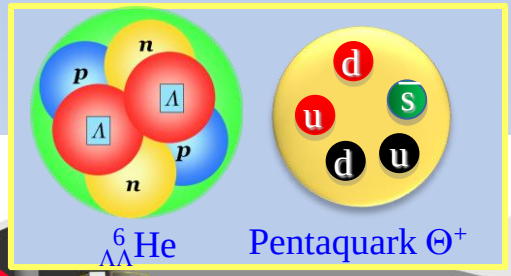
Super Precision Storage Mag
(3T, ~1ppm local precision)

1. Ultra-cold μ^+ beam is injected to storage magnet.
2. Pulse kicker stops muons in storage area
3. Positron tracker measures e+ from $\mu^+ \rightarrow e^+\nu\nu$ decay for the period of 33μs (5 x lifetime)


Nuclear physics Program

Nuclear Physics in Hadron hall





Implantation of Kaon and the nuclear shrinkage

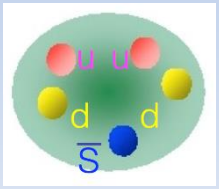
Kaonic atom

Kaonic nucleus

Why are bound quarks haevier？
Mass without Mass Puzzle

Physics outcome from hadron hall

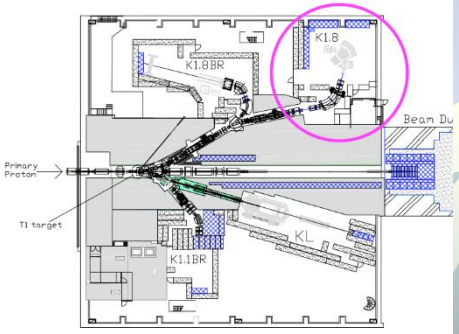
Pentaquark search

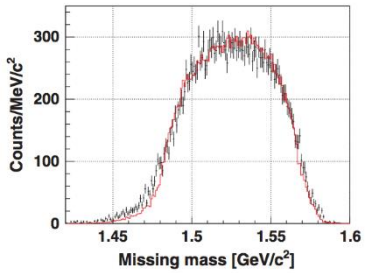


PRL 109, 132002 (2012) PHYSICAL REVIEW LETTERS week ending 28 SEPTEMBER 2012

Search for the Θ^+ Pentaquark via the $\pi^- p \to K^- X$ Reaction at 1.92 GeV/c

E19 experiment @K1.8 w/ SKS
1.92 GeV/c π- beam



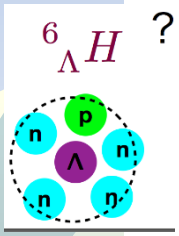


Not found giving upper bound on cross section and width

Physics Letters B 729 (2014) 39–44

Search for ${}^{6}_{\Lambda}$H hypernucleus by the ^{6}Li(π^-, K^+) reaction at $p_{\pi^-} = 1.2$ GeV/c ☆

J-PARC E10 Collaboration



E10 experiment @K1.8 w/ SKS
1.2 GeV/c π- beam

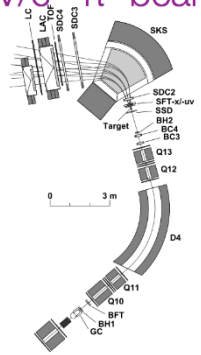
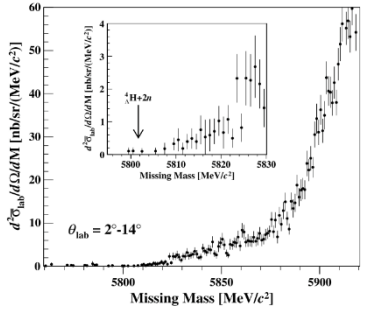


Fig. 1. Schematic view of the K1.8 beam line spectrometer (from GC to BH2), the target area (SSD and Target) and the SKS spectrometer (from SFT to LC). See the text for more details.



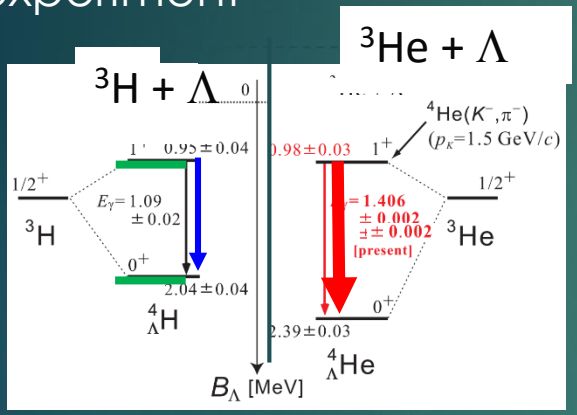
An upper limit of the production cross section for the bound ${}^{6}_{\Lambda}$H hypernucleus was estimated to be 1.2 nb/sr at 90% confidence level.

Physics results with Pion beam are coming out!

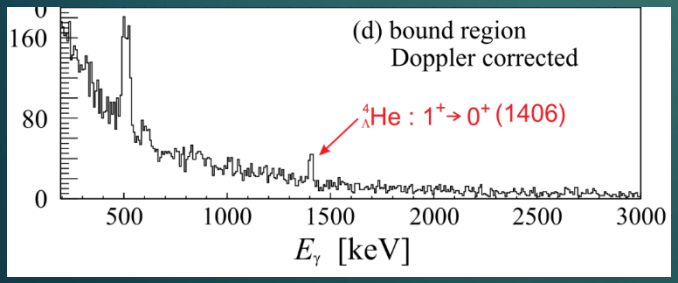
Result from E13

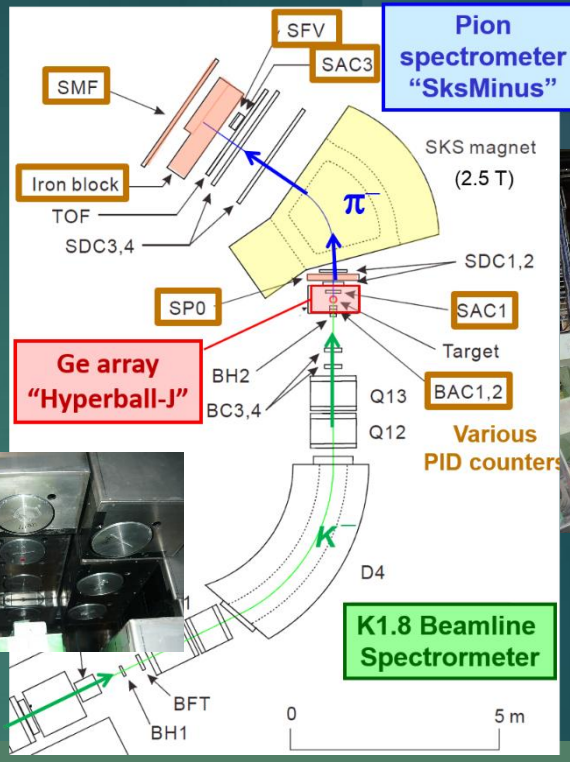
$$ {}^{A}_{\Lambda}Z(K^-,\pi^-){}^{A}_{\Lambda}Z^* \rightarrow {}^{A}_{\Lambda}Z+\gamma $$

Apr,Jun 2015 data
Kaon beam result = "THE" J-PARC experiment



$^4_\Lambda$He(1$^+$-> 0$^+$) : 1406±2±2 keV
Surprisingly large





PHYSICAL REVIEW LETTERS
moving physics forward

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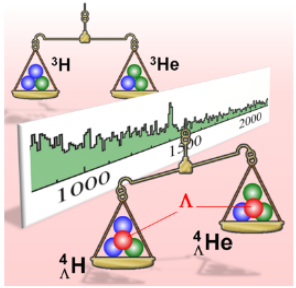


EDITORS' SUGGESTION

Observation of Spin-Dependent Charge Symmetry Breaking in ΛN Interaction: Gamma-Ray Spectroscopy of $^4_\Lambda$He

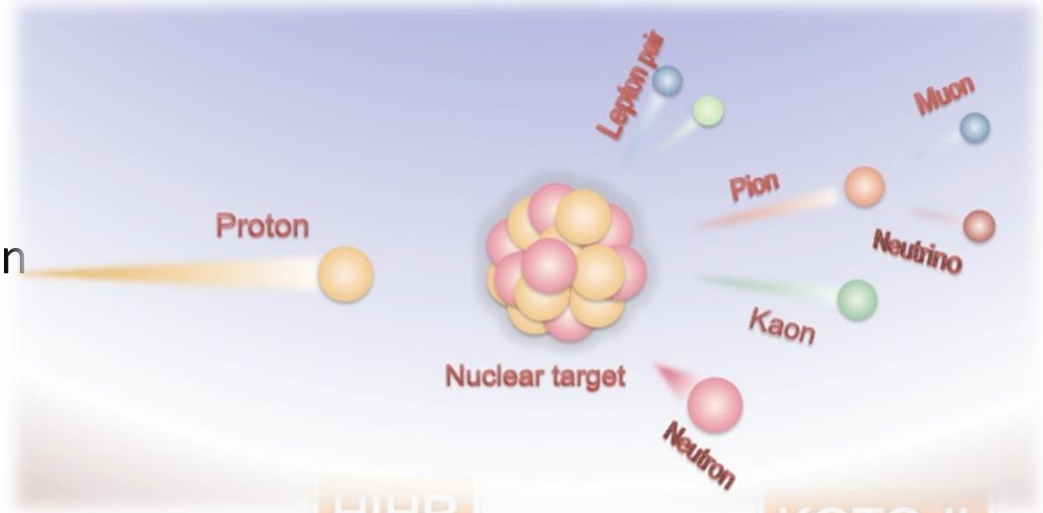
The energy spacing of the spin-doublet states in the $^4_\Lambda$He hypernucleus indicate a large spin dependent charge symmetry breaking in the ΛN interaction.

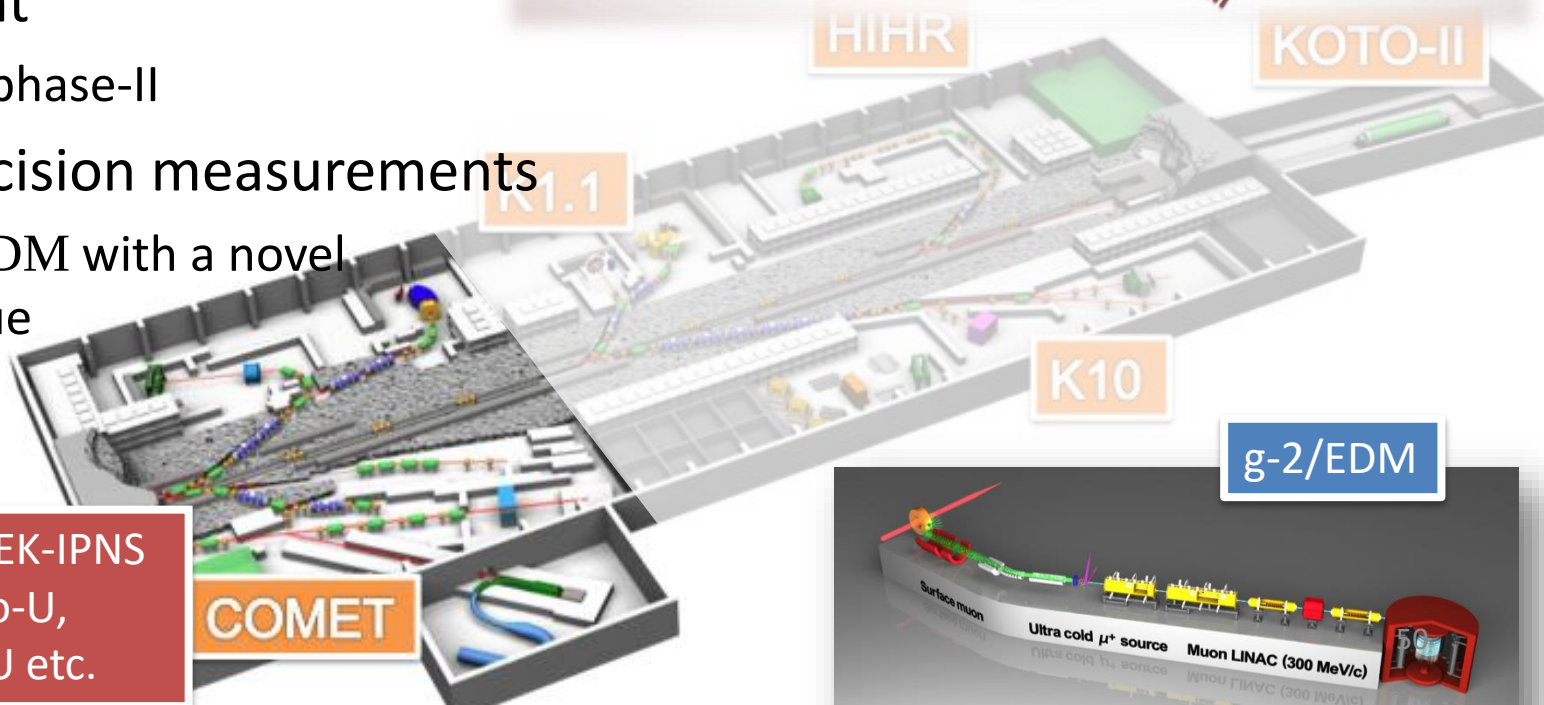
T. O. Yamamoto *et al.* (J-PARC E13 Collaboration)
Phys. Rev. Lett. **115**, 222501 (2015)

Future Plan at J-PARC

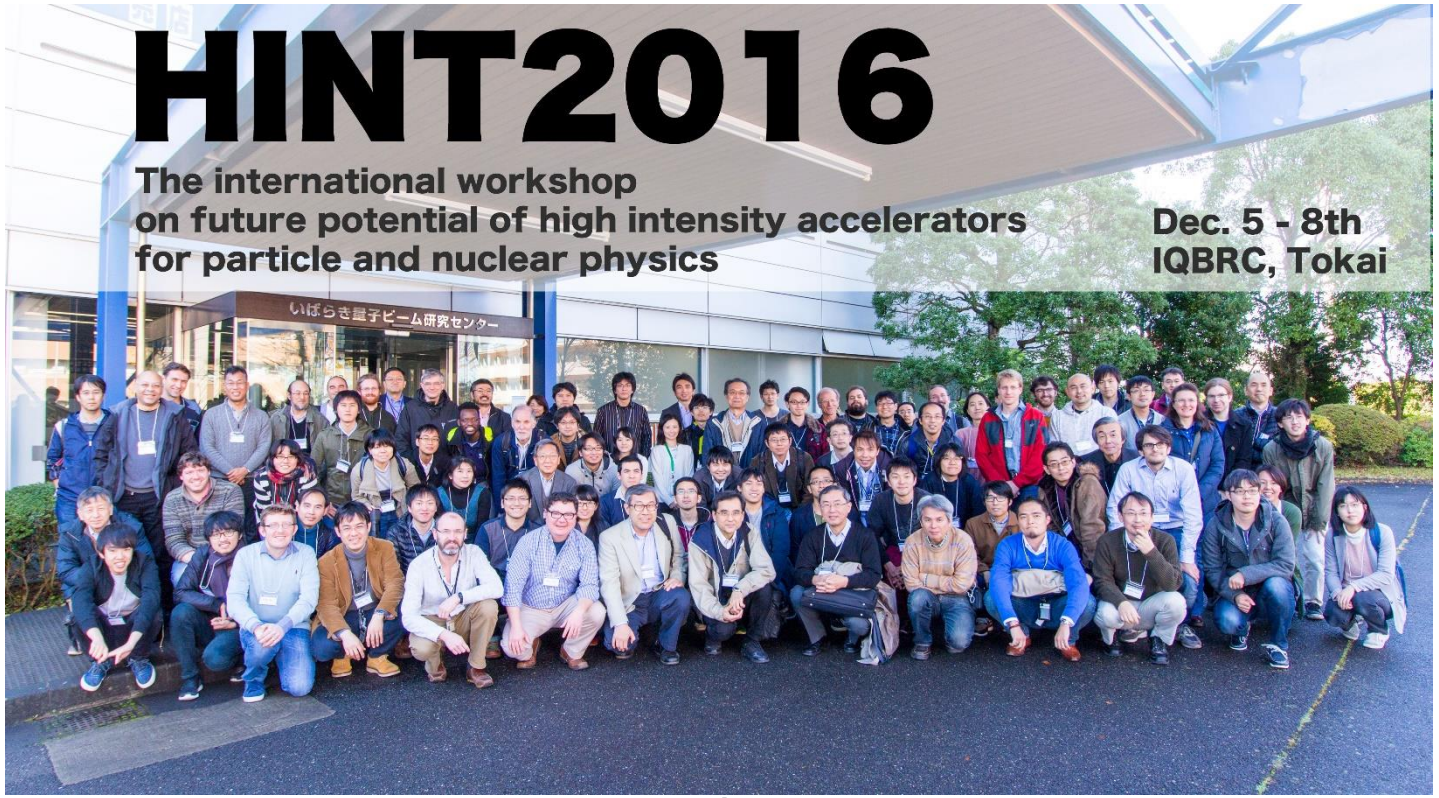
Elucidation of Origin of Matter with J-PARC Upgrades

- Hadron Hall Extension
  - A Search for CPV beyond CKM with Kaon rare decay KOTO-II
  - Strangeness Nuclear and Hadron Physics
- Muon to electron conversion experiment
  - COMET phase-II
- Muon precision measurements
  - g_μ-2/μEDM with a novel technique





Collaboration of KEK-IPNS and U.Tokyo, Kyoto-U, Tohoku-U, Osaka-U etc.



集合写真。12月5日高橋将太氏撮影。

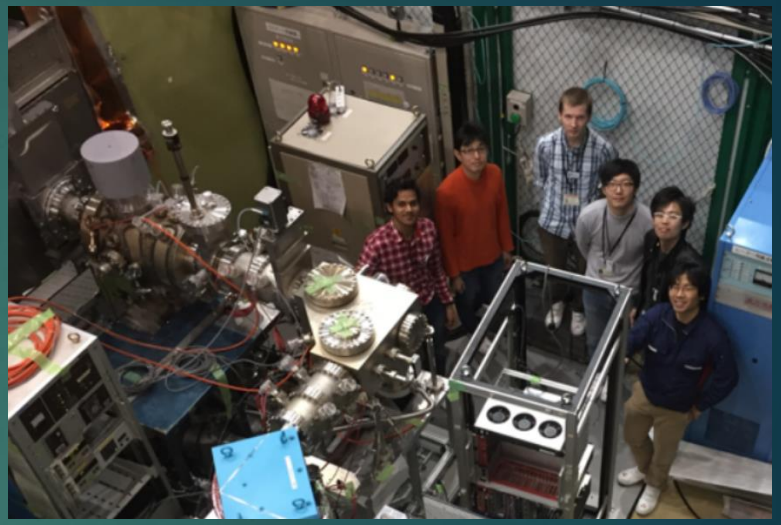
センター長によるオープニングトーク。

会議風景。広報伊藤氏撮影。

Opportunities for student to learn at J-PARC

- JFY2016
  - 2 "under"grad students from IITB stayed and workd at J-PARC for 3month (Sept – Dec)
- JFY2017
  - 2 students from IITH under preparation
  - Interest from IITB
  - JSPS "sakura" program approved

    ~30 undergrad from IITB are staying at J-PARC for 3 weeks



Summary

- J-PARC as a "Intensity frontier" machine started to show its true potential of beam power
  - Currently achieved 390kW/42kW
  - With MR-PS upgrade, aim at 750kW → 1.3MW
- Rich particle and nuclear physics program!
  - Neutrino: T2K → T2K-II → HK
  - Kaon: KOTO
  - Muon: COMET, g-2/EDM
  - Neutron
  - Hadron/Hyper-nuclear physics with Pion/Kaon beams
- Excitement of "Eve" of many discoveries
- Many/various opportunities of collaboration to DISCOVER SOMETHING NEW!

Accelerator Science Indian-KEK Consortium for promoting accelerator based science is under consideration by Indian Institutes
KEK Proposal was submitted to many Indian Institutes.

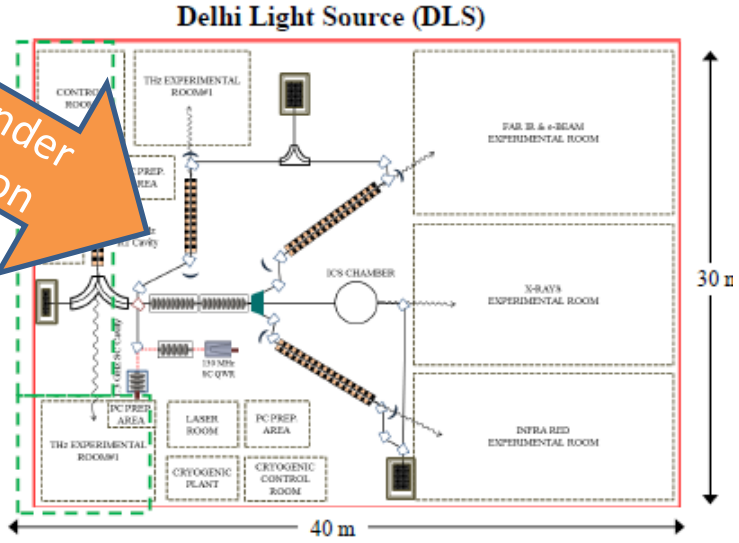
Accelerator Science India-KEK Consortium

I:IUAC,VECC, RRCAT, BHU J:KEK	I:TIFR, IUAC, IITH, IITB, BHU J:KEK	I:IUAC,SINP RRCAT,JNCA SR,BHU J:KEK	I:TIFR, IITH, IITB, BHU J:KEK	I:DSCI, SAMEER, BHU J:KEK	I:IUAC, SAMEER, BHU J:KEK
Accelerator R&D	Detector R&D	Materials Science	Particle Physics	Medical Application	School
FEL@IUAC	photon	Energy materials	Belle II	Ion therapy	Accelerator
Light source	neutron	Nano-materials	Neutrino	BNCT	Physics
ILC			Muon	**Protein crystallography**	

Super conducting acceleration cavity (Homemade by KEK)

Accelerator Technologies Transfer from KEK, Waseda Univ. and Osaka Univ.

IUAC DLS (Delhi Light Source) under construction with KEK cooperation



Fast phase plan which is world smallest FEL.

Main Accelerator Laboratories in India

Raja Rammana Centre for Advanced Technology (RRCAT), Indore : INDUS 1 & INDUS 2; SCRF Program

Inter University Accelerator Centre (IUAC), Delhi : 15 UD Pelletron & SC Booster

Bhabha Atomic Research Center (BARC), Mumbai: HIPA ; 7 MeV Linac

Variable Energy Cyclotron Centre (VECC), Kolkata: Hosts 88" Cyclotron; SC Cyclotron; Building RIB Facility

Institute of Physics (IOP), Bubhaneshwar: 3 MeV Pelletron

Tata Institute of Fundamental Research (TIFR) : 14 UD Pelletron

Pune University: 10 MeV Microtron; 7 MeV Linac

Mangalore University: 10 MeV Microtron