# The J-PARC accelerator complex for rare muon and kaon decays

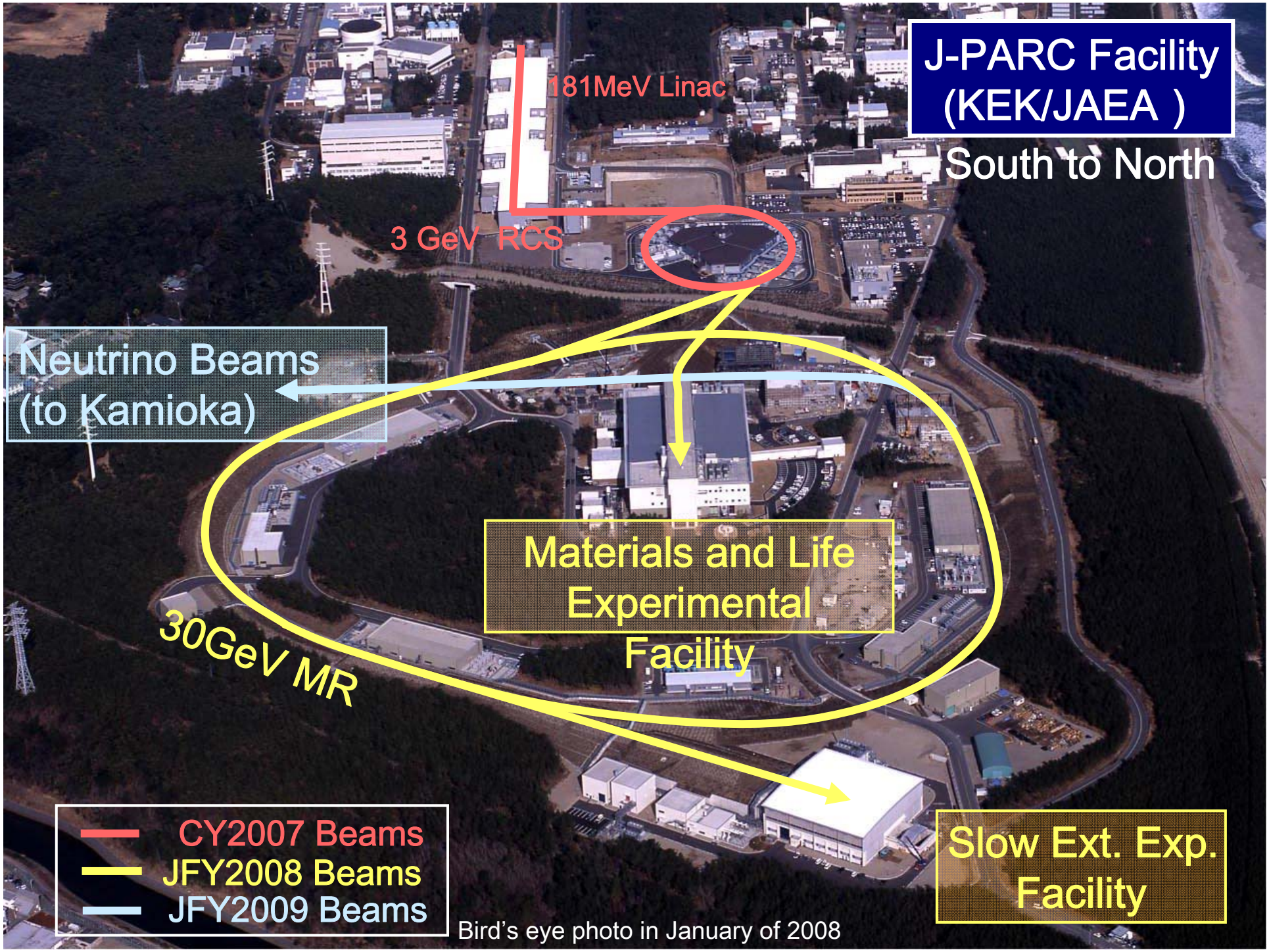
particle physics experiments and beamlines
accelerator status
plan

Project X Workshop
November 9-10, 2009

Koichiro Nishikawa
KEK

# Status of J-PARC accelerator and slow extraction

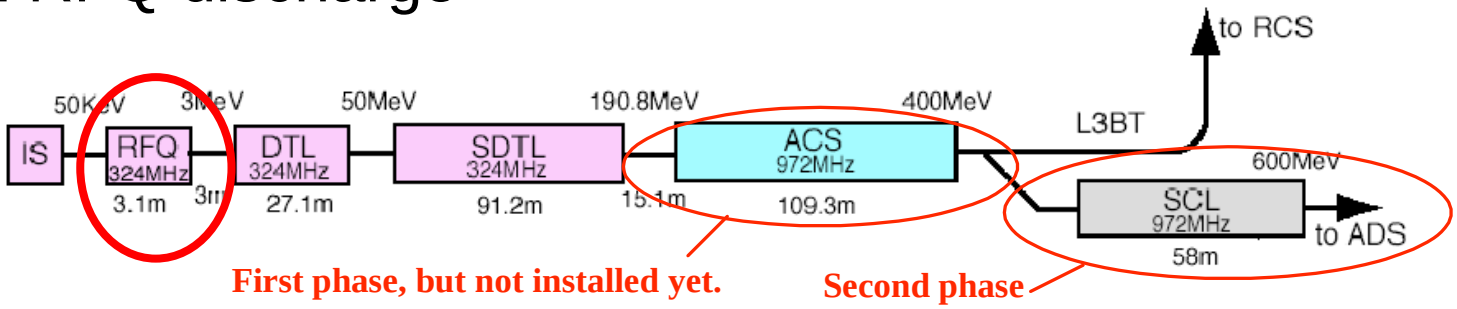
- 3 major problems before summer
- Slow extraction
  - –Spill structure
  - –Beam loss studies just started
  - –May pose severe constraint



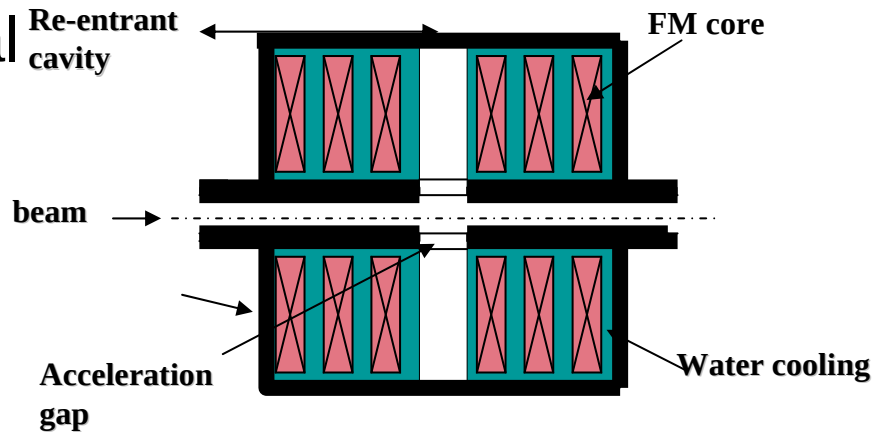

Bird's eye photo in January of 2008

# 3 major problems before summer

1 RFQ discharge

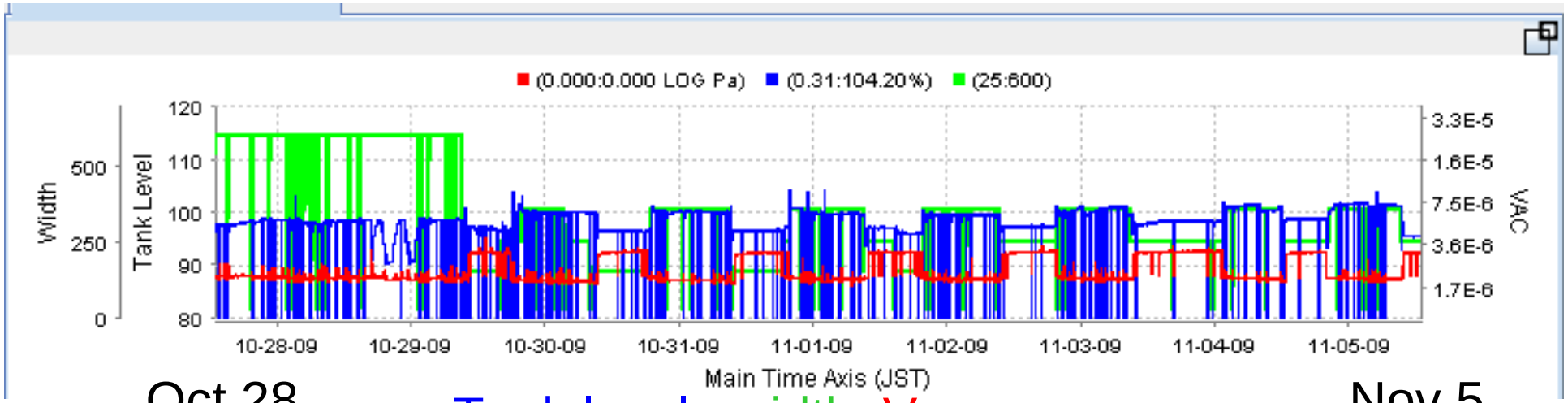



2 RF FM core mechanical collapse




3 Power supply ripple

# RFQ improvement in last 7 days




Oct.28 Tank level , width, Vacuum Nov.5

**Oct : 5mA/100μs**
**Nov : 15mA/200μs RCS 120kW equivalent**

- Serious discharge problem in RFQ since 2008
  - Operation was limited to 5mA/100us (RCS20kW)
- Various improvements in vacuum in Mar/Jul/Aug,2009
- Conditioning Sep.~, Beam started Oct.
- RCS 120kW ~ MR 20-30kW

# RF core problem

- Problem has been identified
- Occurred only for one type of core
  - Method of coating and procurement

Collapse Glass cloth separation total cores

| | 座屈 | ガラスクロスの剥がれ | 全数 |
|---|---|---|---|
| Type1 | 0 | 0 | 13 |
| Type2 | 0 | 8 | 35 |
| Type3 | 25 | 0 | 42 |

含浸及びコーティングタイプ別のコア据付け状況を以下に示す。

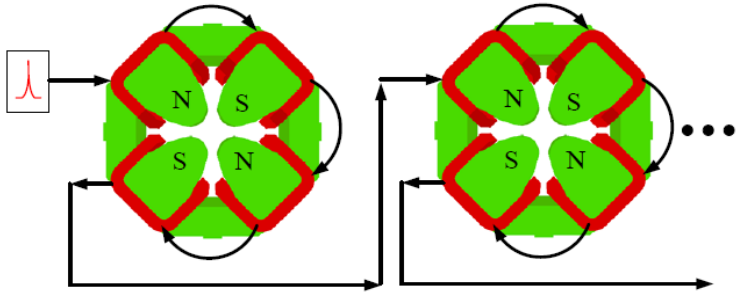
Number of cores of each type

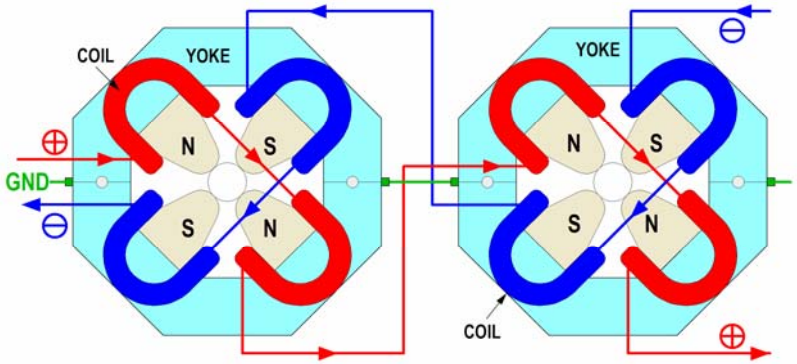
Already replaced

| | Cav.1 | Cav.2 | Cav.3 | Cav.4 | Cav.5 | Cav.6 | Cav.7 | Cav.8 | Cav.9 | Cav.10 | Cav.11 | 合計 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type1 | 0 | 7 | 0 | 0 | 0 | 9 | 4 | 0 | 6 | 6 | 0 | 32 |
| Type2 | 8 | 5 | 9 | 12 | 12 | 0 | 0 | 8 | 4 | 6 | 0 | 64 |
| Type3 | 10 | 6 | 9 | 6 | 6 | 9 | 14 | 10 | 8 | 6 | 18 | 102 |

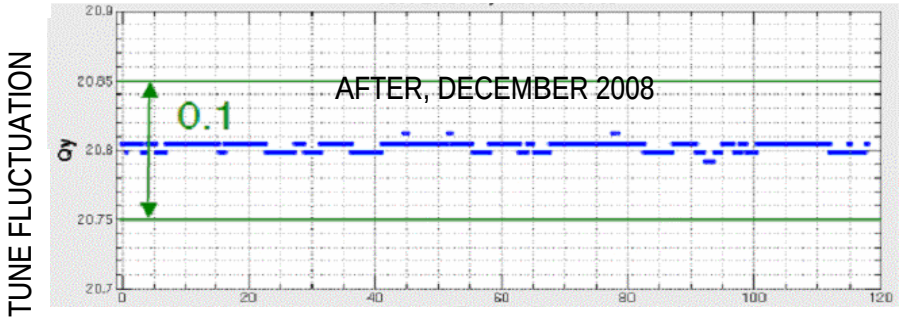
# Cabling Network improvements

K. Sato and H. Toki NIM A565(2006) 351, JPSJ Vol.78 No.9(2009)



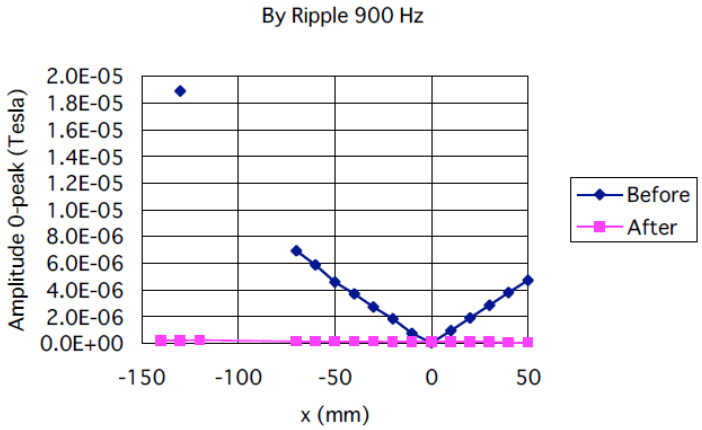







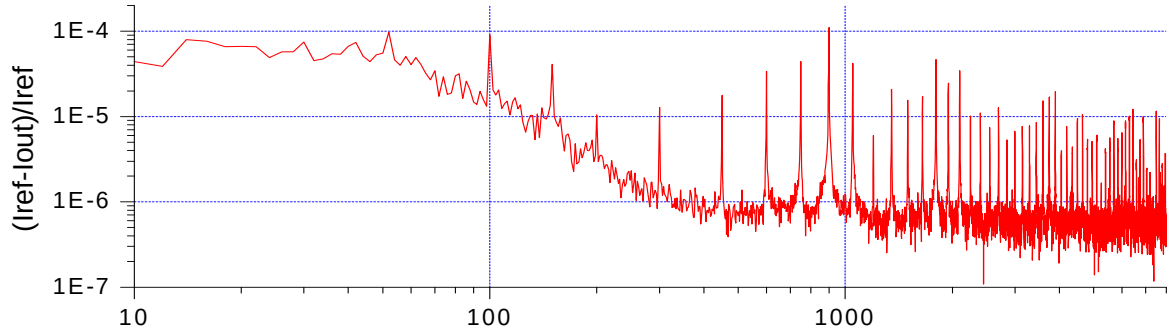

**Symmetric configuration:**
decouple normal and common mode

**Same pole connection:**
eliminate magnetic field by common mode

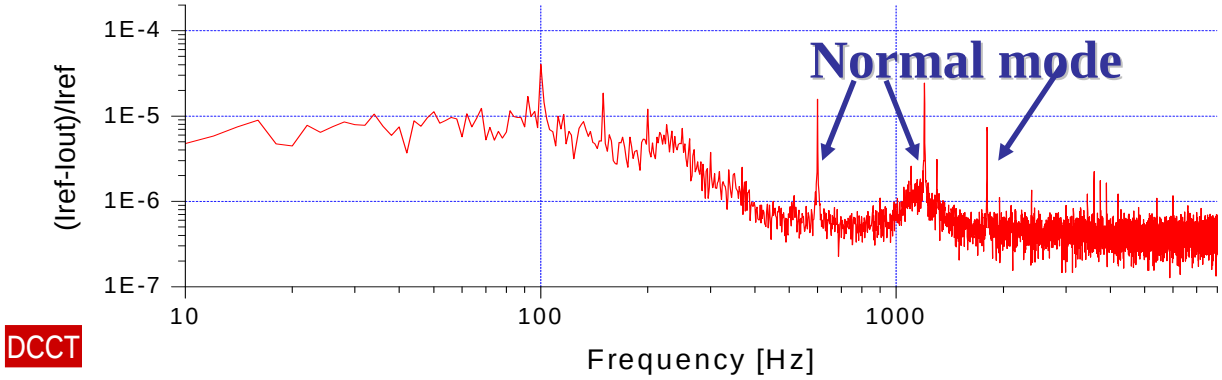


# FFT of P-N current

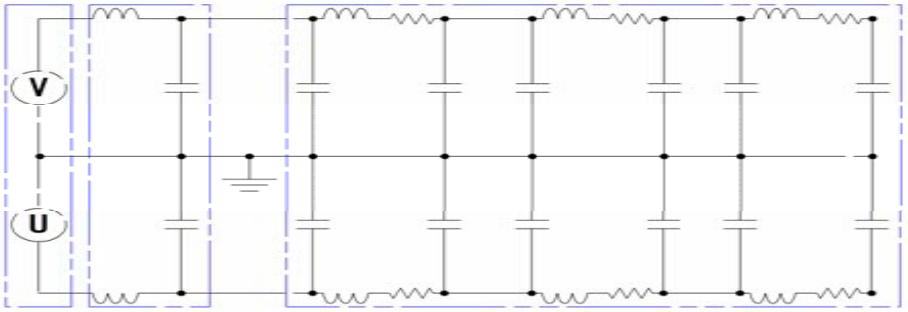
**Before symmetry (10/8)**




**After symmetry Q,B chain (10/29)**



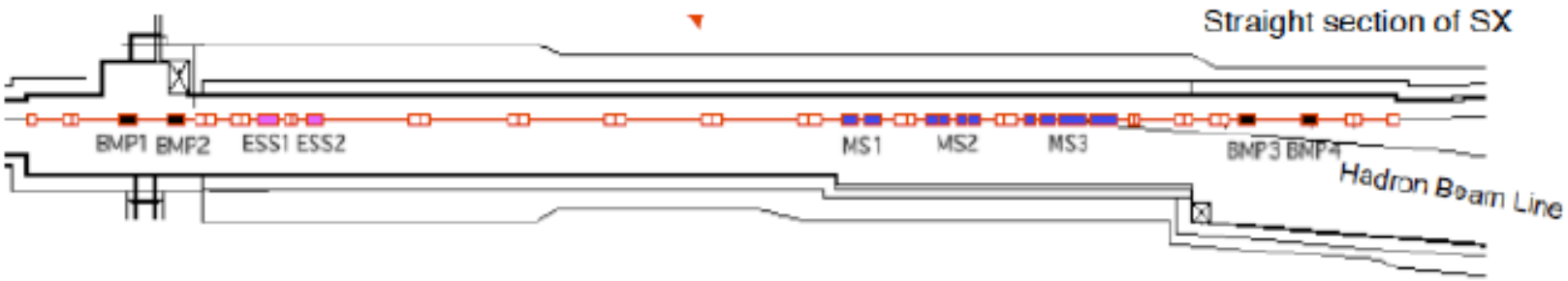

DCCT

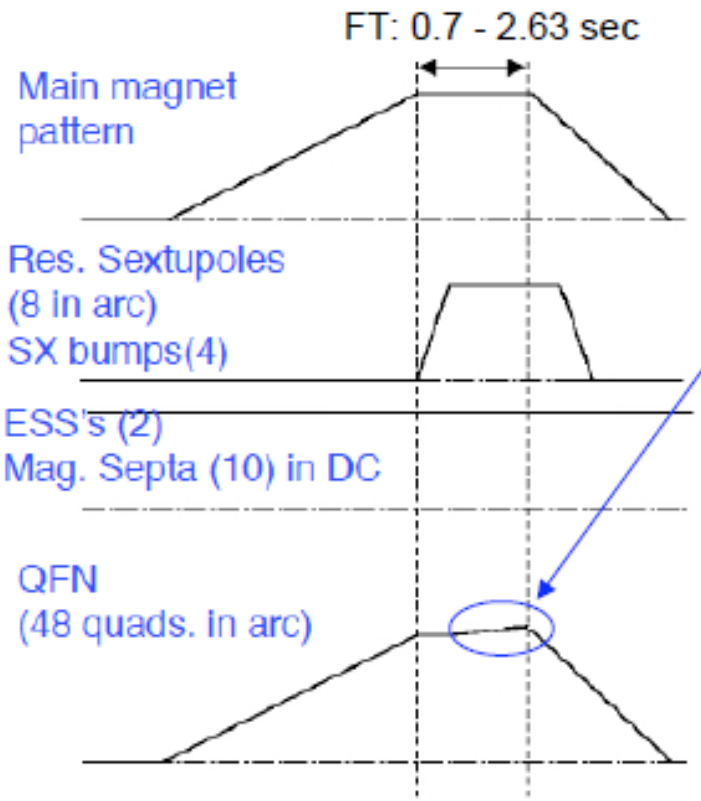


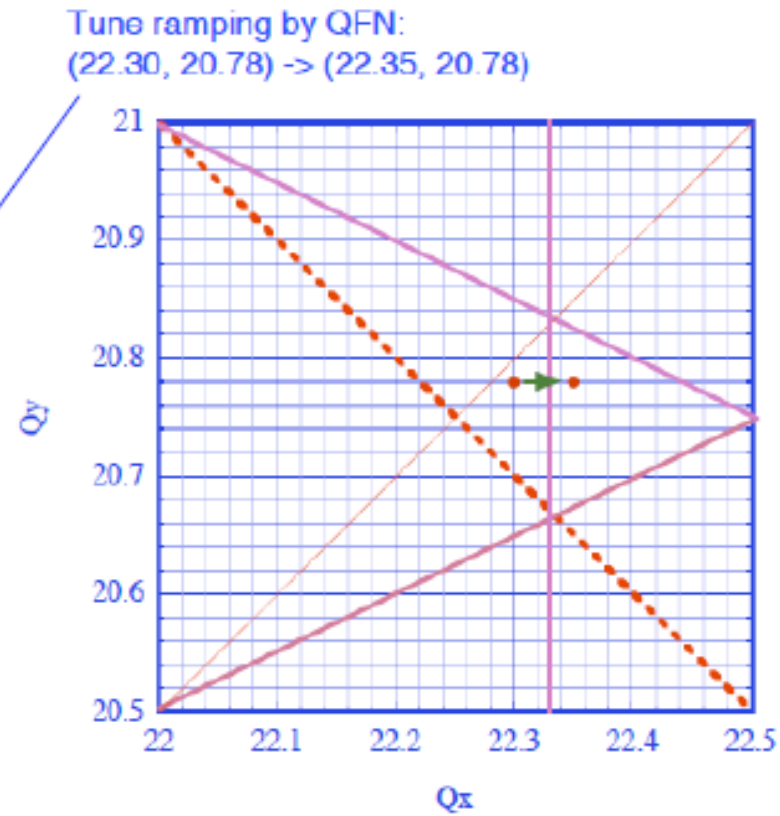

DCCT

# Slow extraction

Talk by Koseki (accel)

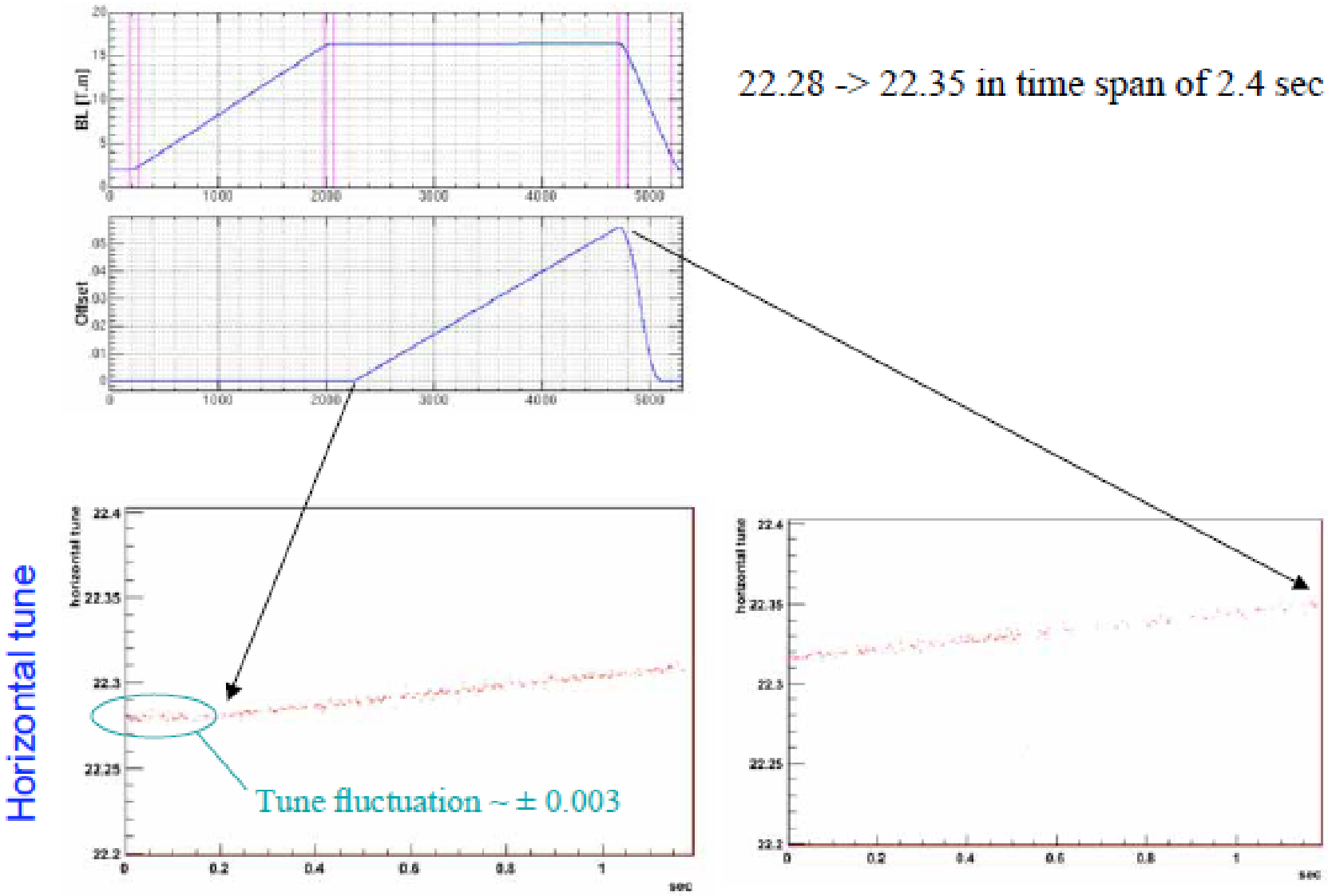


# Tune Rumping by QFN

Moving near to resonance




22.28 -> 22.35 in time span of 2.4 sec

# Status of slow extraction at MR

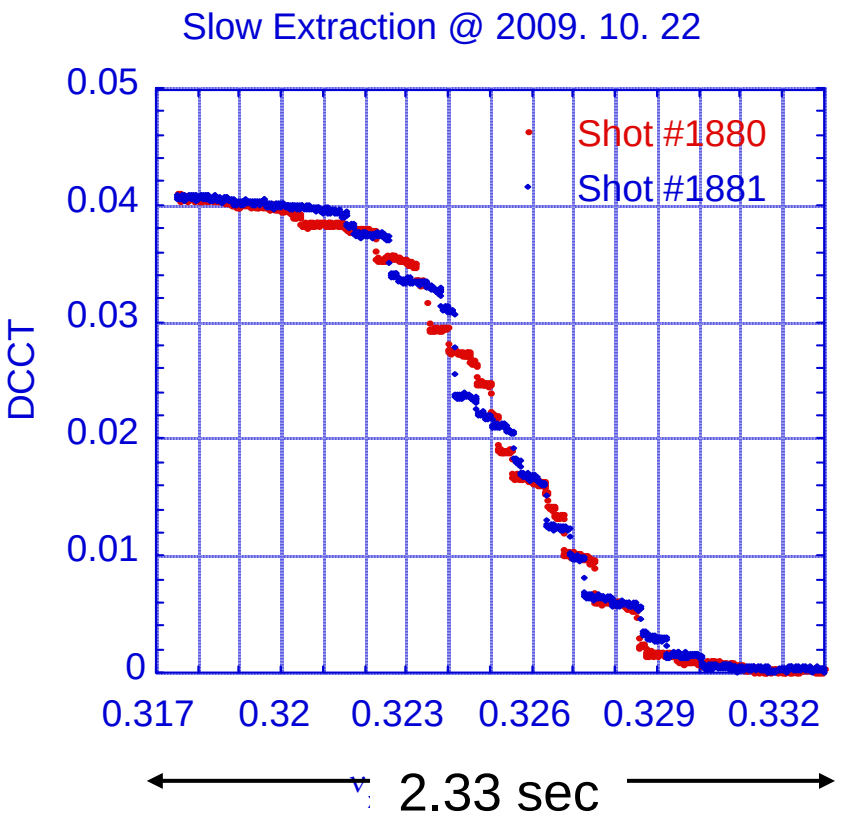
Tune change : ± 2.0 E-4

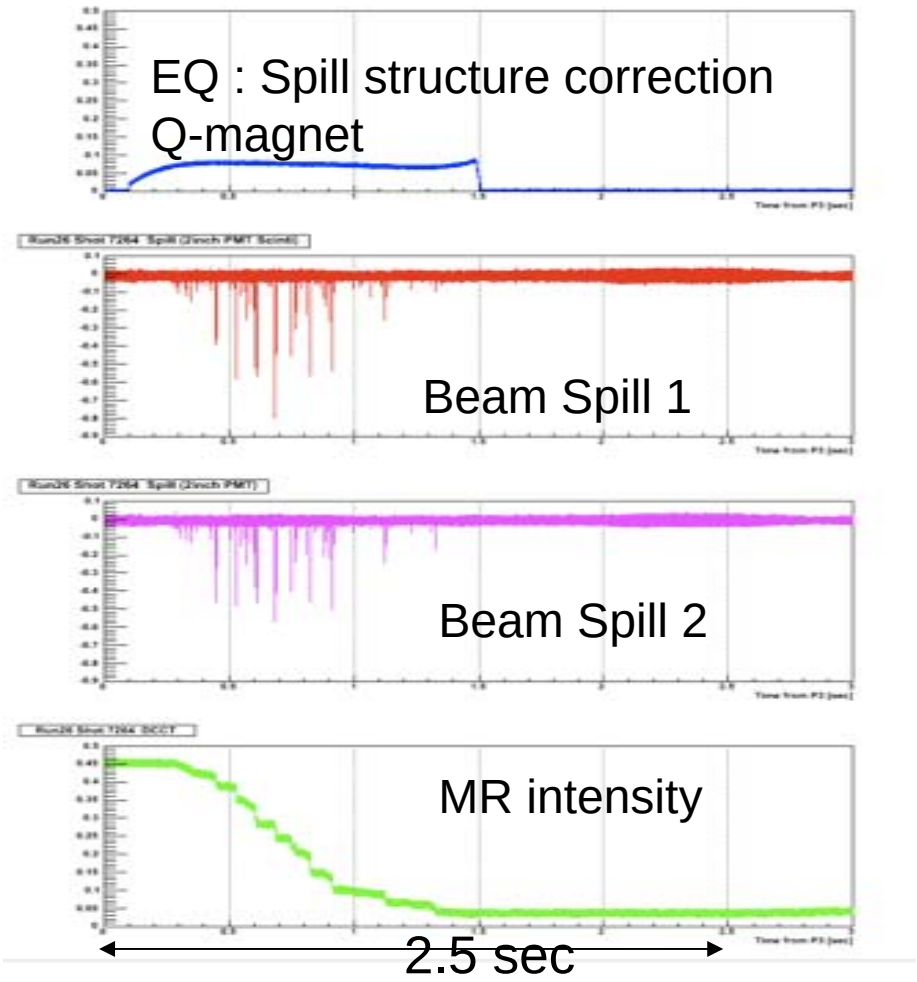
If only due to Q, the stability is ± 1.0 E-5

10 times KEK-PS-MR

Need more stability for good spill

Quantative studies on beam loss



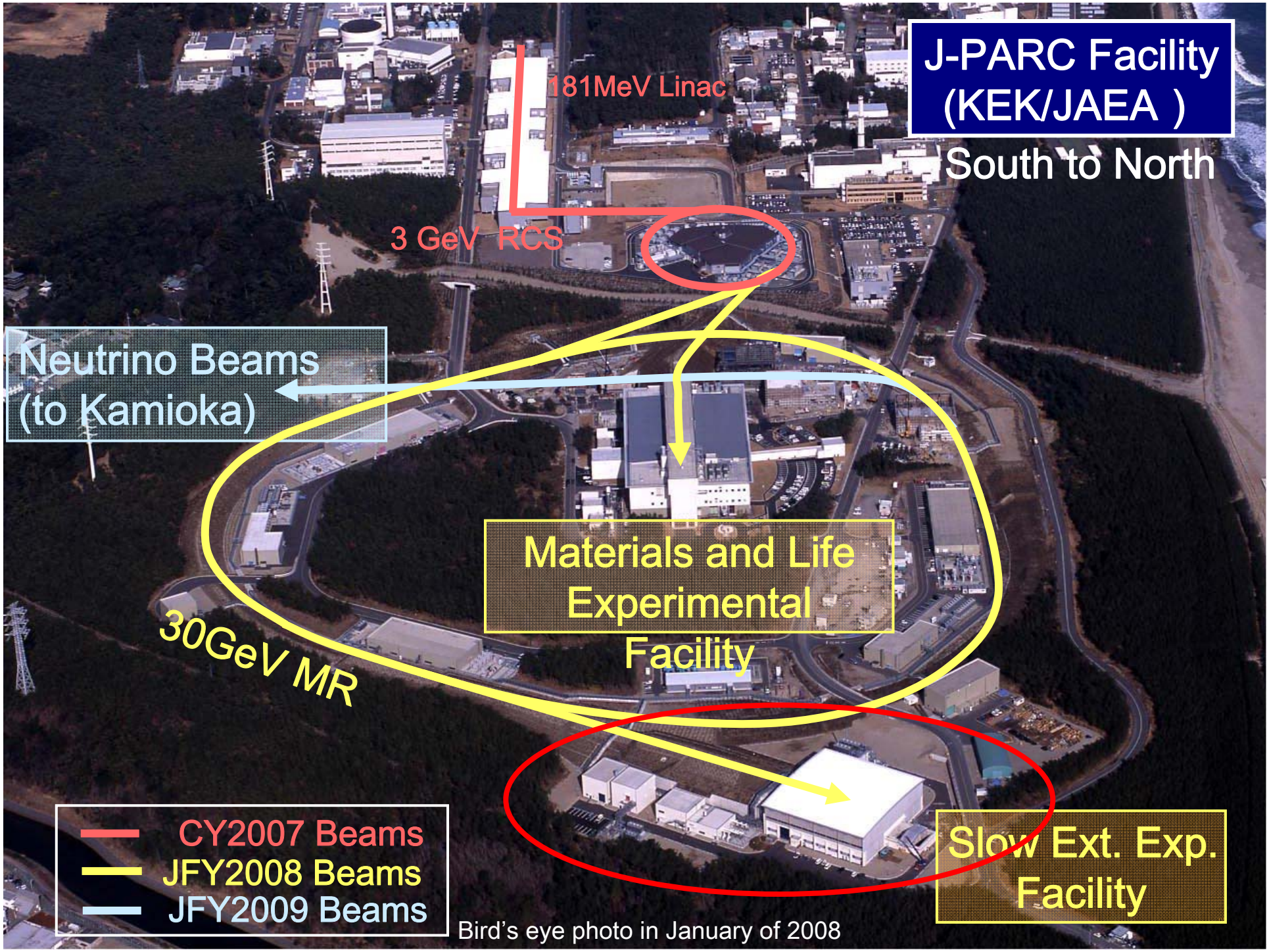
# Slow extraction summary

## Beam loss and spill structure

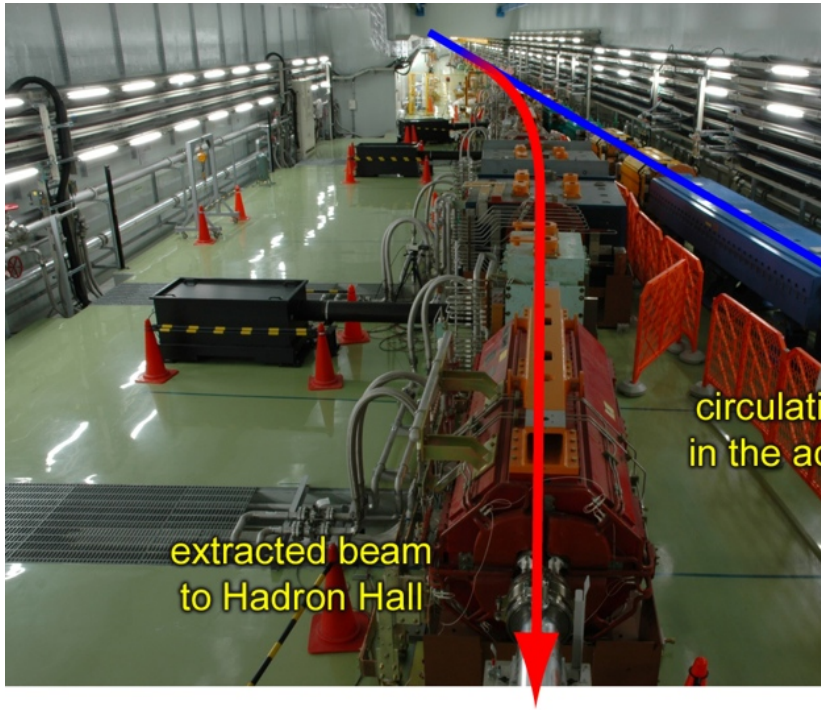
- Stabilize power supply
  - Symmetric cable configuration (B,Q,S)
  - Improvement/replace power supply
- Tune FB/FF

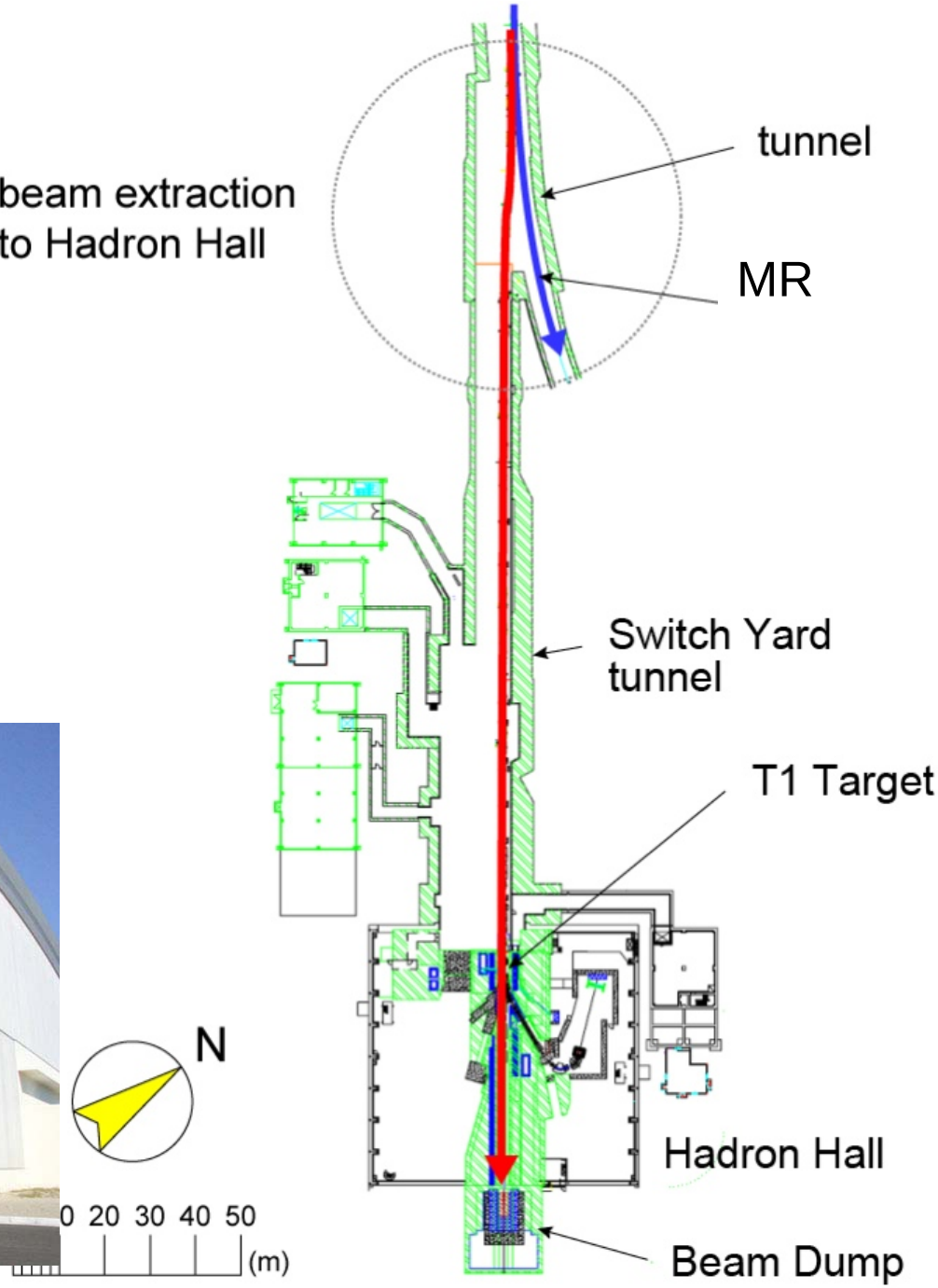
1. 5kW level operation
   - Beam loss studies, spill control
2. 30-50kW
   - Local shielding, radiation maintenance
3. Aim for higher power
   - Idea, R&D

# Slow extracted beam facility (‘hadron hall’)




Bird's eye photo in January of 2008


circulati
in the ac
extracted beam
to Hadron Hall


beam extraction
to Hadron Hall
tunnel
MR
Switch Yard
tunnel
T1 Target
Hadron Hall
Beam Dump
N
0 20 30 40 50
(m)

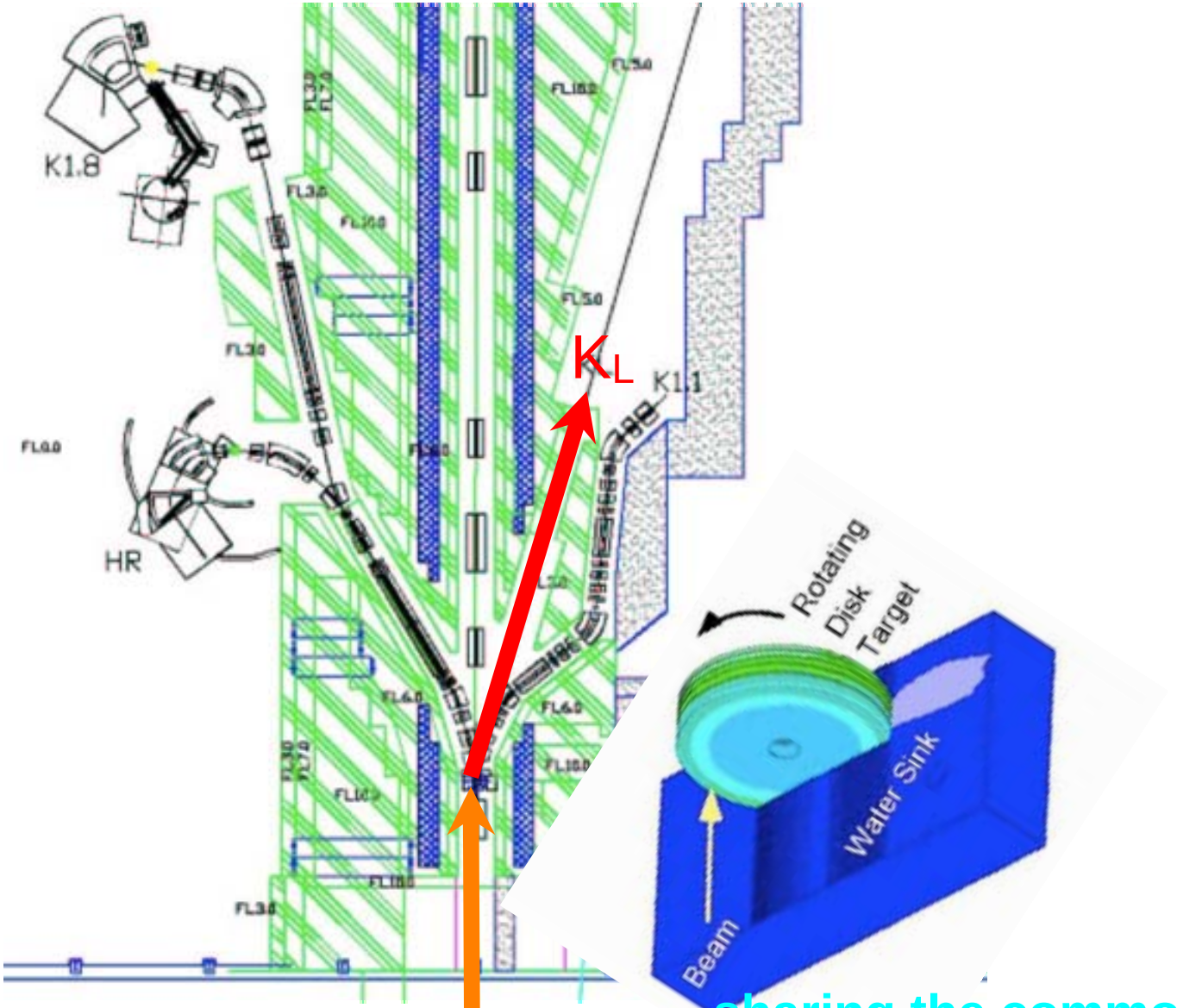
---- J-PARC PAC Approval summary after the 8th meeting ---

Proposals

| | (Co-)Spokespersons | Affiliation | Title of the experiment | Approval status (PAC recommendation) | Slow line priority | | Beamline |
|---|---|---|---|---|---|---|---|
| | | | | | Day1? | Day1 Priority | |
| E03 | K. Tanida | Kyoto U | Measurement of X rays from $\Xi^-$ Atom | Stage 2 | | | K1.8 |
| P04 | J. C. Peng; S. Sawada | U. of Illinois at Urbana-Champaign; KEK | Measurement of High-Mass Dimuon Production at the 50-GeV Proton Synchrotron | Deferred | | | Primaly |
| E05 | T. Nagae | KEK | Spectroscopic Study of $\Xi$-Hypernucleus, $^{12}{}_{\Xi}$Be, via the $^{12}$C($K^-$, $K^+$) Reaction | Stage 2 | Day1 | 1 | K1.8 |
| ● E06 | J. Imazato | KEK | Measurement of T-violating Transverse Muon Polarization in $K^+ \to \pi^0 \mu^+ \nu$ Decays | Stage 1 | | | K1.1BR |
| E07 | K. Imai, K. Nakazawa, H. Tamura | Kyoto U., Gifu U., Tohoku U. | Systematic Study of Double Strangeness System with an Emulsion-counter Hybrid Method | Stage 2 | | | K1.8 |
| E08 | A. Krutenkova | ITEP | Pion double charge exchange on oxygen at J-PARC | Stage 1 | | | K1.8 |
| E10 | A. Sakaguchi, T. Fukuda | Osaka U | Production of Neutron-Rich Lambda-Hypernuclei with the Double Charge-Exchange Reaction (Revised from Initial P10) | Stage 2 | | | K1.8 |
| E11 | K. Nishikawa | KEK | Tokai-to-Kamioka (T2K) Long Baseline Neutrino Oscillation Experimental Proposal | Stage 2 | | | neutrino |
| E13 | T. Tamura | Tohoku U. | Gamma-ray spectroscopy of light hypernuclei | Stage 2 | Day1 | 2 | K1.8 |
| ● E14 | T. Yamanaka | Osaka University | Proposal for $K_L \to \pi^0 \nu\nu$-bar Experiment at J-PARC | Stage 2 | | | K0 |
| E15 | M. Iwasaki, | RIKEN, KEK | A Search for deeply-bound kaonic nuclear states by in-flight 3He(K-, n) reaction | Stage 2 | Day1 | | K1.8BR |
| E16 | S. Yokkaichi | RIKEN | Electron pair spectrometer at the J-PARC 50-GeV PS to explore the chiral symmetry in QCD | Stage 1 | | | High pt |
| E17 | R. Hayano, H. Outa | U. Tokyo, RIKEN | Precision spectroscopy of Kaonic $^3$He 3d->2p X-rays | Stage 2 | Day1 | | K1.8BR |
| E18 | H. Bhang, H. Outa, H. Park | SNU, RIKEN, KRISS | Coincidence Measurement of the Weak Decay of $^{12}{}_{\Lambda}$C and the three-body weak interaction process | Stage 1 | | | K1.8 |
| E19 | M. Naruki | RIKEN | High-resolution Search for $\Theta^+$ Pentaquark in $\pi^- p \to K^- X$ Reactions | Stage 2 | Day1 | | K1.8 |
| ● E21 | Y. Kuno | Osaka U | An Experimental Search for $\mu$ - e Conversion at a Sensitivity of $10^{-16}$ with a Slow-Extracted Bunched Beam | Stage 1 | | | New beamline |
| E22 | S. Ajimura, A. Sakaguchi | Osaka U | Exclusive Study on the Lambda-N Weak Interaction in A=4 Lambda-Hypernuclei (Revised from Initial P10) | Stage 1 | | | K1.8 |
| T25 | S. Mihara | KEK | Extinction Measurement of J-PARC Proton Beam at K1.8BR | test experiment | | | K1.8BR |
| P26 | K. Ozawa | U. Tokyo | Direct measurements of omega mass modifcation in A(pi $^-$n)omega reaction and omega -> pi0 gamma decays | Deferred | | | K1.8 |
| E27 | T. Nagae | Kyoto U | Search for a nuclear Kbar bound state $K^-pp$ in the d($\pi^+$, $K^+$) reaction | Stage 1 | | | K1.8 |
| P28 | H. Fujioka | Kyoto U | Study of isospin dependence of kaon-nucleus interaction by in-flight 3He(K-,n/p) reactions | approved as a part of E15 | | | K1.8BR |
| P29 | H. Ohnisi | RIKEN | Study of in medium mass modification for phi meson using phi meson bound state in nucleus | Deferred | | | K1.1 |
| P30 | T. Suzuki | U. Tokyo | The investigation of $\Lambda$(1405) state via the d($K^-$stopped, n) ($\Sigma\pi^0$) reaction | Rejected | | | K1.8BR |
| P31 | M. Noumi | Osaka U | Spectroscopic study of hyperon resonances below KN threshold via the ($K^-$n) reaction on Deuteron | Deferred | | | K1.8 |

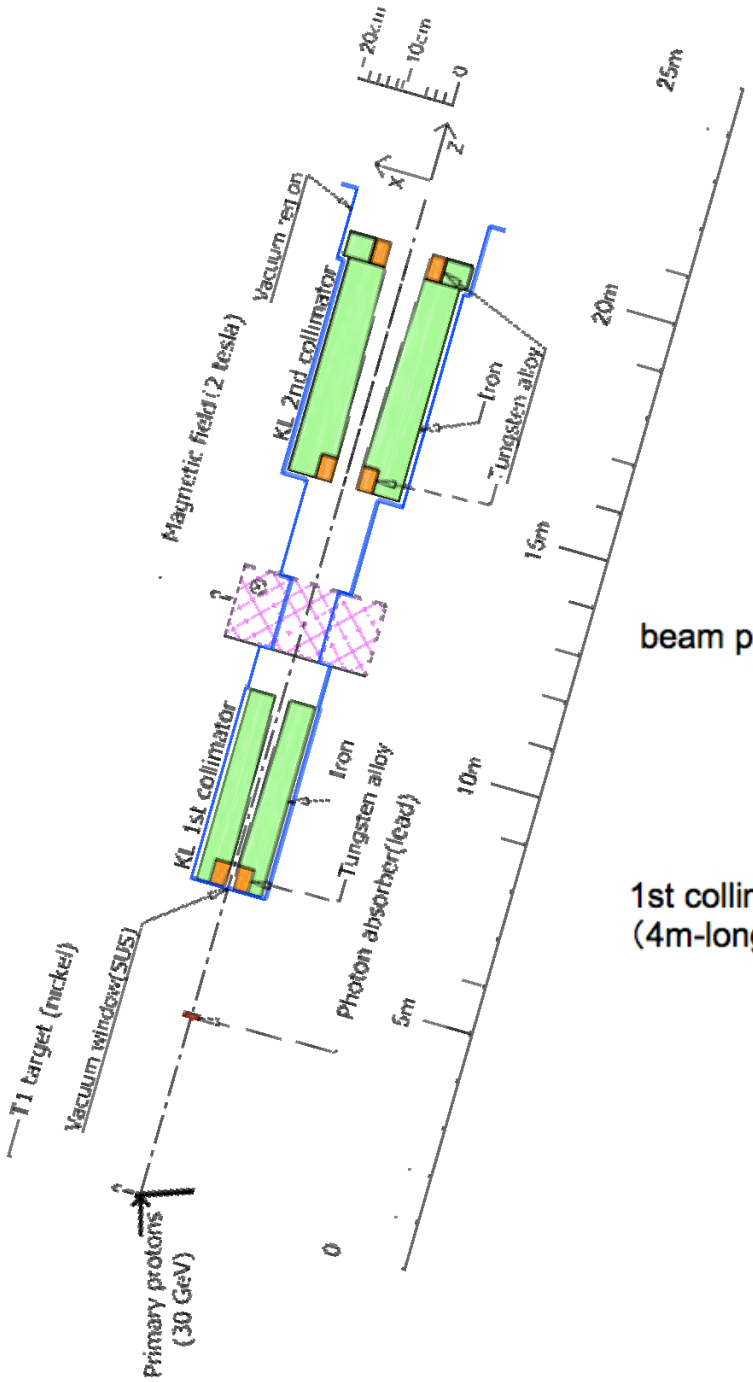
# KOTO experiment

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

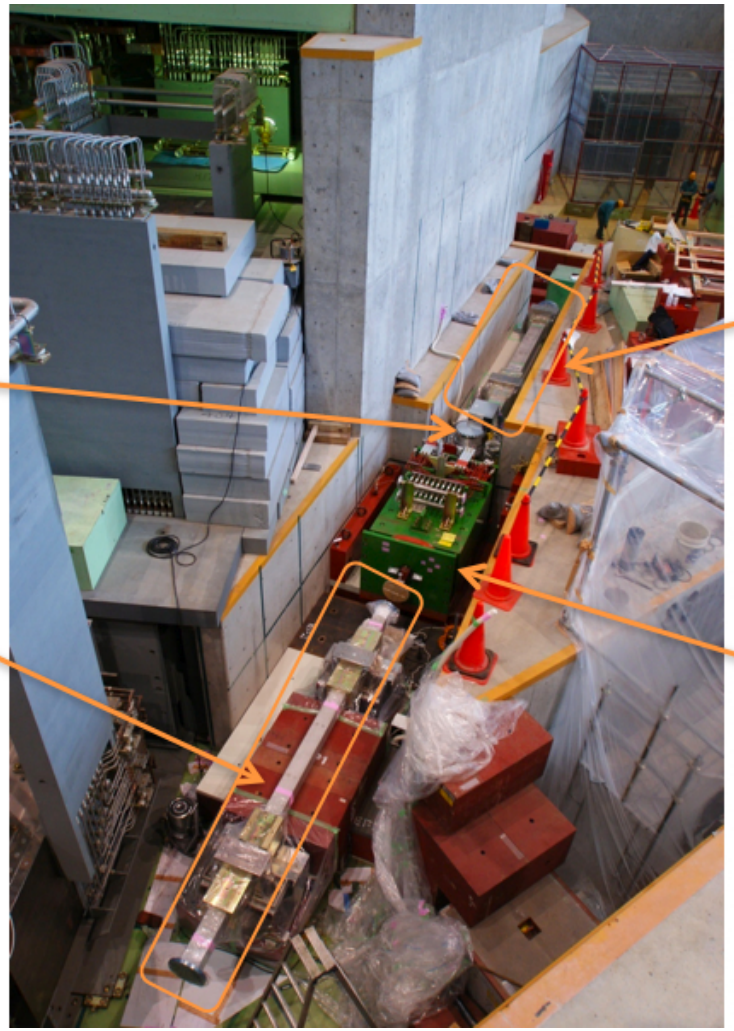


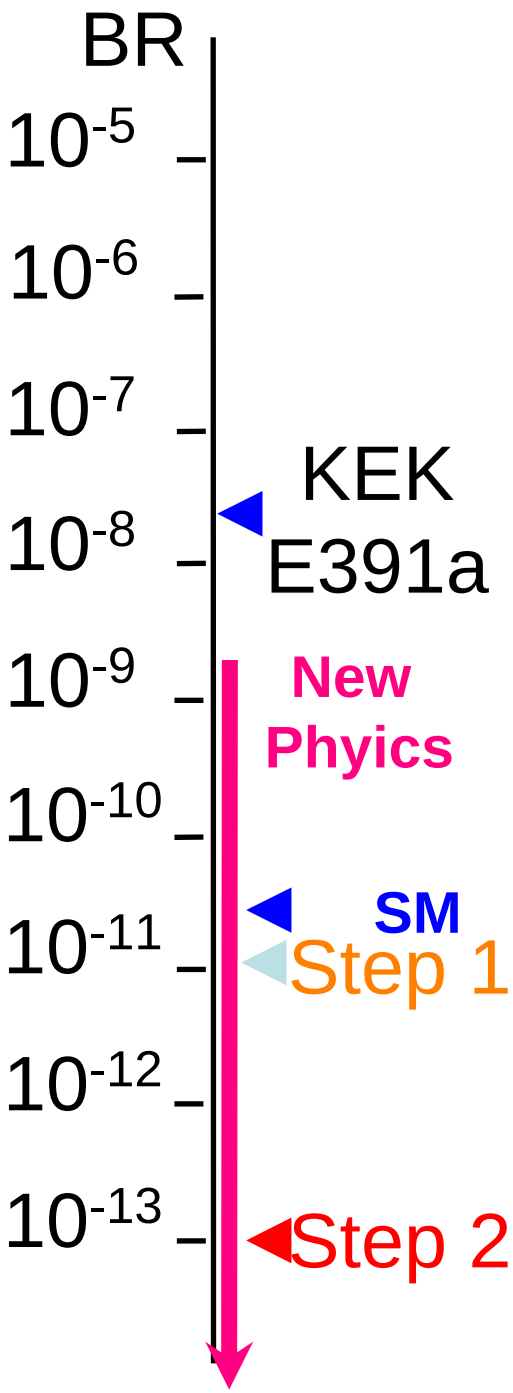

**30GeV proton**

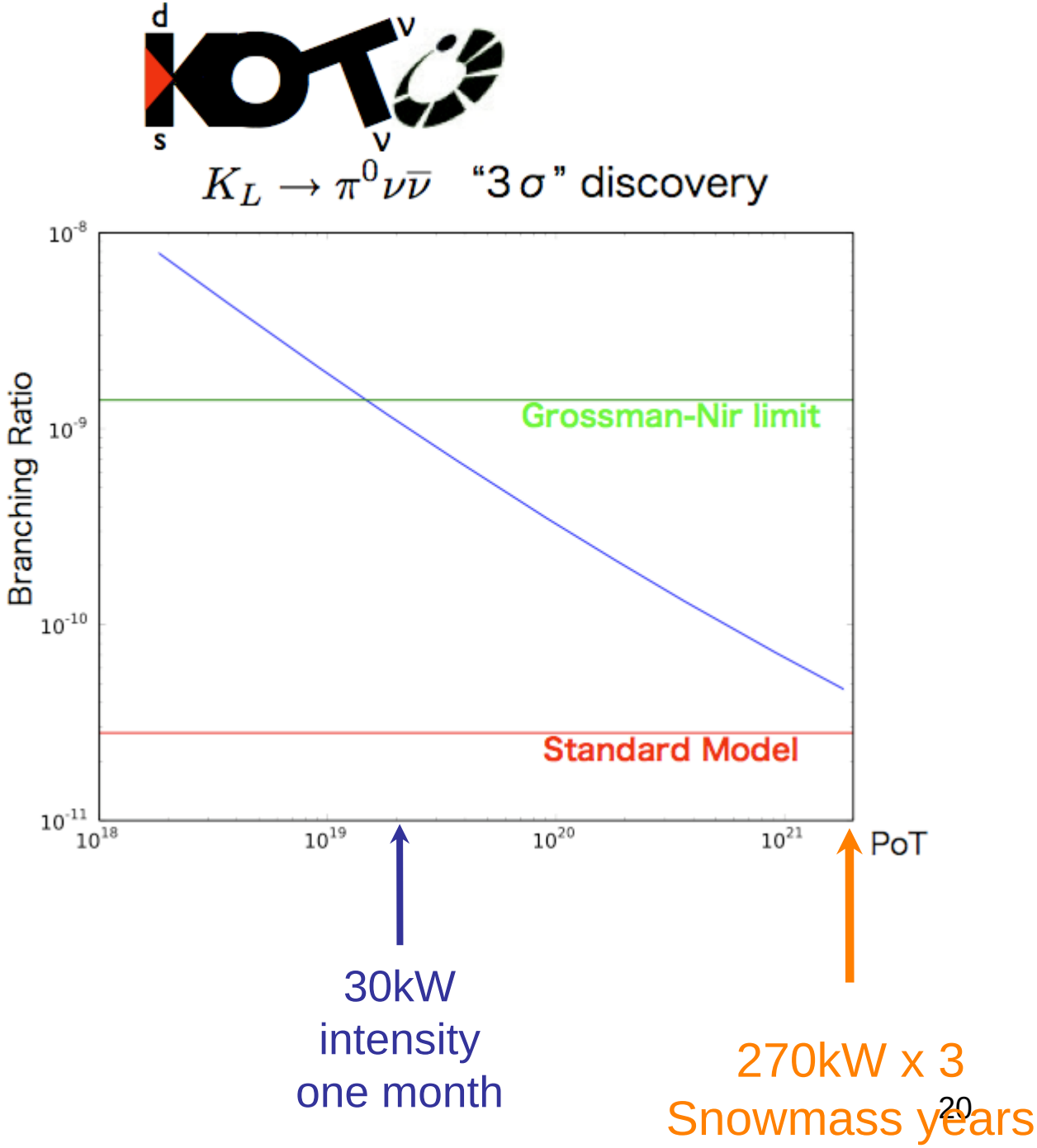
**sharing the common T1 target**




- Double collimator system
- 16º (!) production angle




BR
10-5
10-6
10-7
10-8
10-9
10-10
10-11
10-12
10-13
KEK
E391a
New
Phyics
SM
Step 1
Step 2

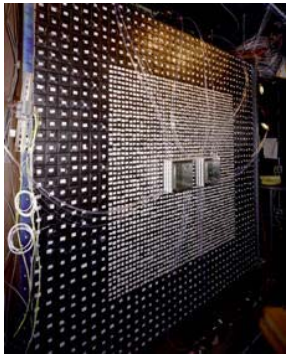

$K_L \to \pi^0 \nu\bar{\nu}$ "3 σ" discovery
Branching Ratio
10-8
10-9
10-10
10-11
Grossman-Nir limit
Standard Model
10^18
10^19
10^20
10^21
PoT
30kW
intensity
one month
270kW x 3
Snowmass years

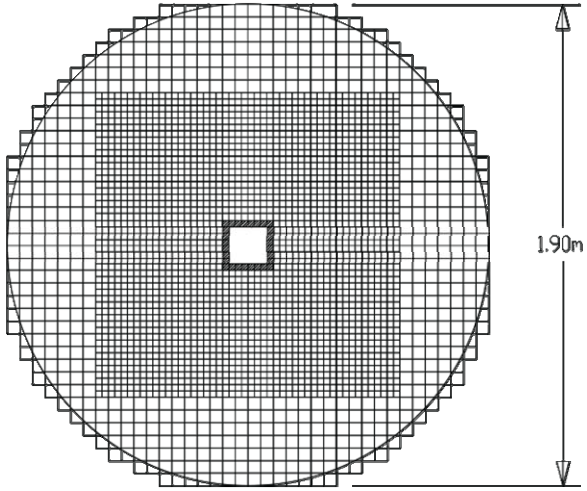
$K_L \rightarrow \pi^0 \nu\bar{\nu}$

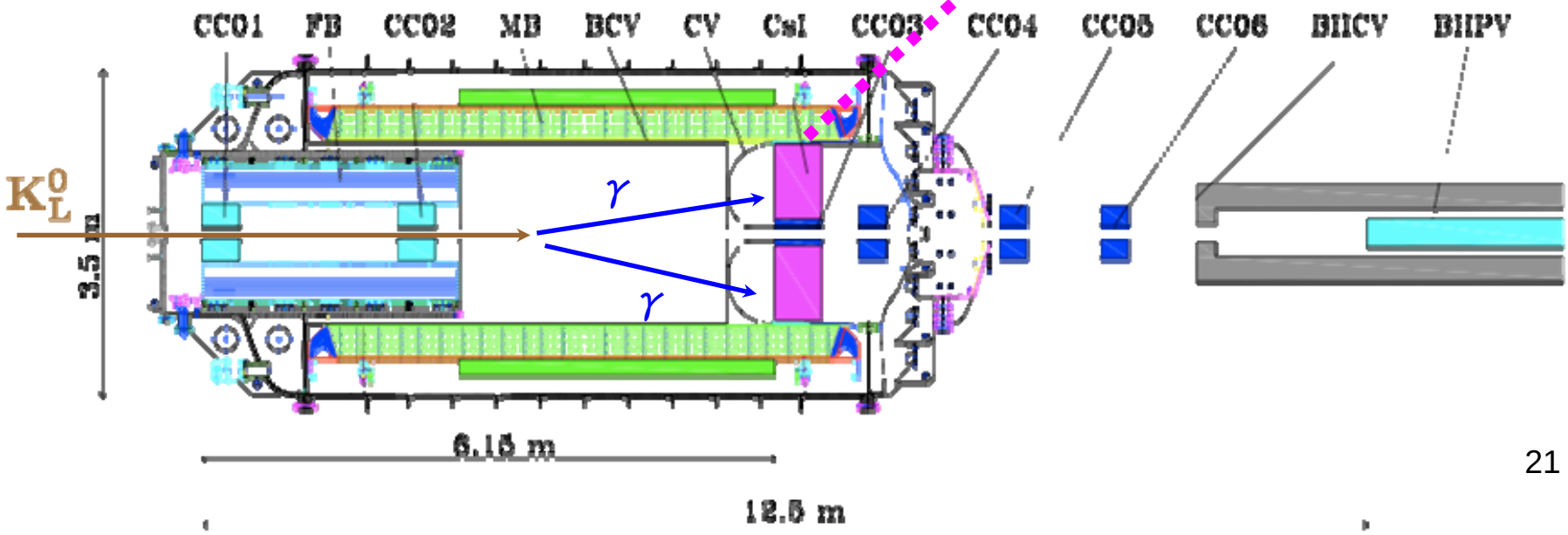
KOTO

a long Japanese musical instrument (zither) with thirteen strings

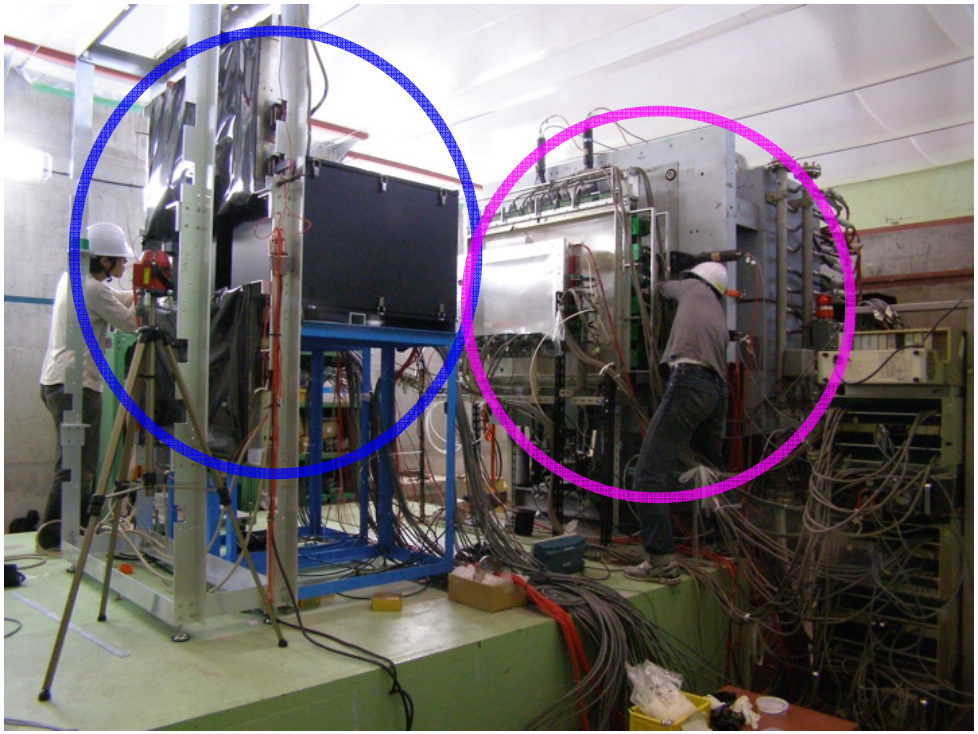
- new beamline
- Move and modify E391a detector
  - CsI calorimeter (KTeV)
  - readout: waveform digitization
  - photon veto in the beam



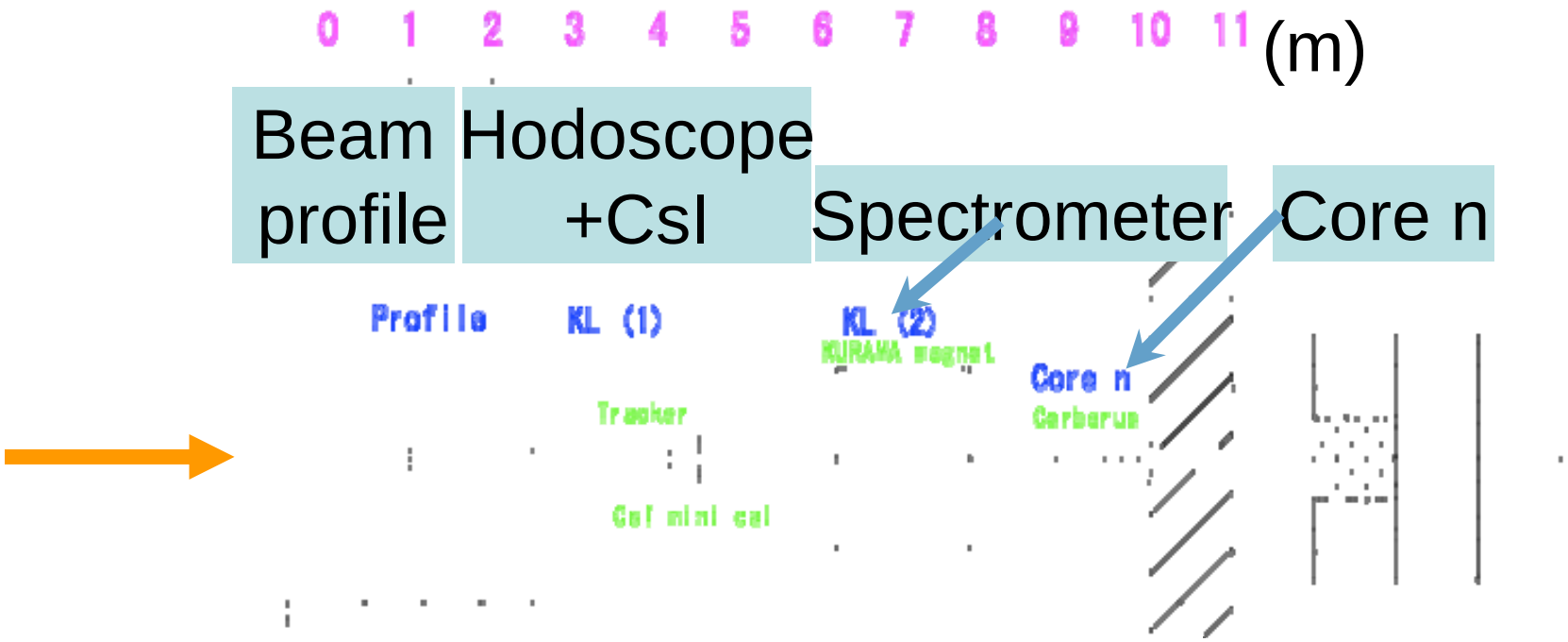


hodoscope
+ CsI crystals
for
$K_L \rightarrow \pi^+ \pi^- \pi^0$
measurement



spectrometer
for
$K_L \rightarrow \pi^+ \pi^-$
measurement



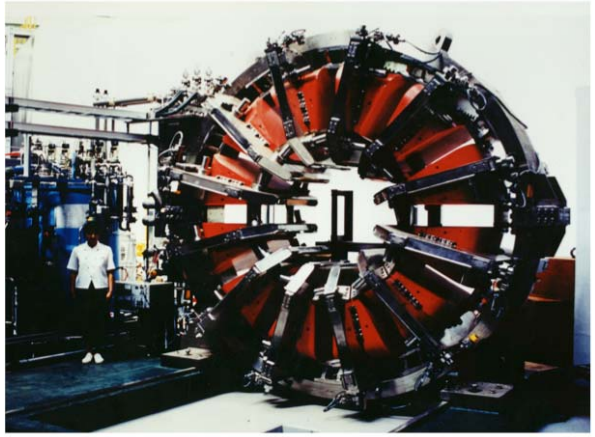
# TREK experiment

A search of T-violating

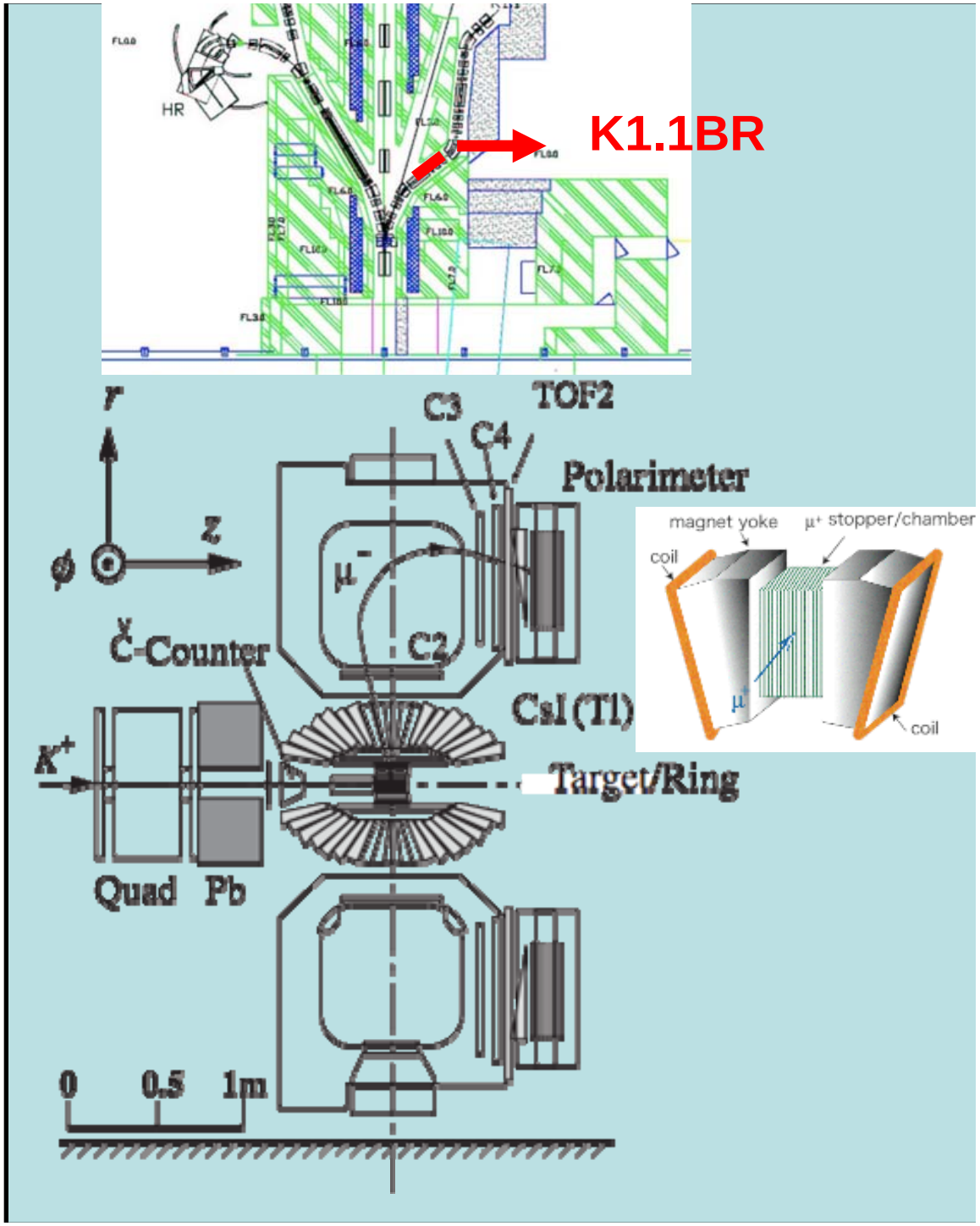
$\mu$ polarization in $K\mu 3$

# E06(TREK)

- New beamlilne **K1.1BR** for low-momentum K+
- SC toroidal spectrometer (from KEK-PS E246)

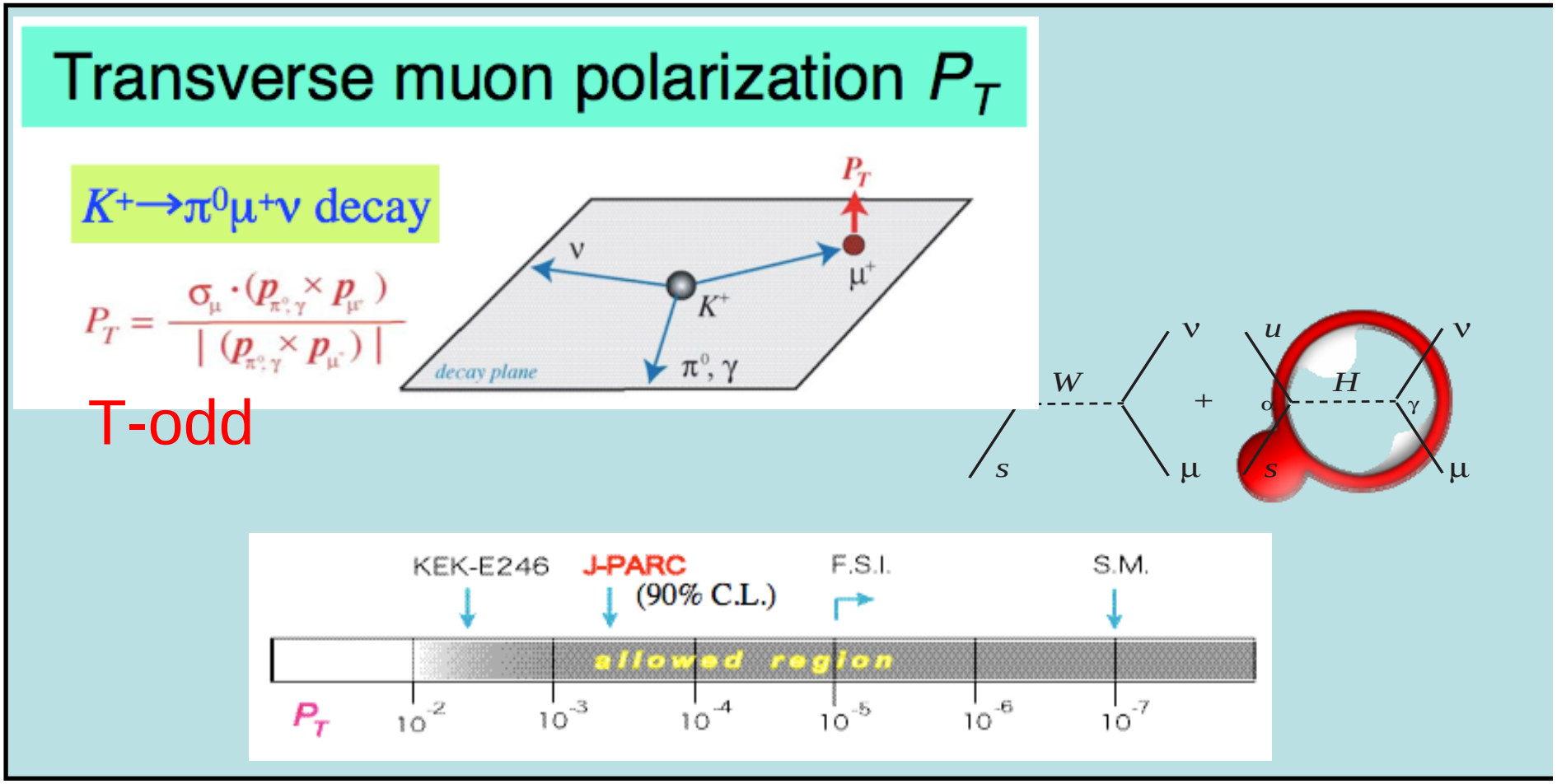


- upgrades with active muon polarimeter, tracking with GEM



J-PARC E06(TREK) for Time reversal violation

http://trek.kek.jp/

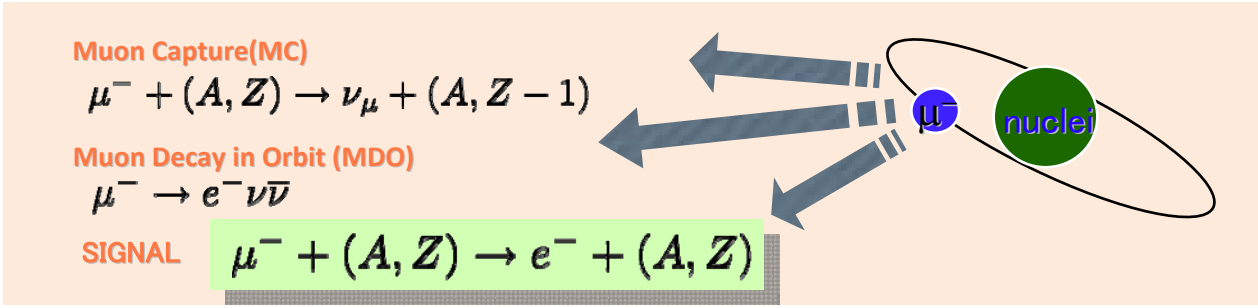


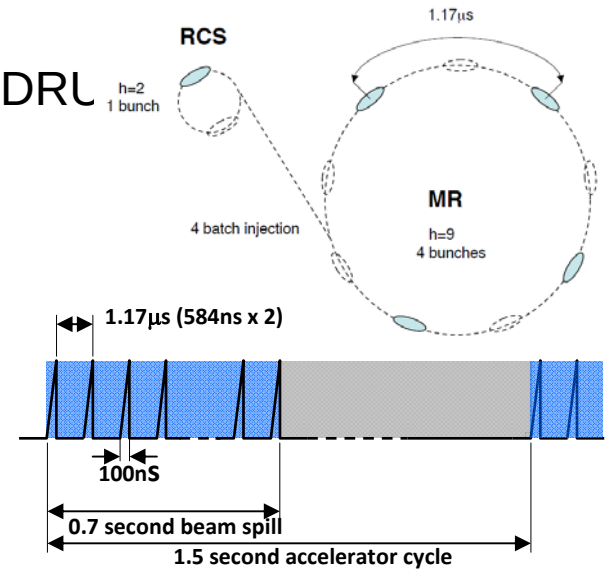

- unique physics reach to new physics

# Lepton flavor violation

# COMET at J-PARC

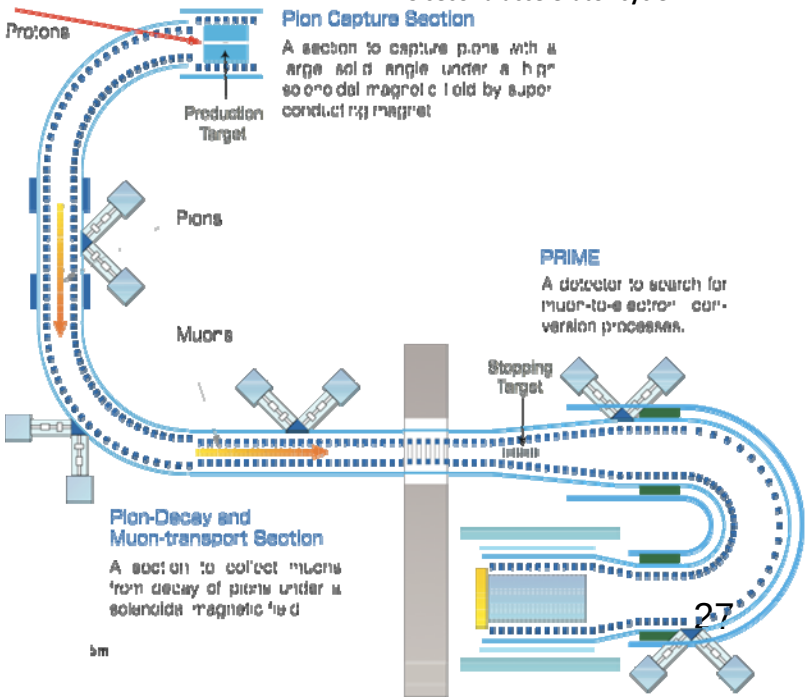
- μ-e conversion search experiment at J-PARC
- Target sensitivity ~$10^{-16}$ (current limit $7\times10^{-13}$ by SINDRUM II)
- SUSY-GUT models predict <$10^{-13}$




## Requirements

- Pulsed Proton Beam
  - **Beam extinction < $10^{-9}$**
- Large μ yields
  - **J-PARC/MR 50-60kW**
  - π-capture SC-solenoid
  - $10^{11}$ μ/sec (cf. $10^{8}$μ/sec at PSI PiE5)
- Curved-solenoid detector
  - Lower detector rate

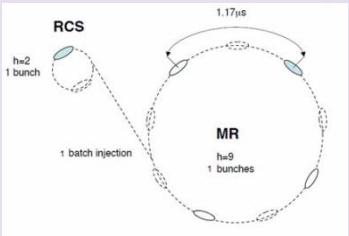


# COMET Activity Status

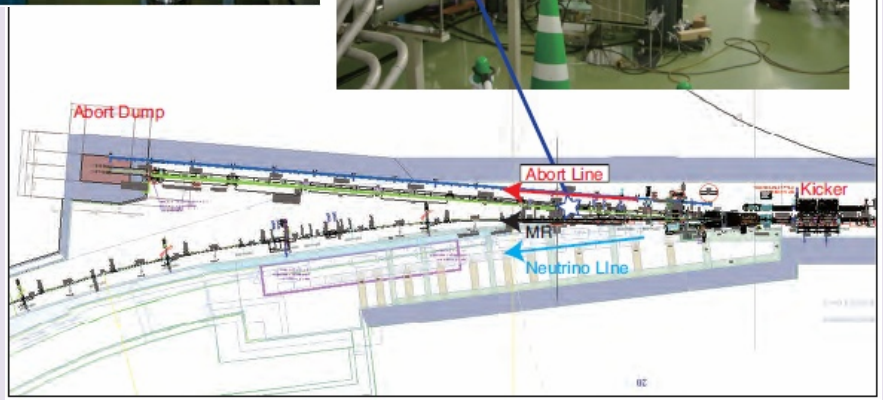
- **Beam Extinction Study**
  - Abort line measurement

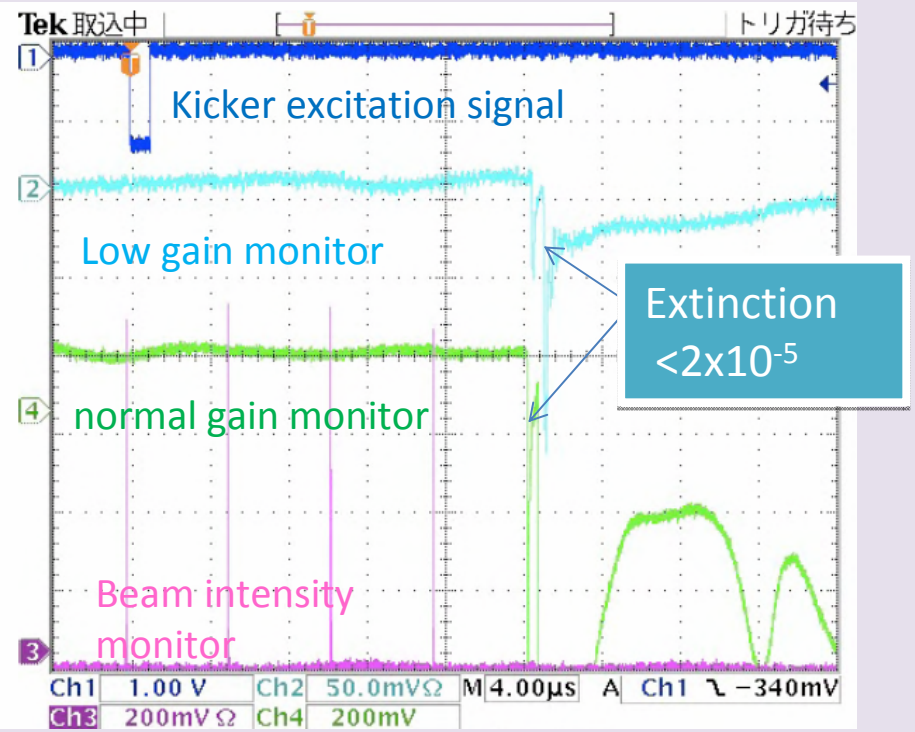
•Single bunch, single shot operation of MR

**•Count the number of protons in the EMPTY bucket in front of a filled bucket**







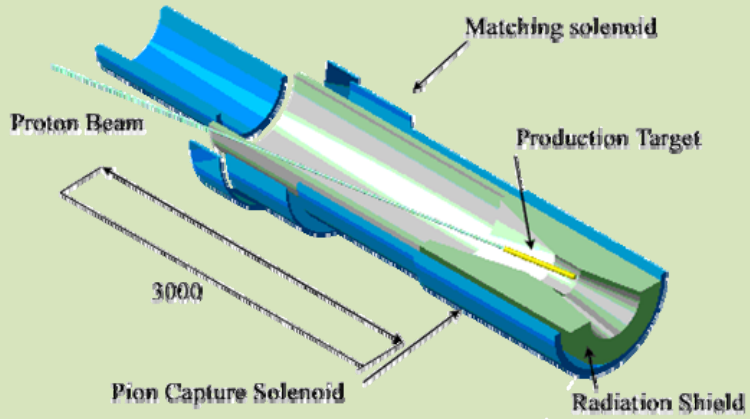

- This is proved to be due to inefficiency of the chopper (creating empty buckets)
- Further improvement is expected by using
  - Pre-chopper at the Linac, factor of 100 (measurement)
  - External extinction device, factor of 1000 (simulation)

# COMET Activity Status

- Super-conducting solenoid
  - Pion capture solenoid

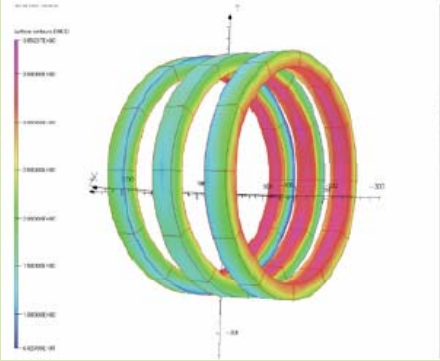
•B=5T
•Radiation transparent
•Technology
  •Detector Solenoid Tech.
  •NbTi+Al conductor
  •Indirect pipe cooling

  •Conductor ordered in Fall 2009
  •Test coil construction and test in 2010




  - Design of high Intensity muon beam line

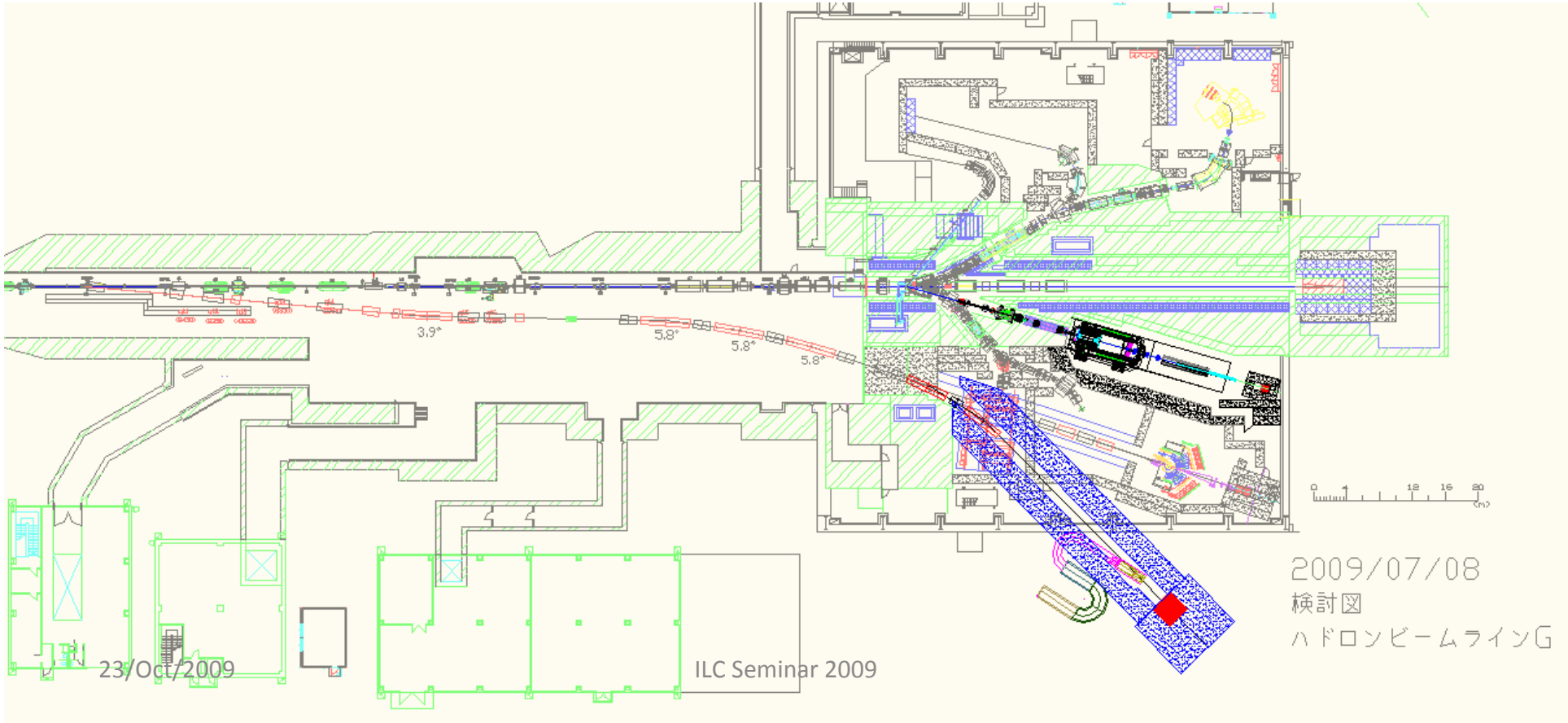
•B=2T
•Smaller radiation load
•Technology
  •NbTi copper stabilized conductor
  •Constructed by arranging coil "pancakes"
    •A new high-Tc superconductor, MgB2, will be used for one of the coils for the first time.
    •MgB2 will be used for the electron-spectrometer and detector solenoids




basic parameter study by a prototype comprising of 3 pancakes.
  cooling performance
  electromagnetic forces between pancakes
  quench back system

# A possible layout in future

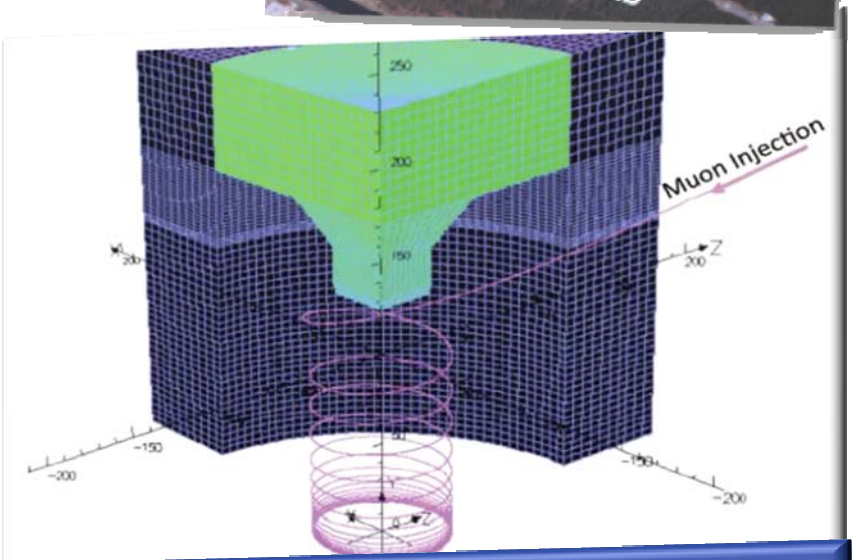
- Target and beam dump outside the hall
- Share the upstream proton transport line with the high p beam line
- External extinction device in the switch yard

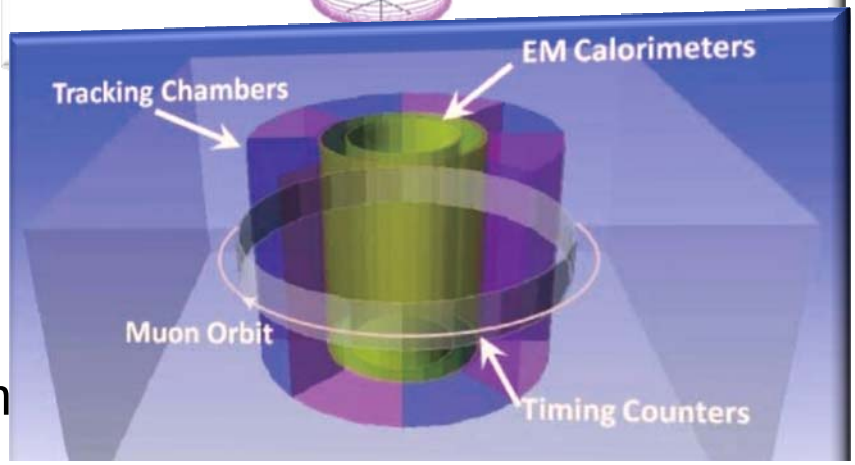


# New Generation of Muon g-2/EDM Measurements @ J-PARC proposal in preparation


- Ultra Cold Muon Beam
  - $\sigma(p_T)/p_L < 10^{-5}$ ; $10^6$ $\mu^+$ /sec
  - 10 cm spread over 10 km travel
  - No focusing field needed
  - No magic momentum or magic everywhere

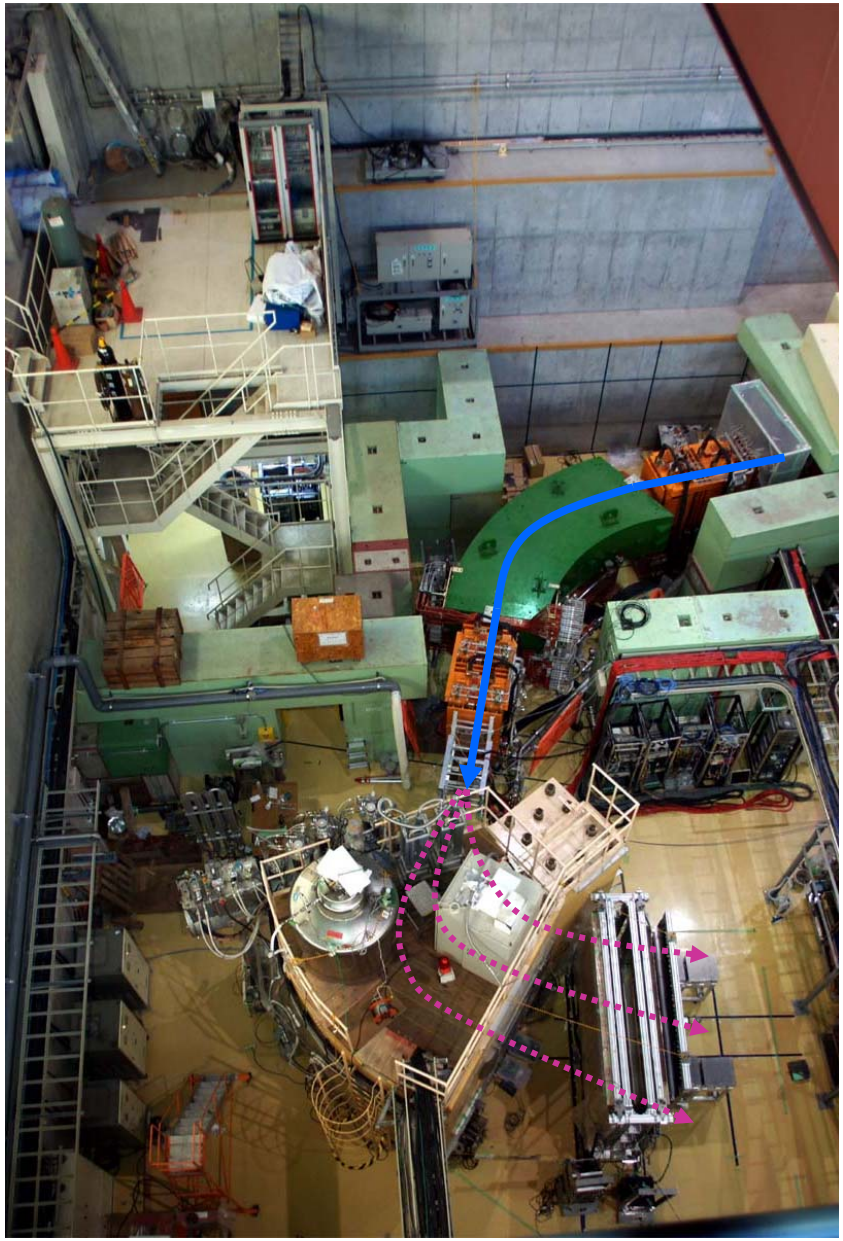
  Low momentum (300 MeV/c)
  Small Magnet (R=33 cm)
  Strong Filed (B= 3 T)
- Ultra Precision B Field
  - Utilize MRI Technologies
    - Shimming down to local precision of 1ppm (to be compared to 100 ppm in the past )
- Goals:
  - g-2 : 0.1 ppm (E821 0.54 ppm)
  - EDM : 5 x $10^{-22}$ ecm (1.9 x $10^{-19}$ ecm

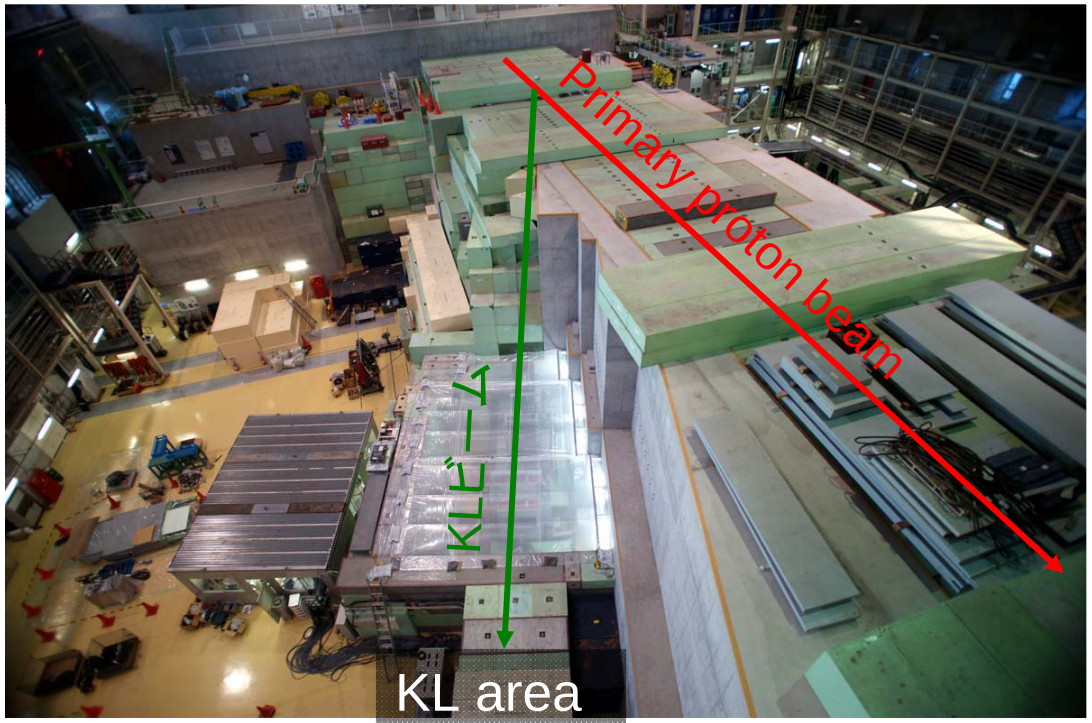


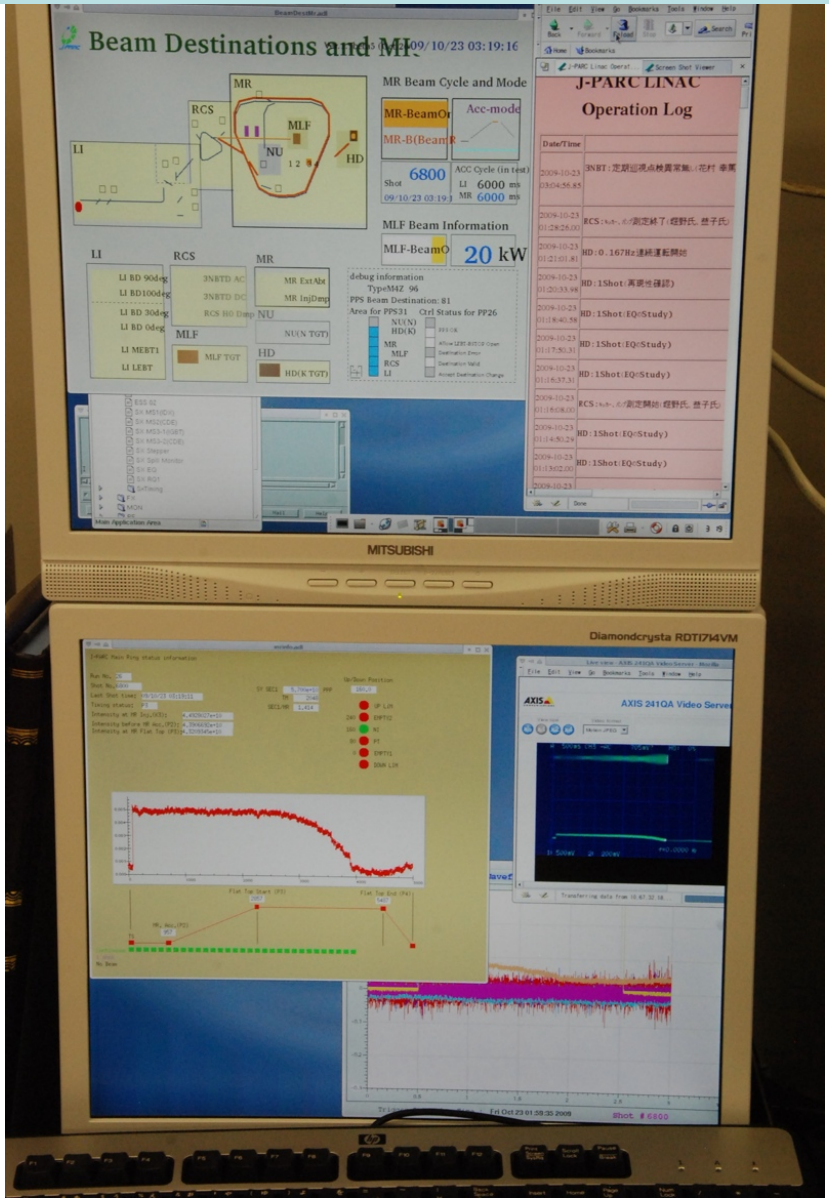
# First look of slow extracted beam by detectors

# K1.8 area






# Run#26 (Oct.1~Oct.23) MR SX tuning




- <u>10/21(wed)</u>
  one-shot operation x 4shots
- <u>10/22(thur)</u>
  one-shot operation

  4 x E11 pps 0.2% of design

  continuous operation

  16:00~07:00

  0.17Hz(6 sec cycle)

  0.5 x E11 pps

area survey

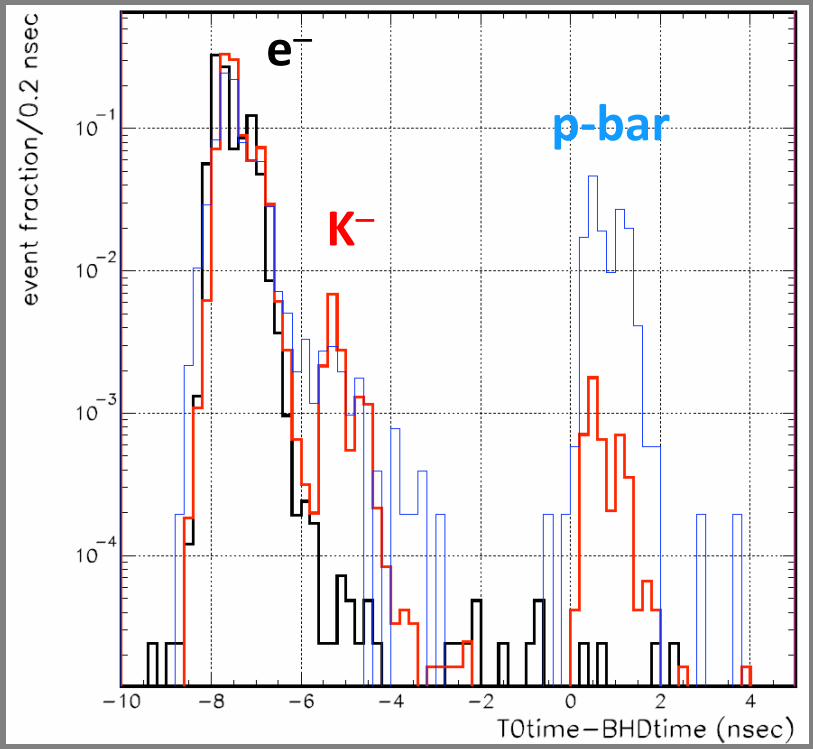
# Beam Study at K1.8BR/K1.8 on Oct.22

## K1.8BR

- BeamPID Trigger

–1.1GeV/c unseparated beam

"e⁻" trigger
"K⁻" trigger
"p-bar" trigger




## K1.8

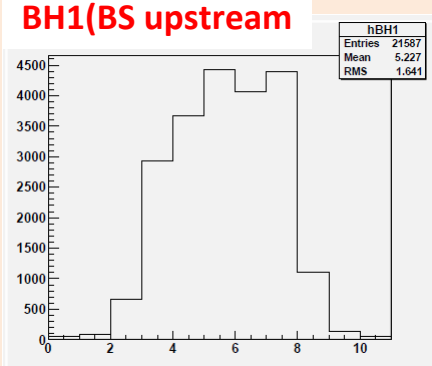
First beam to K1.8

- beam scan
- p/$\pi^+$ separation

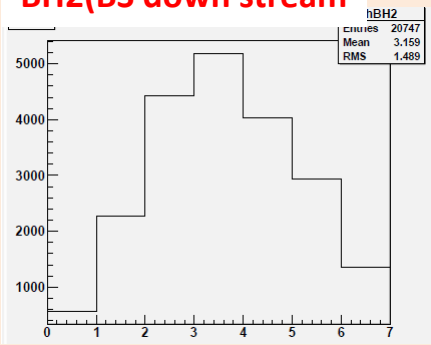
+1.1GeV/c unseparated beam

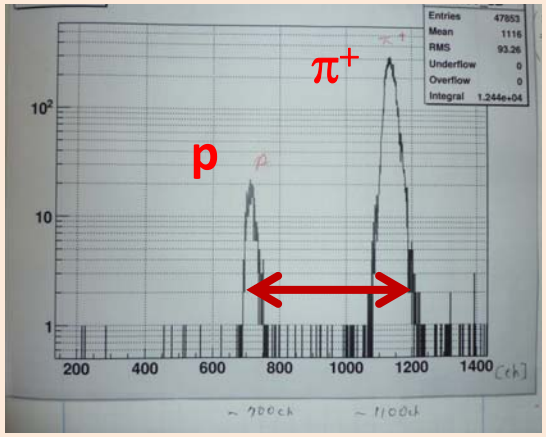
**Hit pattern at the beam hodoscope**

BH1(BS upstream




BH2(BS down stream



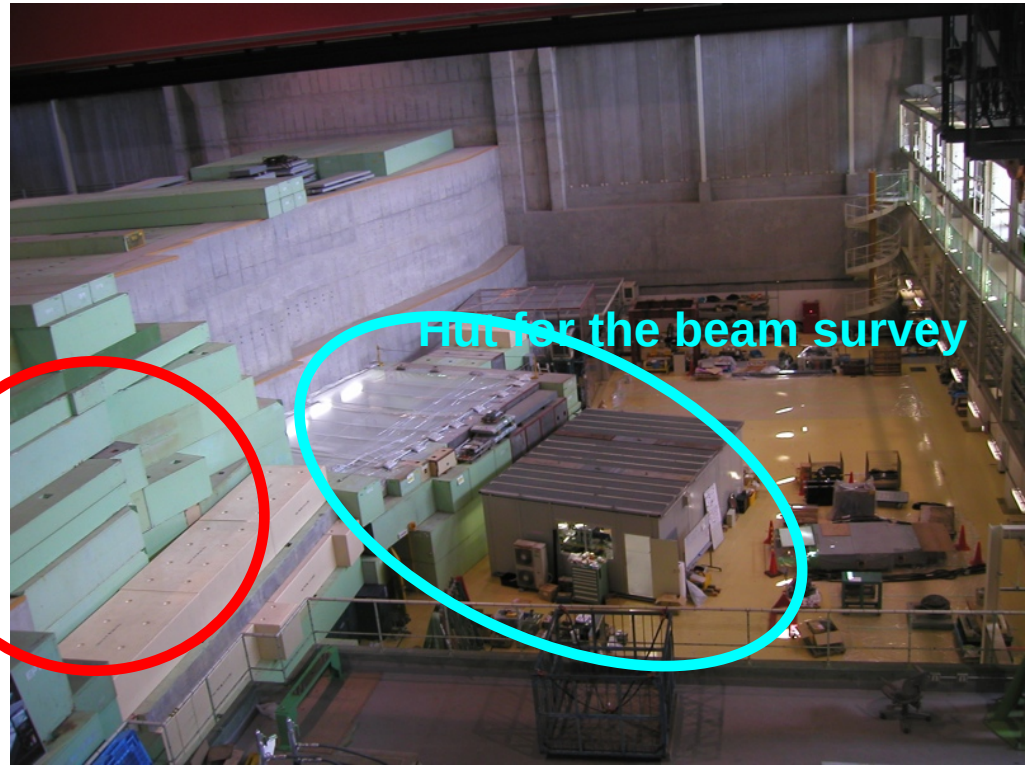




BH1-BH2
Time of Flight
(online)

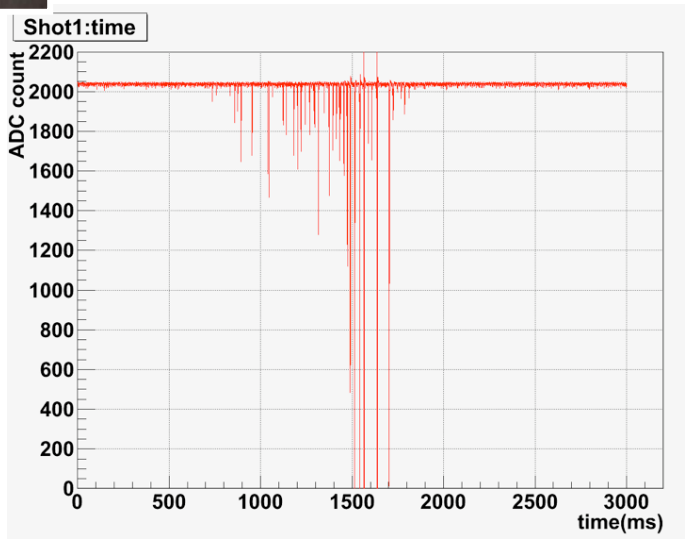
~450ch =11ns

# First beam to KL Oct.22,23

KL beamline(Aug)




**KL beam monitor Extracted beam has spiky structure**




# Slow extraction summary

## Beam loss and spill structure

- Stabilize power supply
  - Symmetric cable configuration (B,Q,S)
  - Improvement/replace power supply
- Tune FB/FF

1. 5kW level operation
   - Beam loss studies, spill control
2. 30-50kW
   - Local shielding, radiation maintenance
3. Aim for higher power
   - Idea, R&D