A Study of a Neutrino Factory in Japan

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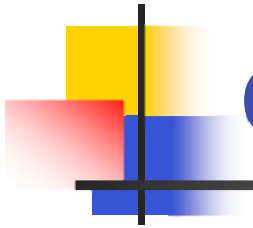
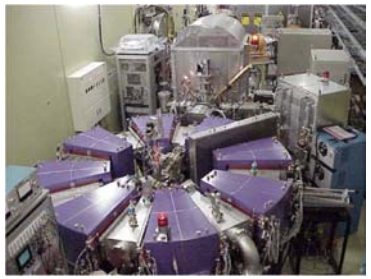


Outline

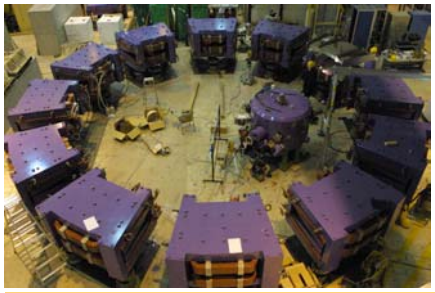
- Neutrino Factory in Japan
- R&D activities
- Facility at J-PARC
- Summary

Japanese FFAG Scheme

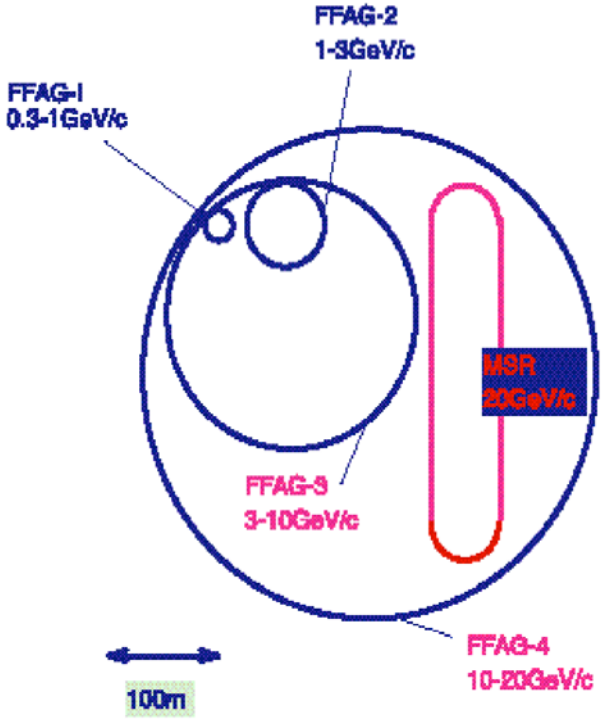
- FFAG Acceleration (FFAG=Fixed Field Alternating Gradient synchrotron)
  - Large Acceptance ($\varepsilon_{H,V}$, dp/p)
  - Muon cooling is not mandatory. (better if available)
- Advantages
  - Costs saving
    - Small # of low freq RF
    - no cooling needed.
  - Simple and compact (R~200m)
  - Earlier readiness
    - Hardware can be commonly used
    - R&D (POP -> 150 MeV FFAG)



0.5-MeV Proton FFAG
POP at KEK



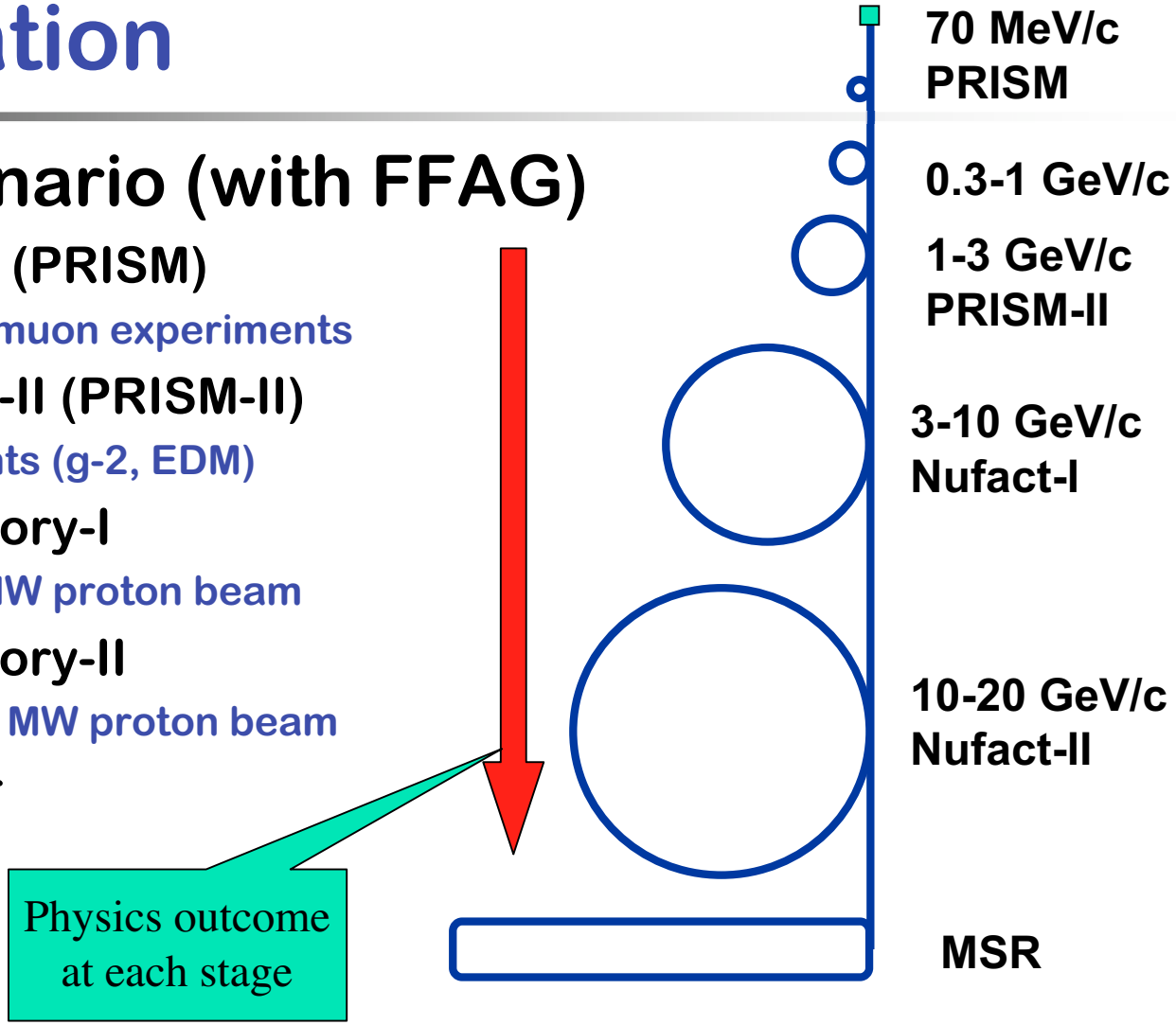
150-MeV Proton FFAG
Under construction at KEK

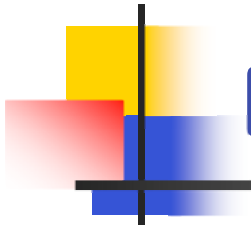


Series of FFAG acceleration

Staging Approach towards Realization

- **Staging scenario (with FFAG)**
  - Muon Factory (PRISM)
    - For stopped muon experiments
  - Muon Factory-II (PRISM-II)
    - Muon moments (g-2, EDM)
  - Neutrino Factory-I
    - Based on 1 MW proton beam
  - Neutrino Factory-II
    - Based on 4.4 MW proton beam
  - Muon Collider





R&D Acitivities

- FFAG
  - 150 MeV Proton FFAG
  - New lattice (non-scaling)*
  - Phase rotator simulation
- Liquid H2 Absorber
  - Convection type for MICE*
  - MUCOOL absorber*
- Scifi tracker
  - MICE detector*
- High field gradient RF
  - Ferrite-loaded cavity
  - Ceramic-loaded cavity*
- Targetry/Collector
  - R&D for high field SC solenoid
    - Prototype magnet of 10.9 T
    - Beam test to measure radiation heat load using 12 GeV proton beam
  - Mercury loop for study of conducting target*

* International collaboration

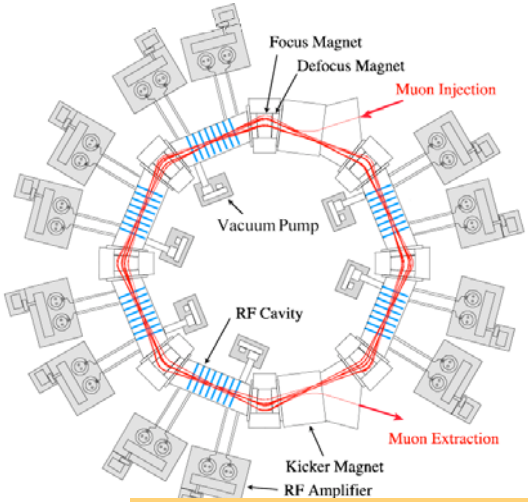
150 MeV Proton FFAG R&D

- **Parameters**
  - 12 sectors
  - Repetition ~ 250Hz
  - 10 MeV to 150 MeV
- **Study on**
  - Yoke-free magnet
  - Beam extraction
  - Fast repetition rate
- **Commisioning March 2003**

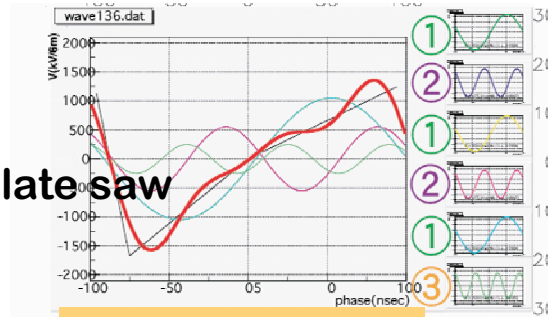
KEK PS HALL

FFAG Phase Rotator for PRISM

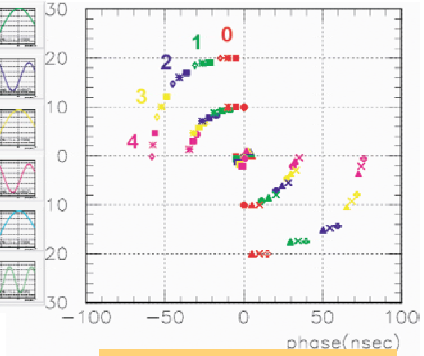
- **PRISM-FFAG**
  - **Intense slow muon beam**
    - **20 MeV (62 MeV/c)**
    - **10^{11}~10^{12} μ/s**
    - **dE/E ~ a few %**
    - **For stopped muon exp.**
      - **μ-e conversion**
  - **Budget request is being submitted**
- **Simulation**
  - **3D tracking**
  - **RF kick**
    - **Higher harmonics to simulate saw tooth shape**
  - **dE/E ~ 5 %**



PRISM-FFAG simulation



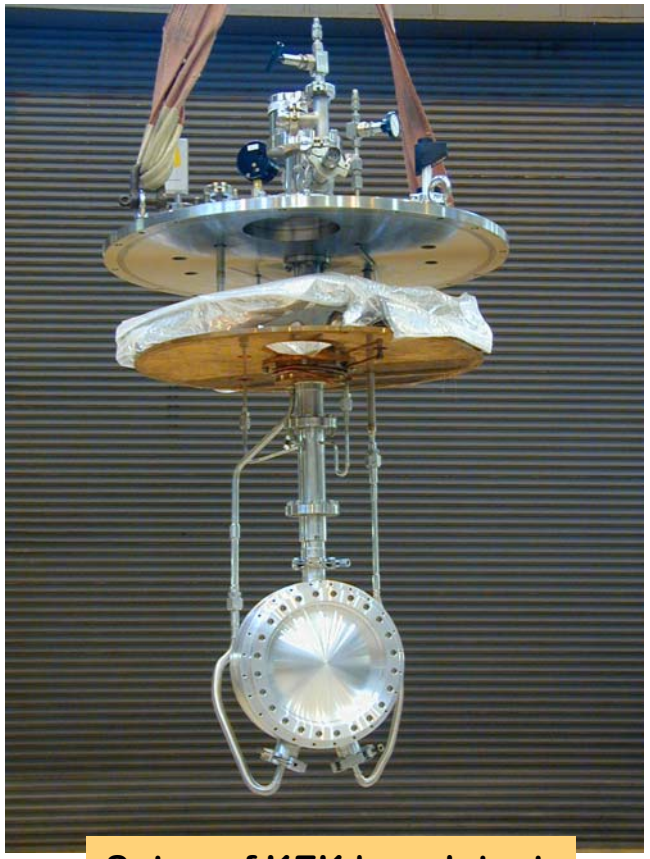
Saw-tooth shaped RF pulse



dp/p vs phase

Convection-type L-H_2 absorber

- MICE/MUCOOL collaboration
  - US/EU/Japan (KEK, Osaka)
- KEK bench test of convection absorber I
  - Liquid Ne
  - Heat load Q ~ 70W
  - LHe consumption 29.5 l/hr
  - MICE requirements are met
    - Qtotal ~ 100 W
  - High heat load and high flow rate make solid-Ne
    - Modify flow direction
    - Absorber II

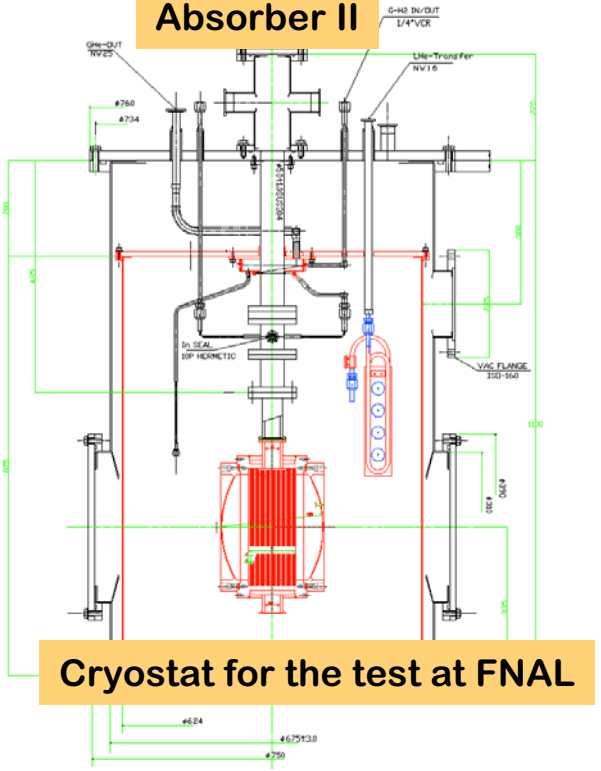


Setup of KEK bench test of convection absorber I

Convection Absorber R&D: Absorber II

- 2 way flow with heater
- Test at FNAL
  - Safety issues
    - Window thickness 1m
      - Pmax > 5bar
    - Volume ratio
      - LH_2/Vac ~ 62 > 52
    - Heaters are sheathed
  - Shippment to FNAL
    - Spring, 2003
  - Initial helium filling test at FNAL
    - Summer, 2003

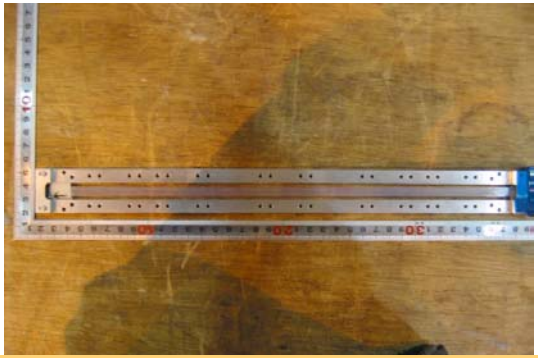
Absorber II



Cryostat for the test at FNAL

MICE Scifi Tracker R&D

- US/UK/Japan Collaboration
- Beam test using KEK 12 GeV PS in December, 2002
  - Imperial college (Dr. Ed. Mckigney)
  - Kurare ϕ=0.3mm, ϕ=0.5mm, UK fibre ϕ=1mm
  - MA-PMT read out
  - Study light yield and timing resolution



Scifi bundle used in the beam test

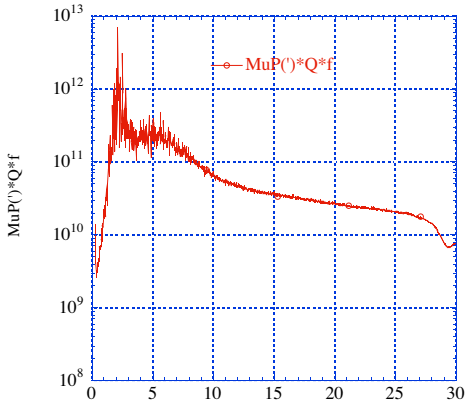
Beam test at KEK Dec, 2002

High Gradient RF R&D

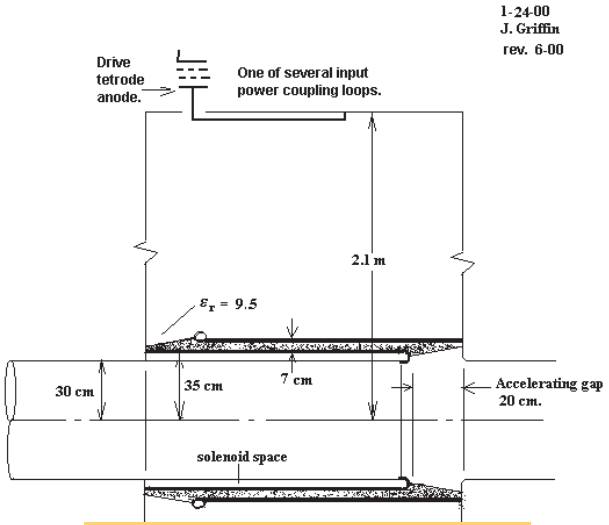
US-Japan collaboration

- **Ferrite-loaded Japan-KEK**
  - SY25(TDK)
    - Large μQf product
    - High shunt impedance
  - To be tested at high power ~ 10 kW
- **Ceramic-loaded US-FNAL**
  - goal: R&D of an RF cavity of 0.5-1.0 MV/m at 7.5 MHz with a high dielectric constant ceramic.

Real size SY25 core



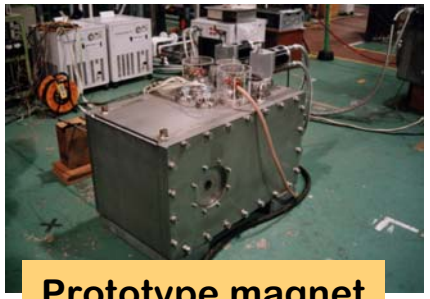
μQf vs frequency (MHz)



Conceptual design of Ceramic-loaded cavity

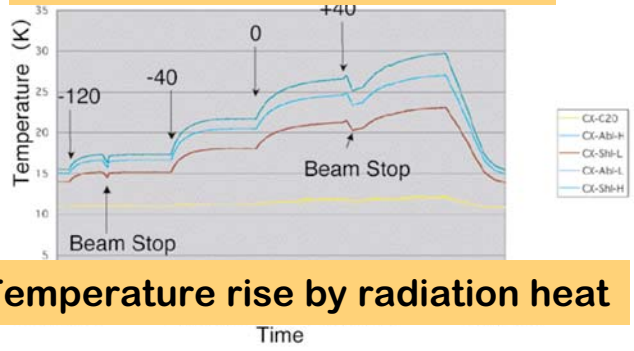
Pion Capture Magnet R&D

- Prototype magnet of 10.9 Tesla
  - Hybrid coil (NbTi, Nb_3Sn, HiTc)
  - Indirect cooling with GM cryocooler
  - 10.9 T in 6 cm warm bore
- Design study
  - Heat load is estimated as ~ 500W with 34cm thick W shield (MARS)
  - Simulation codes (MARS, etc.) should be tested before optimization
  - Beam test at KEK 12 GeVPS in November,2002
    - Direct measurement of radiation heat load from production target, by a coil mockup



Prototype magnet

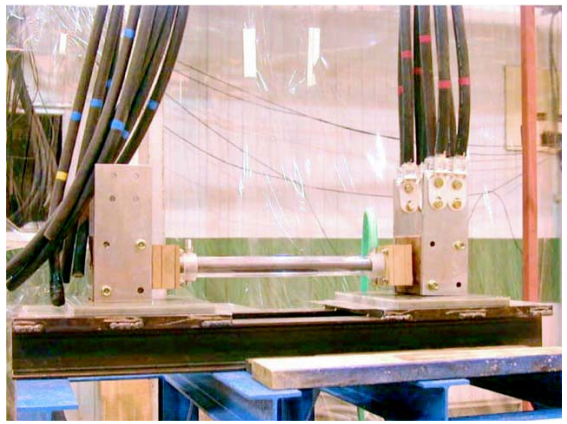
Beam test at KEK Nov, 2002



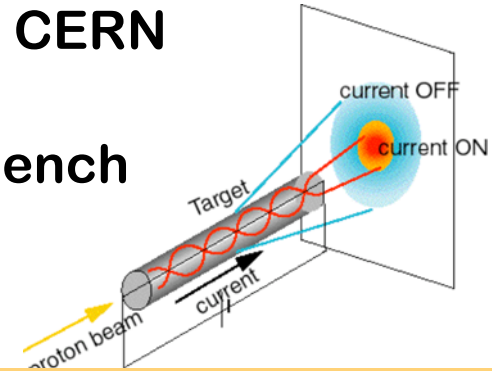
Temperature rise by radiation heat

Target R&D

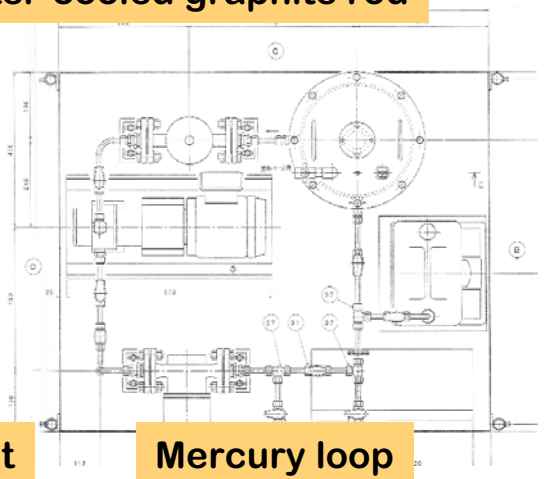
- Stationary target
  - JHF neutrino group (Hayato , Oyabu et.al)
  - Water cooled graphite
  - 100 kW
- Conduction pulsed target
  - Collaboration with CERN
    - B. Autin et al
  - Mercury loop for bench test



Test of a water-cooled graphite rod



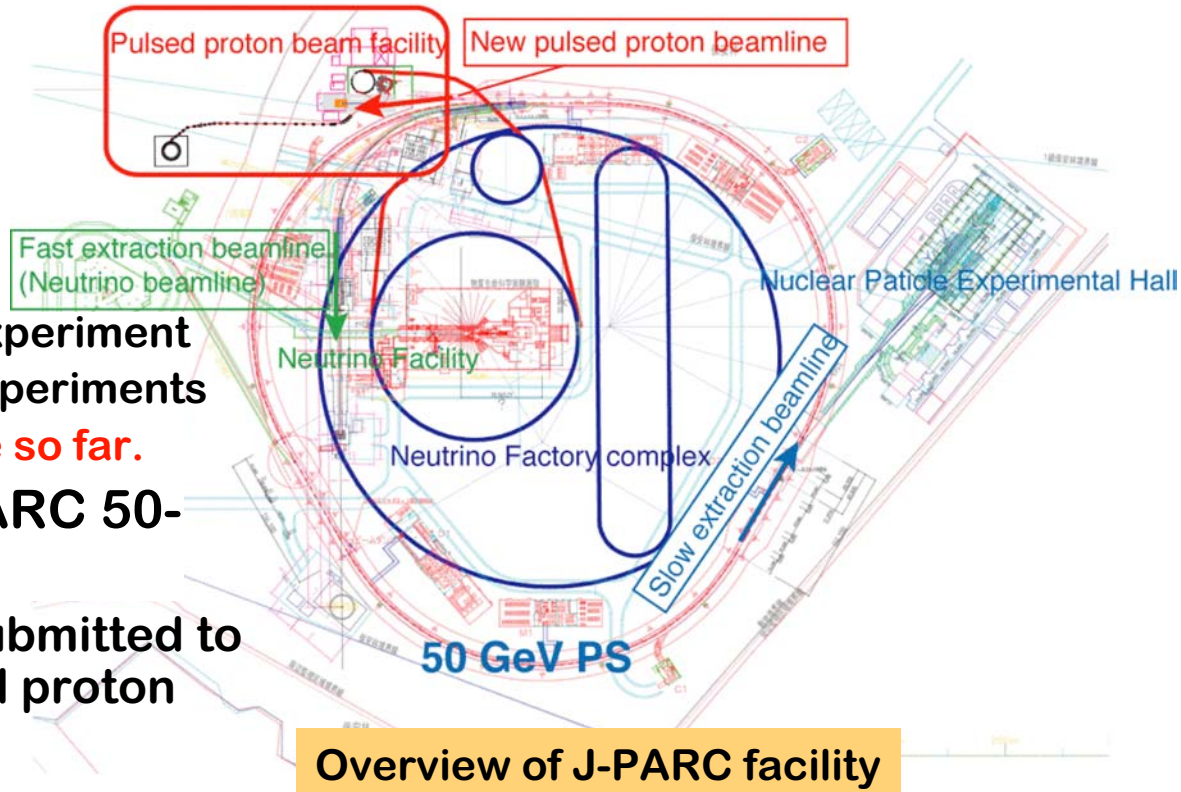
Concept of conducting target



Mercury loop

J-PARC Facility

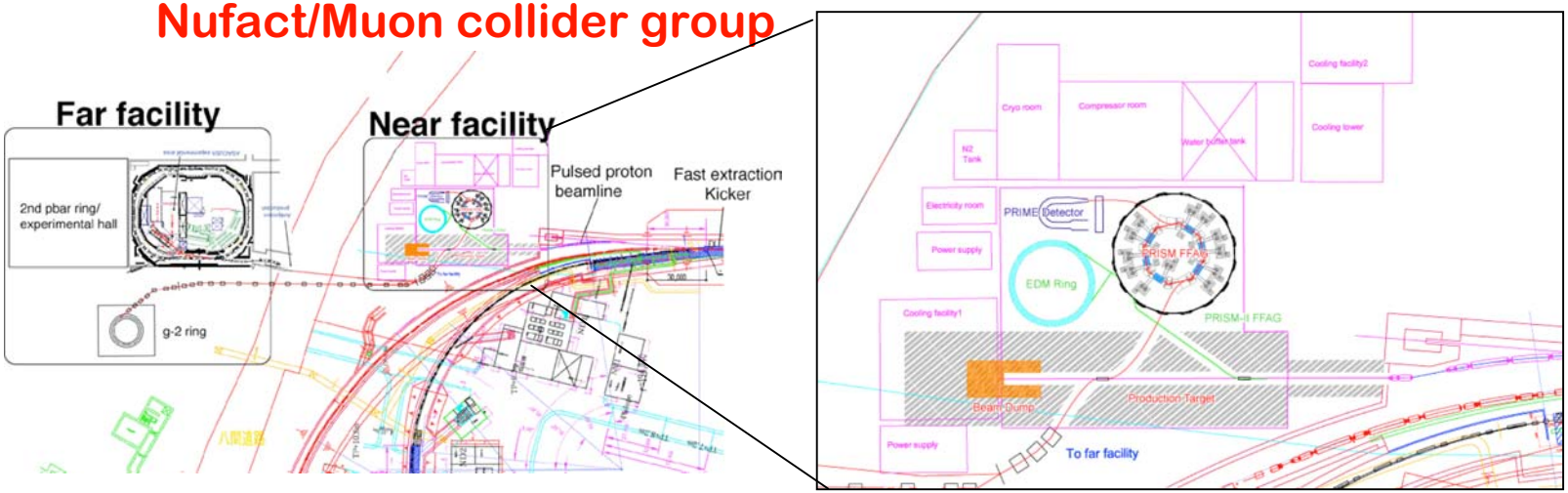
- 50 GeV PS
  - 15μA -> 0.75 MW
  - 3.3×10^{14} proton/spill
  - Rep rate 0.3 Hz
  - Two extraction line
    - Fast for Neutrino experiment
    - Slow for Nuclear experiments
    - No pulsed beamline so far.
- Letter of intent to J-PARC 50-GeV PS Programs
  - 6 LOI's have been submitted to request a new pulsed proton beam facility.



Overview of J-PARC facility

Pulsed proton beam facility

- Pulsed proton beam
  - Fast extraction
    - Fast-risetime kicker is needed
  - Bunch operation
    - 9 bunches -> 90 bunches for PRISM
  - PRISM (for muon-electron conversion), PRISM2(for muon-electric dipole moment) , muon g-2, antiproton
  - A liquid mercury jet target study - LOI was submitted by Nufact/Muon collider group



Summary

- FFAG-based neutrino factory has been proposed and studied.
- J-PARC 50 GeV PS @ Japan
  - Commissioned in 2007
  - A unique MW-class beam
  - A new pulsed proton beam facility is requested:
    - PRISM and PRISM-II (FFAG studies)
    - Suitable for target studies with high intensity proton beam
    - A step toward a neutrino factory
- International R&D
  - Most of R&D works under international collaboration
    - Cooling, FFAG, Target
  - A world-wide collaboration is crucial.
  - We, from Japan, are looking forward to further R&D collaboration with USA and Europe to realize a neutrino factory somewhere in the world!