WAO2010
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Commissioning of J-PARC Main Ring

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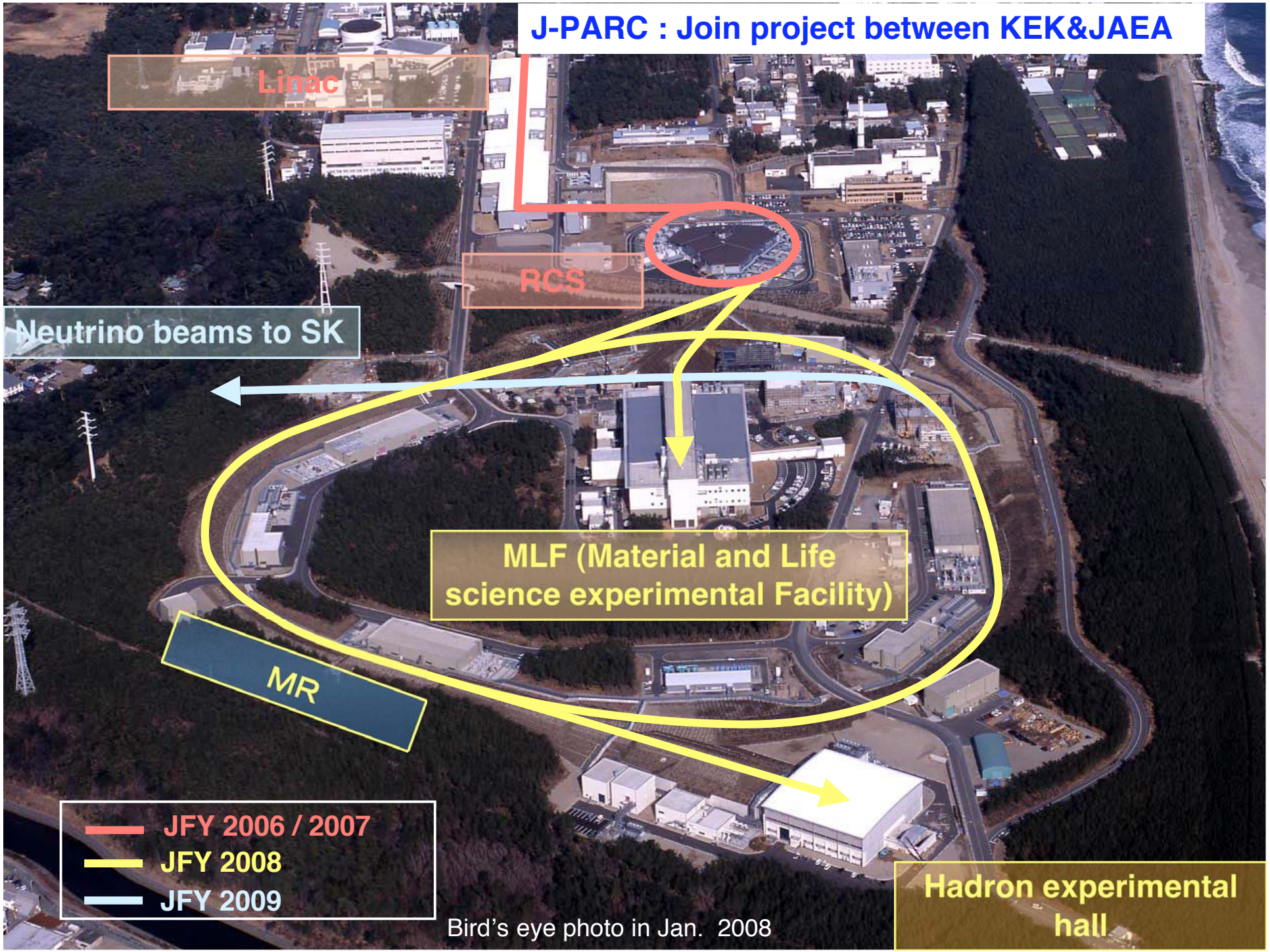
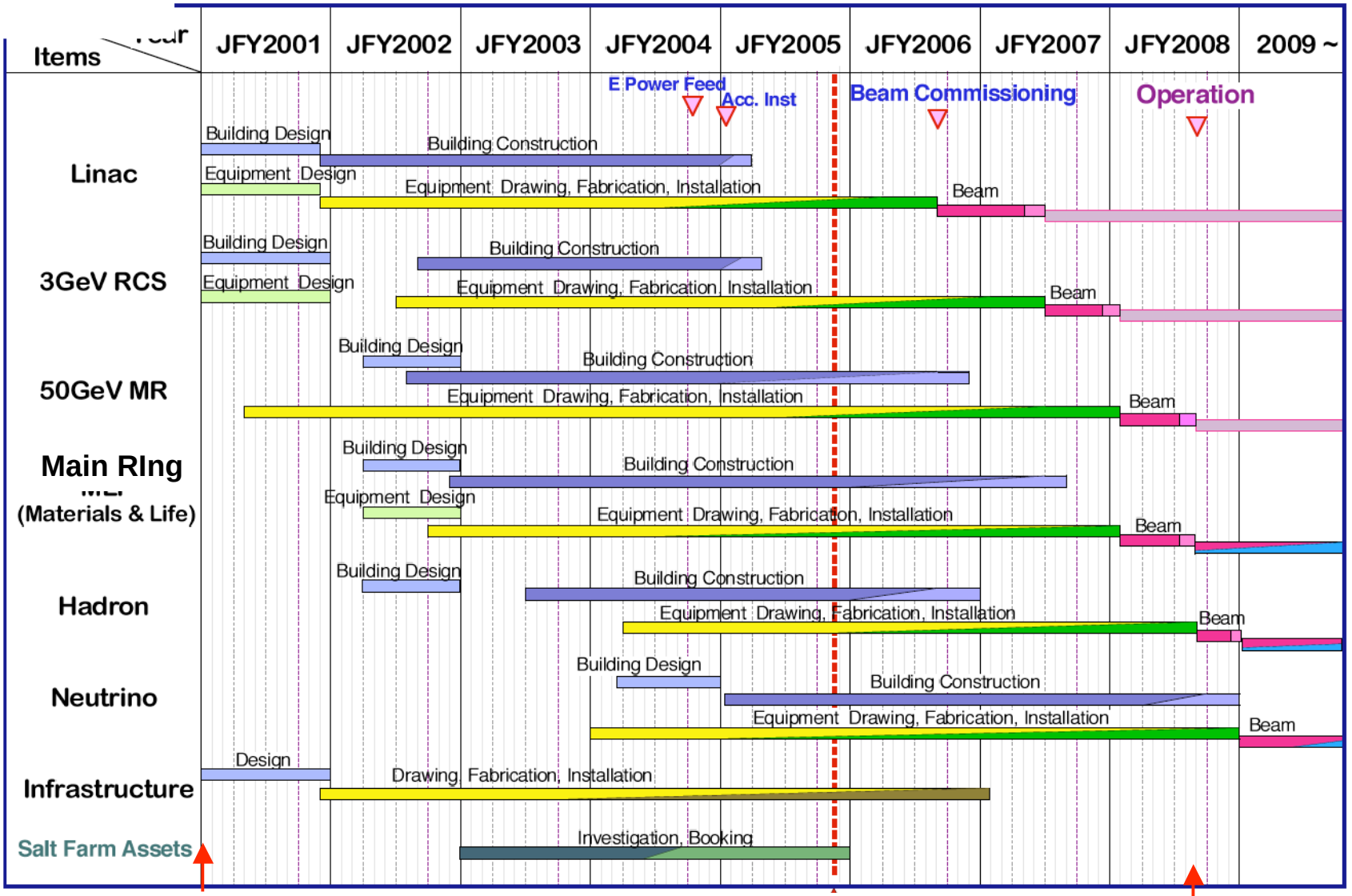

J-PARC : Join project between KEK&JAEA
Linac
RCS
Neutrino beams to SK
MLF (Material and Life science experimental Facility)
MR
Hadron experimental hall
JFY 2006 / 2007
JFY 2008
JFY 2009
Bird's eye photo in Jan. 2008

J-PARC Construction Schedule

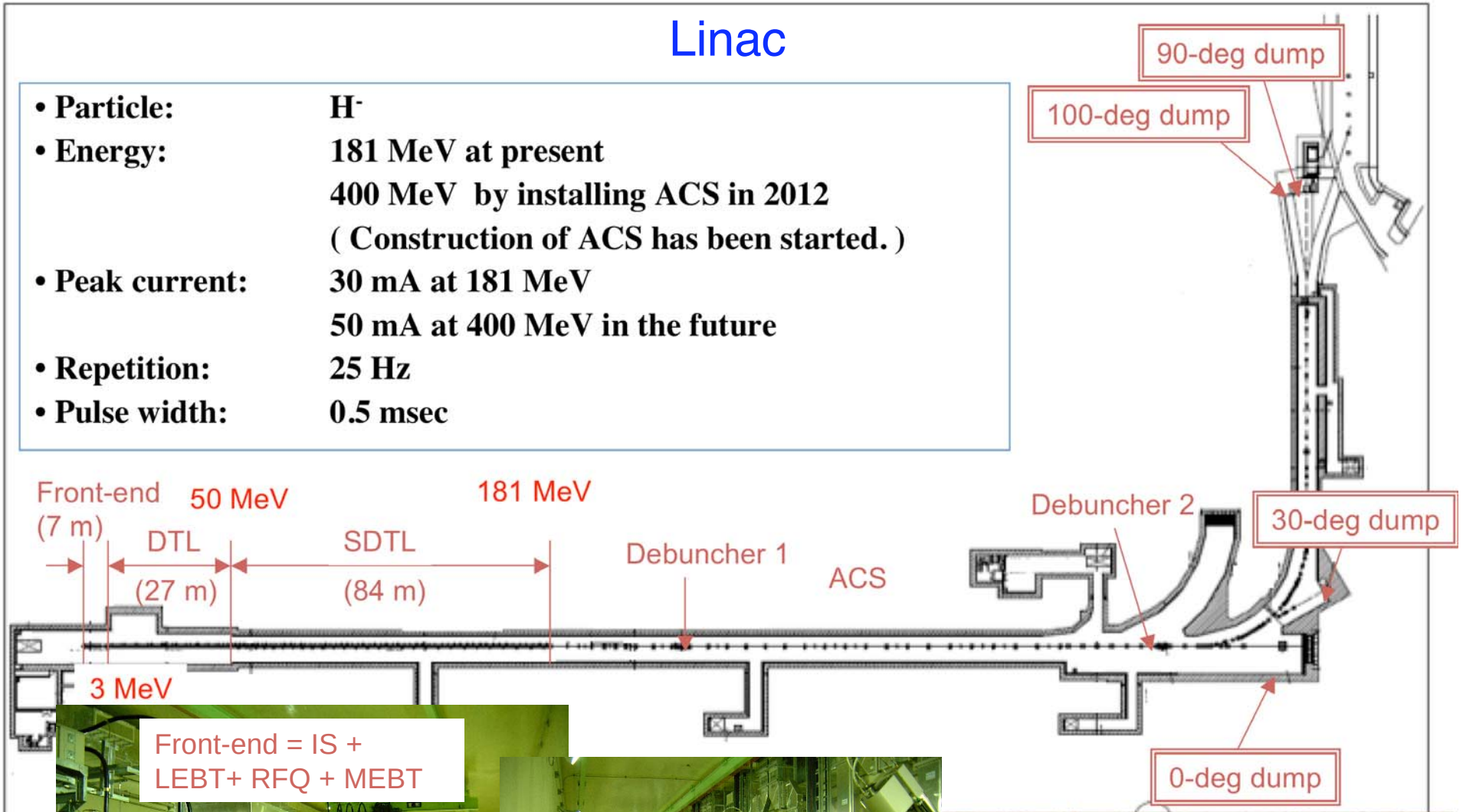
Feb. 27 2006

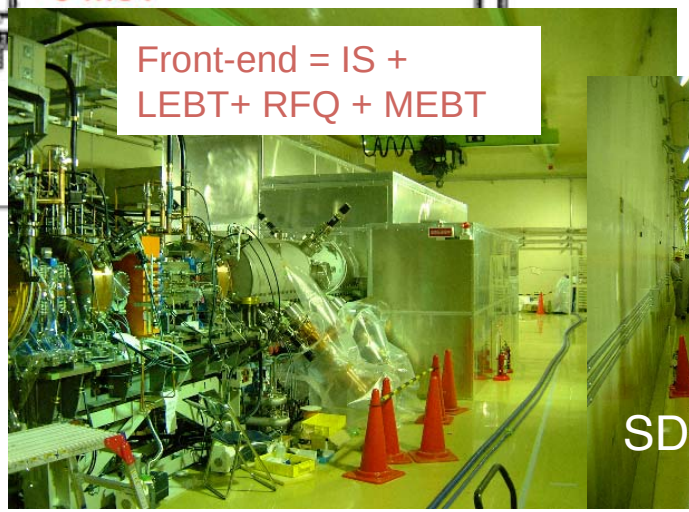


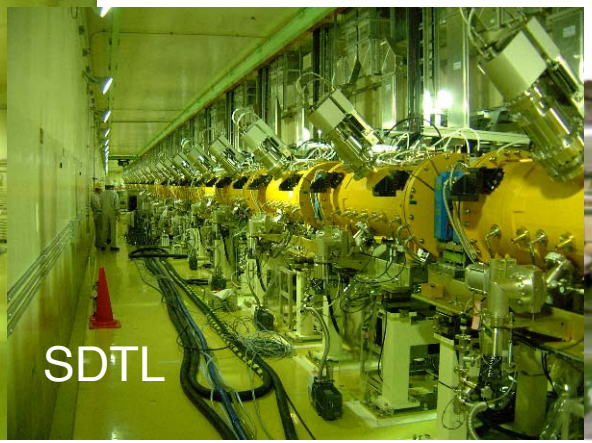
All the facilities started the beam commissioning on schedule.

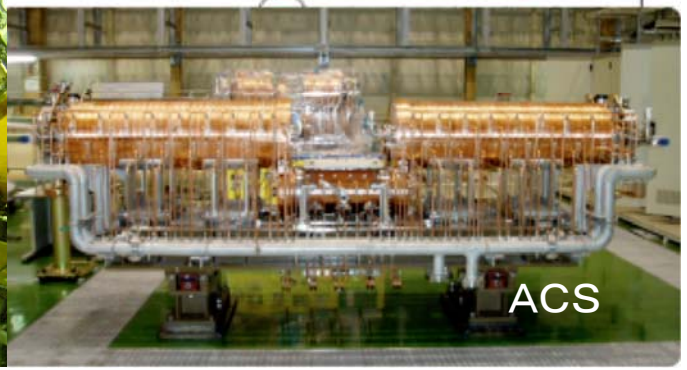
Linac

- **Particle:** H^-
- **Energy:** 181 MeV at present
  400 MeV by installing ACS in 2012
  (Construction of ACS has been started.)
- **Peak current:** 30 mA at 181 MeV
  50 mA at 400 MeV in the future
- **Repetition:** 25 Hz
- **Pulse width:** 0.5 msec



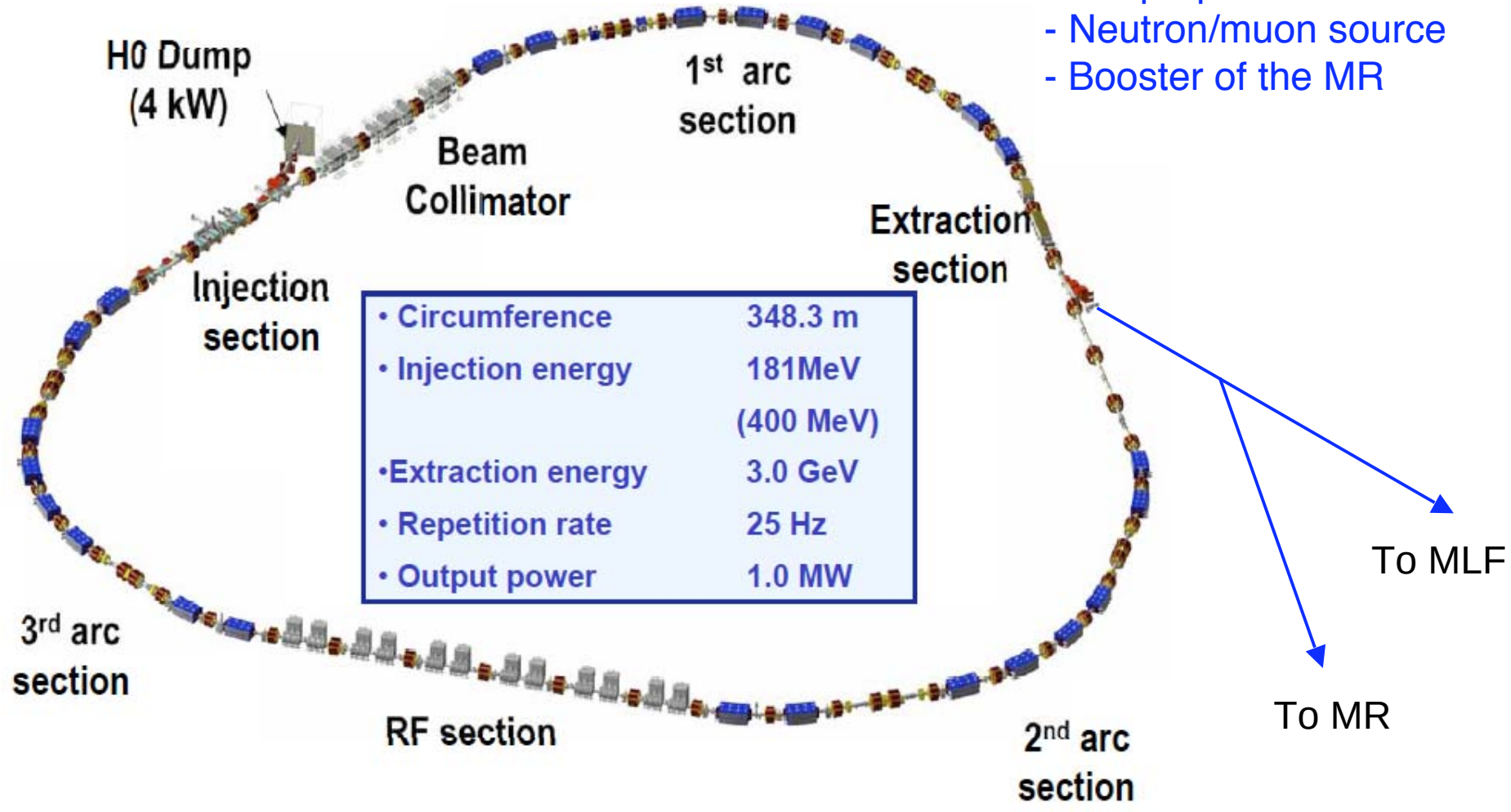




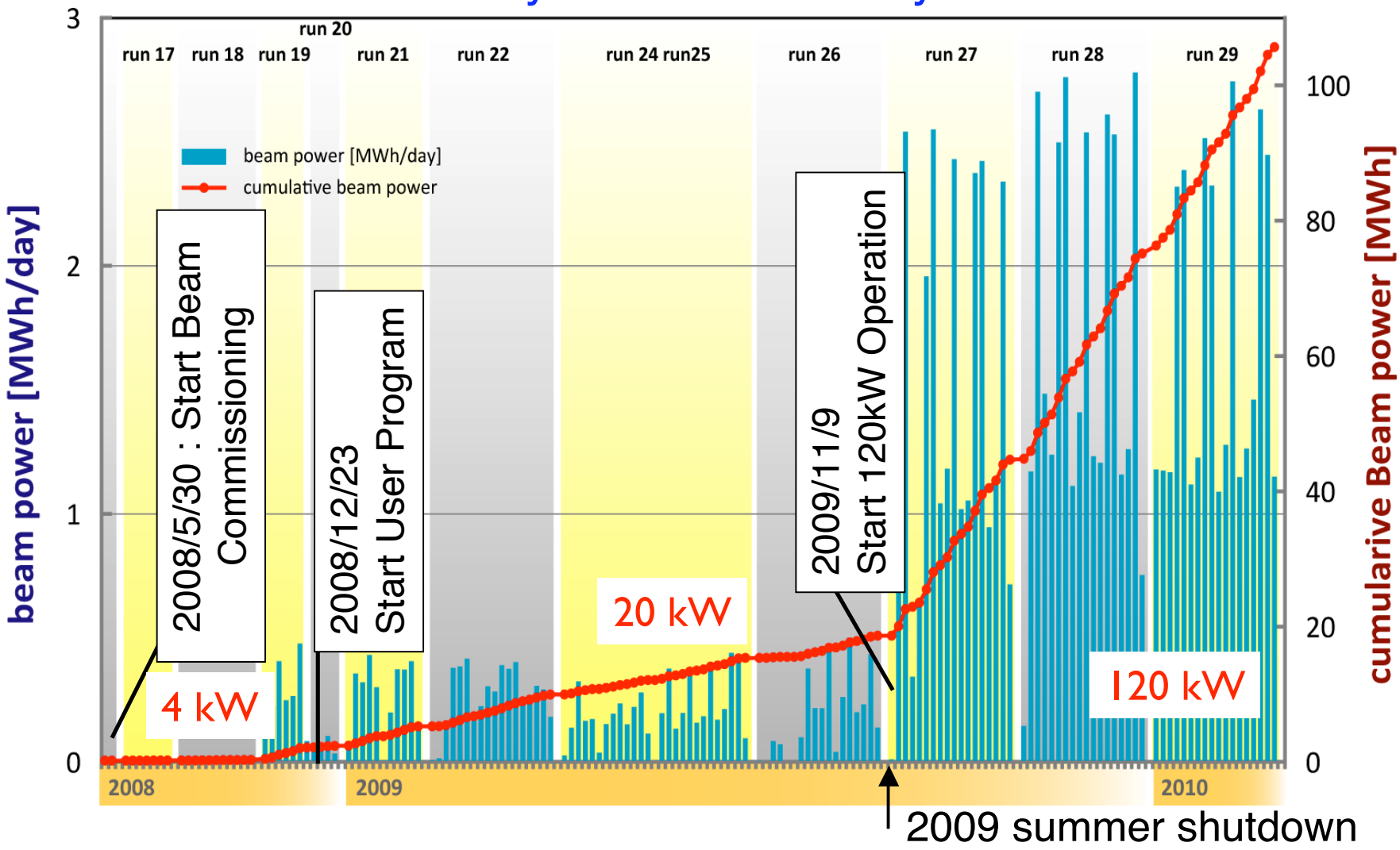


RCS (Rapid Cycling Synchrotron)

Multi-purpose machine:
- Neutron/muon source
- Booster of the MR



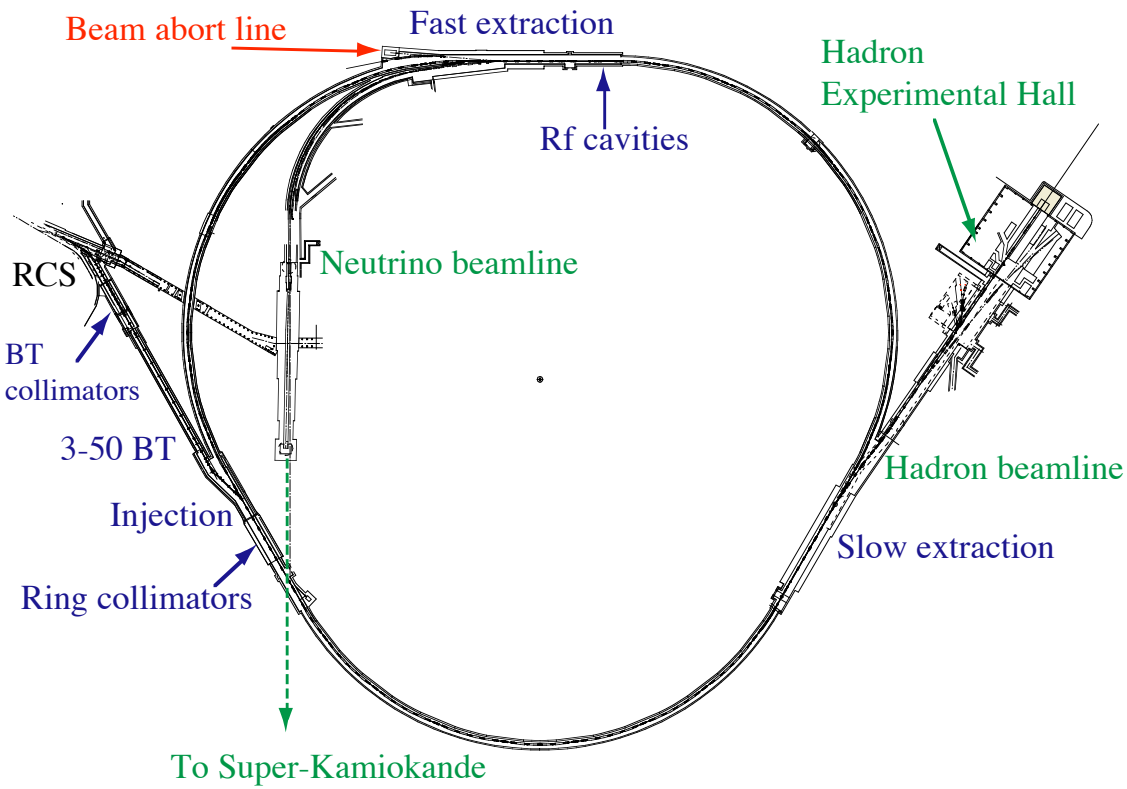
History of beam delivery to MLF



Before the 2009 summer shutdown, RCS beam power for users was limited at 20 kW due to a discharge problem of the Linac-RFQ. In the 2009 summer shutdown, we improved vacuum system of the RFQ. --> High power operation of the RCS has became available and 120 kW operation has started for the MLF users. The RCS has also succeeded to demonstrate a 300 kW operation for one hour in the last December.

Main parameters of MR

Circumference	1567.5 m
Repetition rate	~ 0.3 Hz
Injection energy	3 GeV
Extraction energy	30 GeV(1st phase)
	50 GeV (2nd phase)
Superperiodicity	3
h	9
Number of bunches	8
Rf frequency	1.67 - 1.72 MHz
Transition γ	j 31.7 (typical)
Number of dipoles	96
quadrupoles	216 (11 families)
sextupoles	72 (3 families)
steerings	186
Number of cavities	4 in day-one

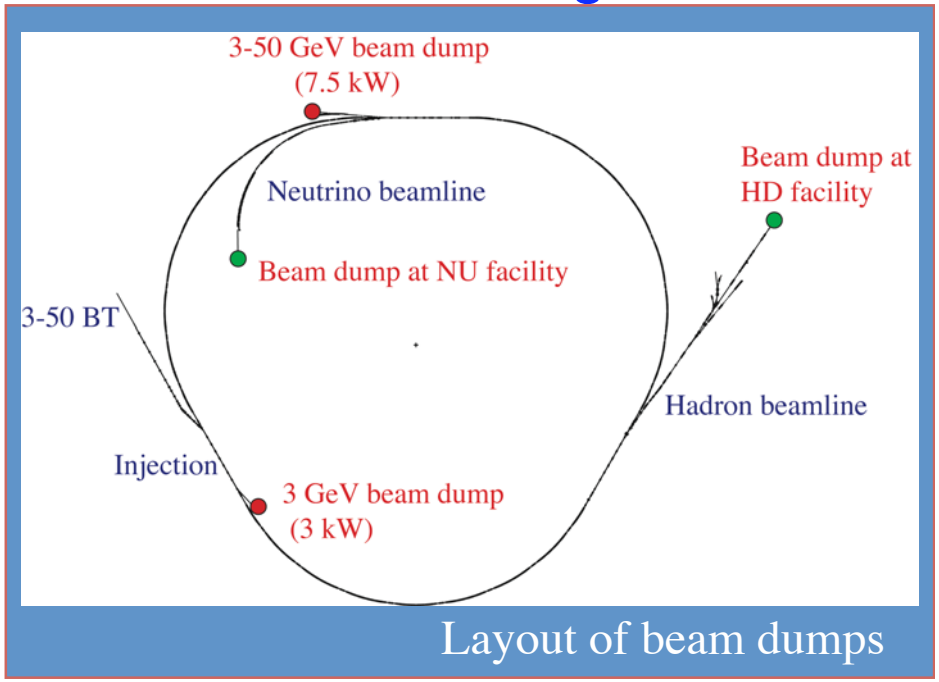


Three dispersion free straight sections of 116-m long:
- Injection and collimator systems
- Slow extraction（SX）
  to **Hadron experimental Hall**

-MA loaded rf cavities and Fast extraction(FX) (beam is extracted inside/outside of the ring)
  outside: Beam abort line
  inside: **Neutrino beamline** (intense ν beam is send to SK)

History of MR initial beam commissioning

Just after the success of
30 GeV acceleration



Layout of beam dumps

First stage: 2008/5-6 (~12 days)
- May 20:First beam circulation without rf capture
- May 22:1000 turns circulation with rf, beam extraction to the injection beam dump

2008 summer/autumn shutdown: 2008/7-11

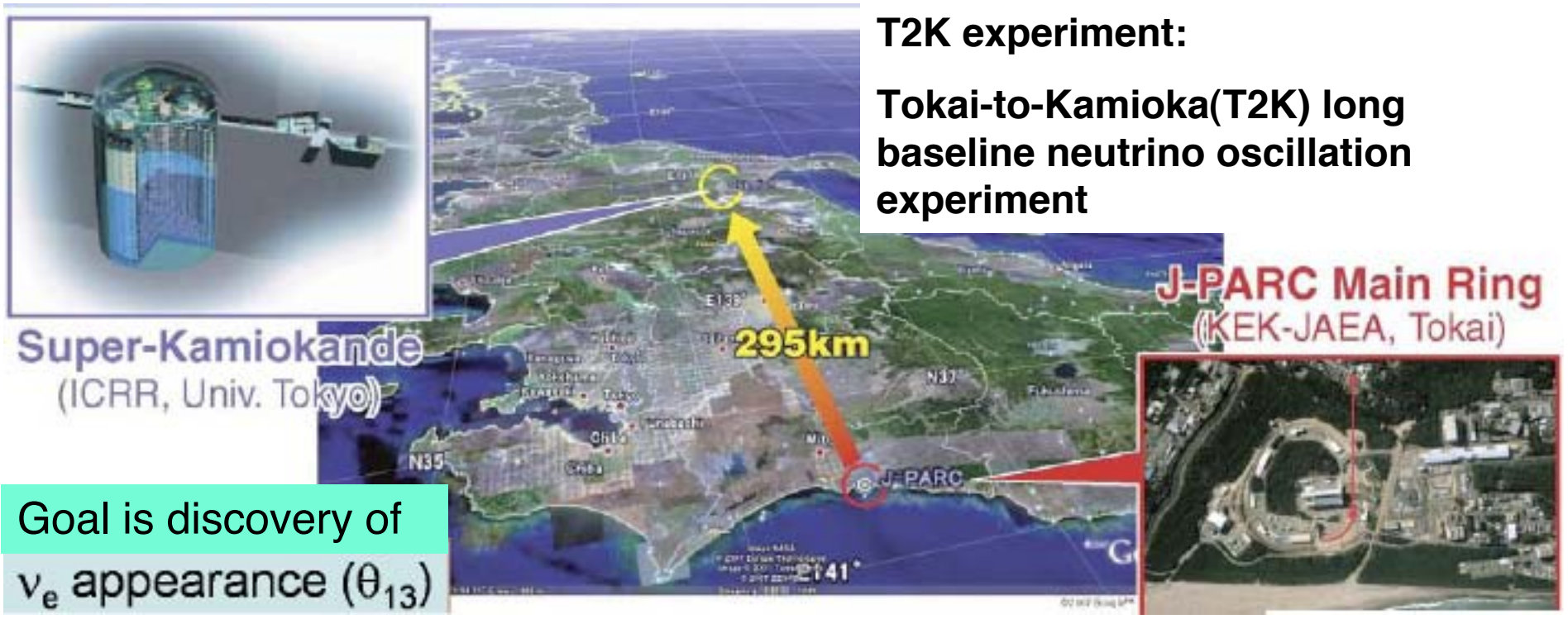
Second stage: 2008/12- 2009/2 (~26 days)
- Dec 23: Acceleration from 3 GeV to 30 GeV and beam extraction to abort beam dump using fast extraction system.
- Jan 27: Beam extraction to the hadron beam line using slow extraction system.

Third stage: 2009/4-6 (~27 days)
- April 23: Beam extraction to neutrino beam line using the fast extraction system.

2009 summer shutdown: 2009/7-9

Recent Highlights

1. Fast extraction / high power demonstration



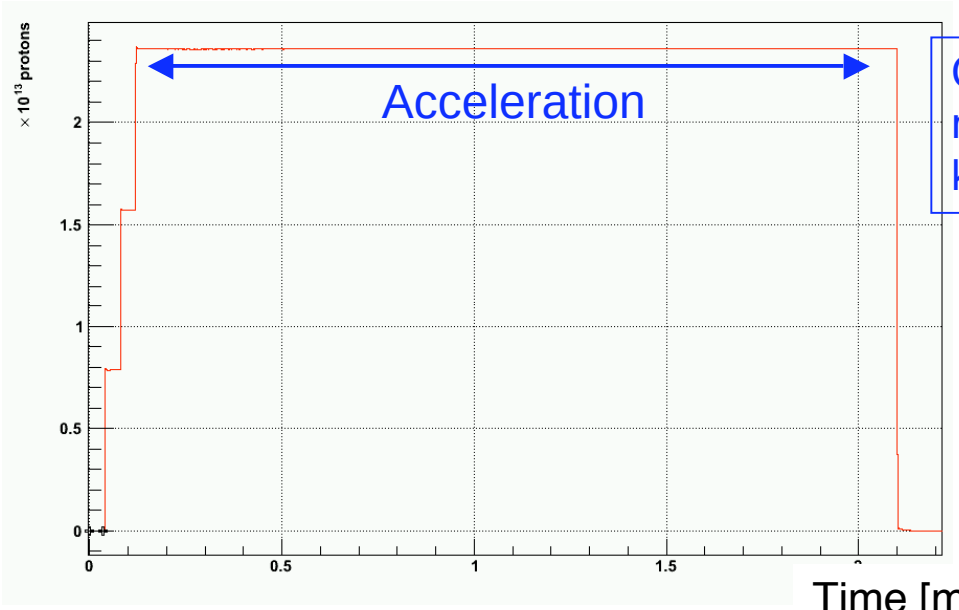
T2K experiment:

Tokai-to-Kamioka(T2K) long baseline neutrino oscillation experiment

Goal is discovery of

ν_e appearance (θ_{13})

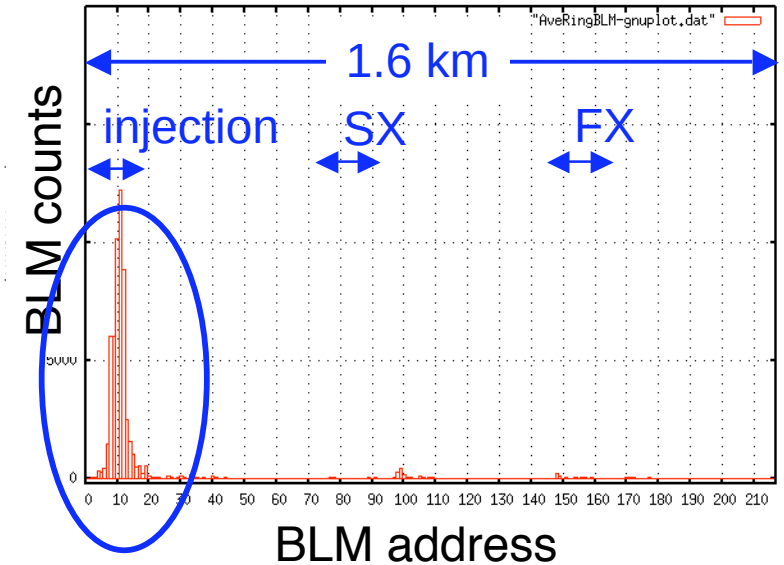
T2K group has started physics data taking since January 2010.

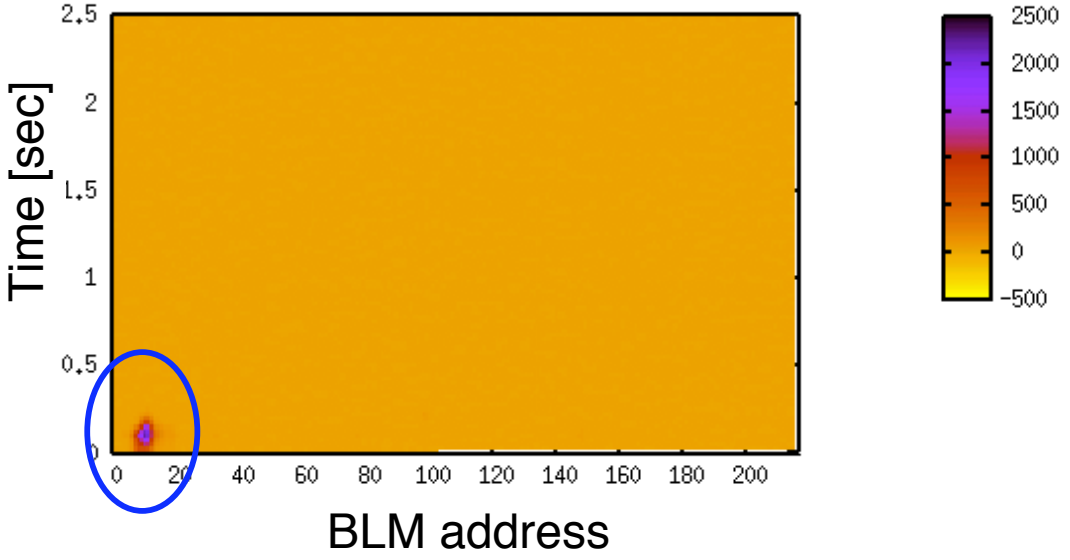


Circulating beam intensity measured by DCCT for 30 kW operation .

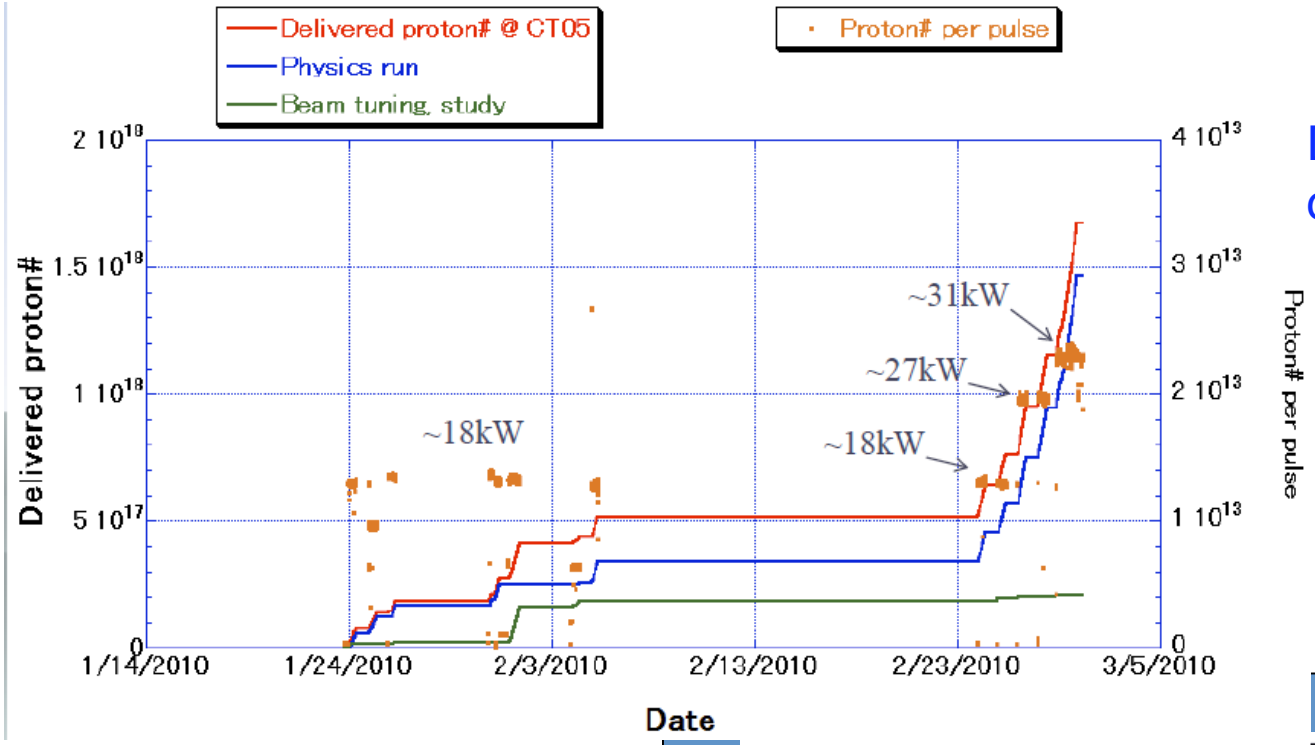
Cycle time = 3.52 sec

Integrated beam loss counts for one shot .



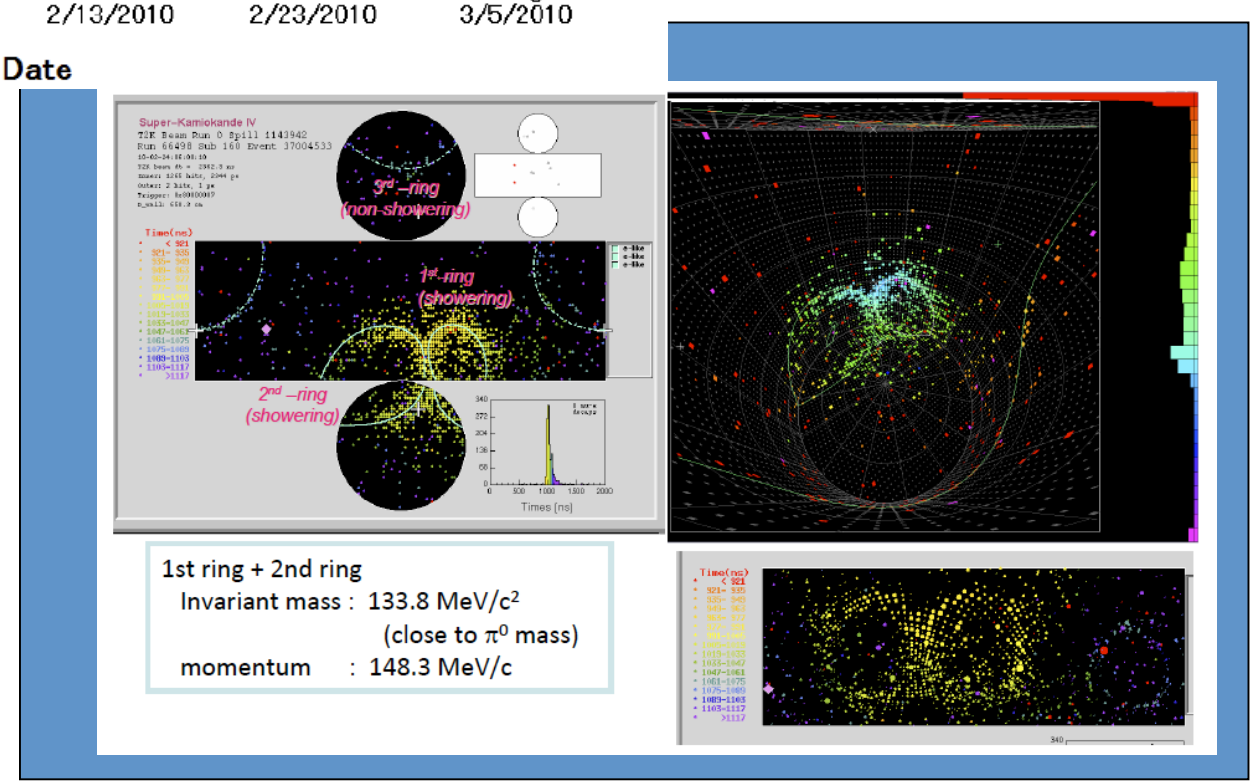


Beam loss localizes on the ring collimator section. No beam loss during acceleration.



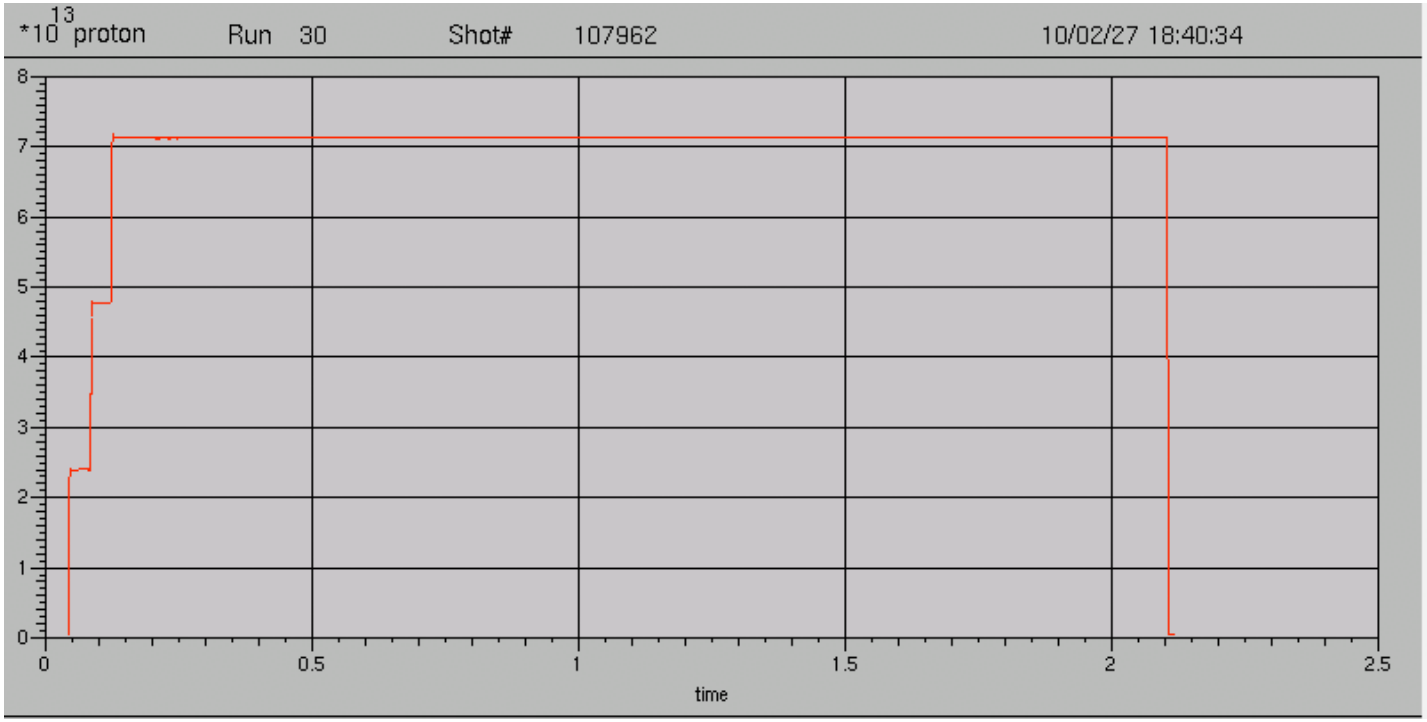
Delivered proton number on the graphite target

First neutrino event at SK on Feb. 24, 2010.



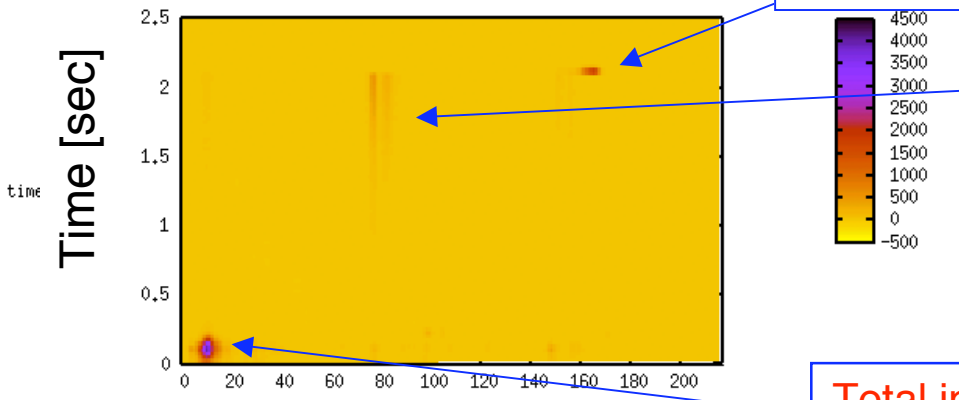
Courtesy of the T2K group

Demonstration of 100 kW equivalent beam



Tune (22.40,20.76)

The extracted particles to abort dump is 7.2e13 ppp, it corresponds to 100 kW if operated in 3.52 sec cycle.



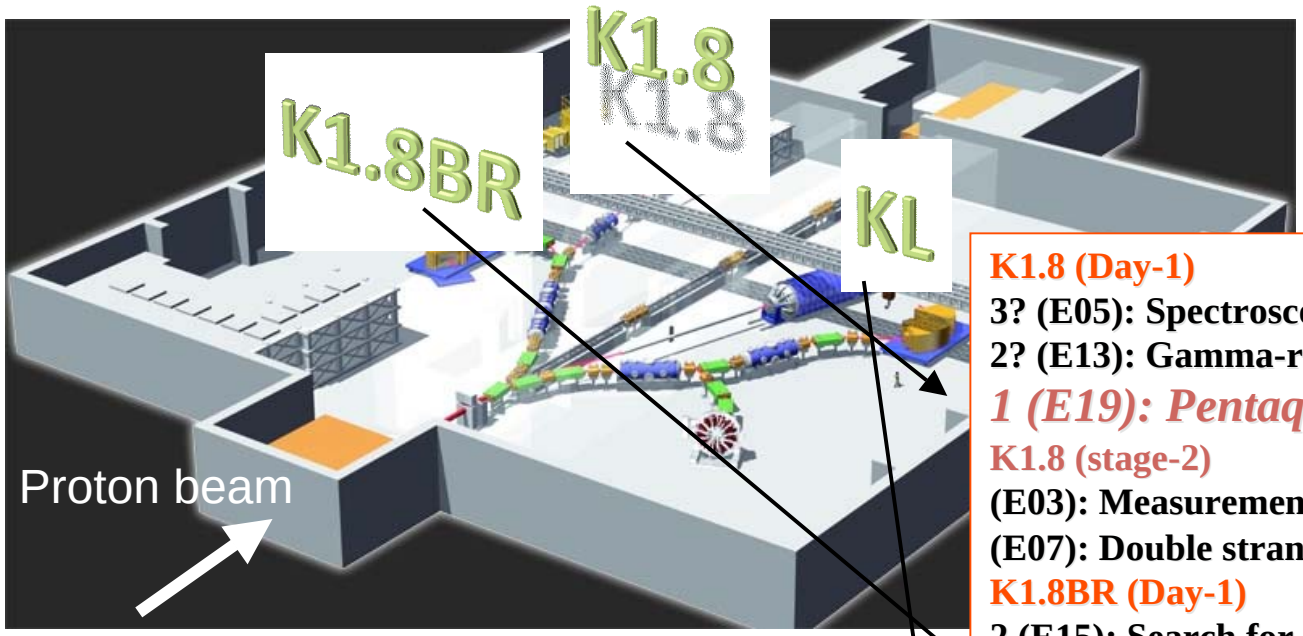
Not a real beam loss: reflection from the beam dump

Beam loss of 10^9 during acceleration:
The cause of beam loss is supposed to be pressure rise.
-> Continuous operation will decrease the loss

Total injection loss is 7.7 e11
~105 W < collimator limit 450 W

Recent Highlights

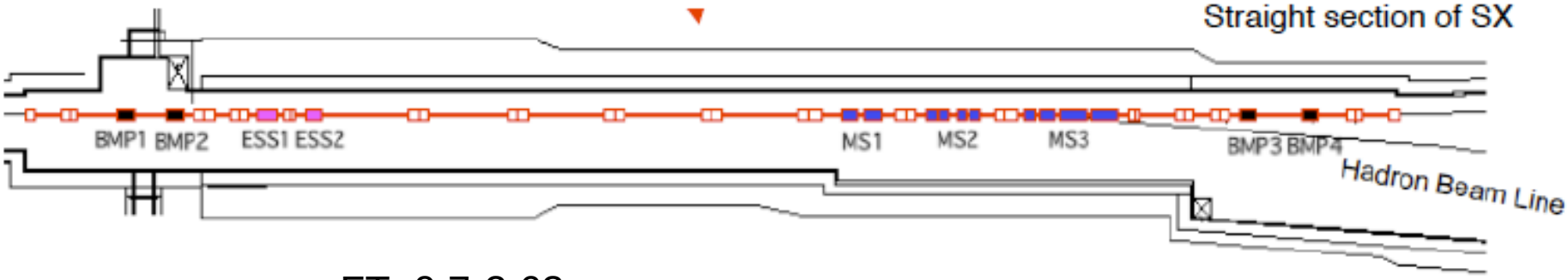
2. Slow extraction



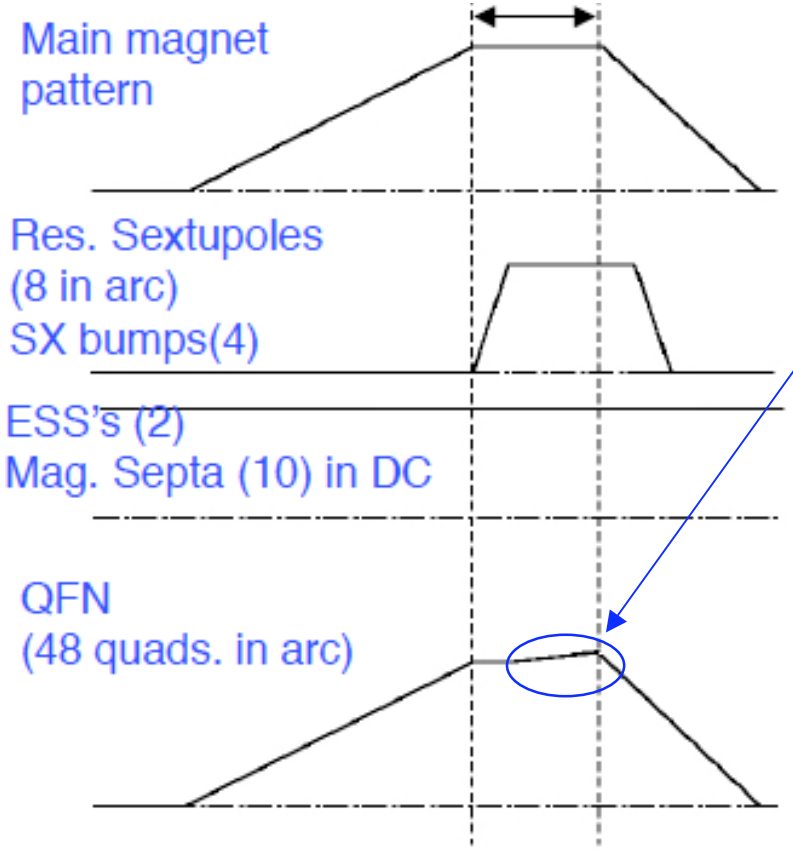
Layout of beam lines at hadron experimental facility in February 2010.

K1.8 (Day-1)
3? (E05): Spectroscopic study of hypernuclei
2? (E13): Gamma-ray spectroscopy of light hypernuclei
1 (E19): Pentaquark search in $\pi p \rightarrow K^- X$
K1.8 (stage-2)
(E03): Measurement of X-rays from Ξ Atom
(E07): Double strangeness system
K1.8BR (Day-1)
2 (E15): Search for deeply-bound kaonic nuclear states
1 (E17): Precision spectroscopy of kaonic ^{3}He
K1.1
K1.1BR (stage-1)
(E06): Measurement of T-violation in $K^+ \rightarrow \pi^0+\mu^++\nu$
High-P (stage-1)
(E16): Chiral symmetry in QCD
KL (stage-2)
(E14): $K_L \rightarrow \pi^0+\nu\nu$
COMET (New beam line, deferred)
μ-e conversion experiment at sensitivity of 10^{-16}

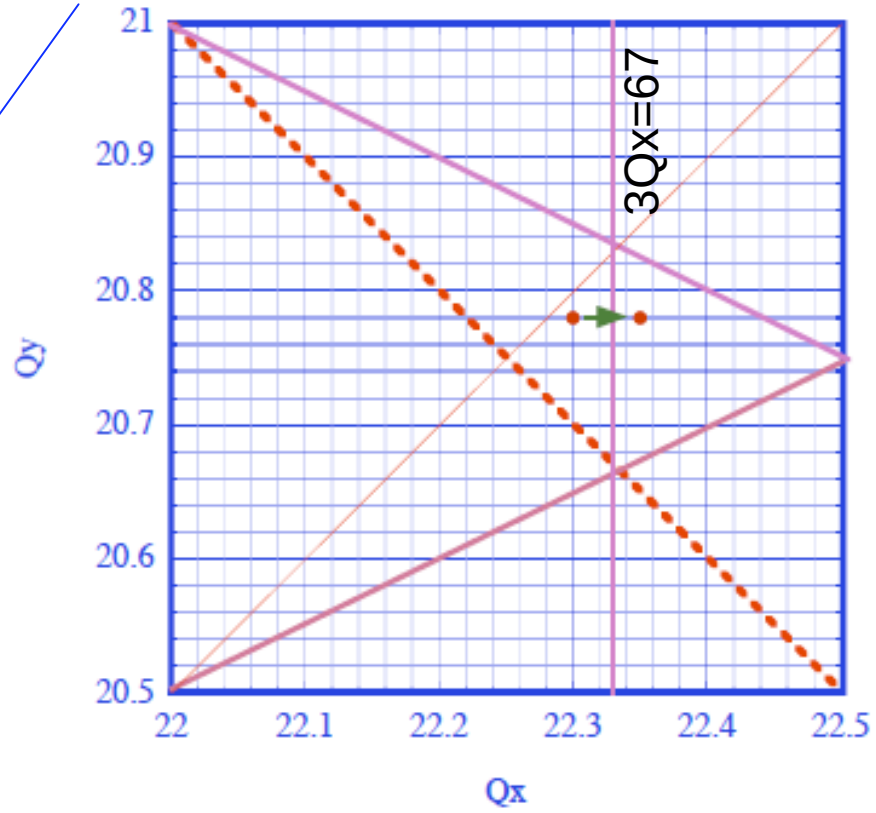
Slow extraction



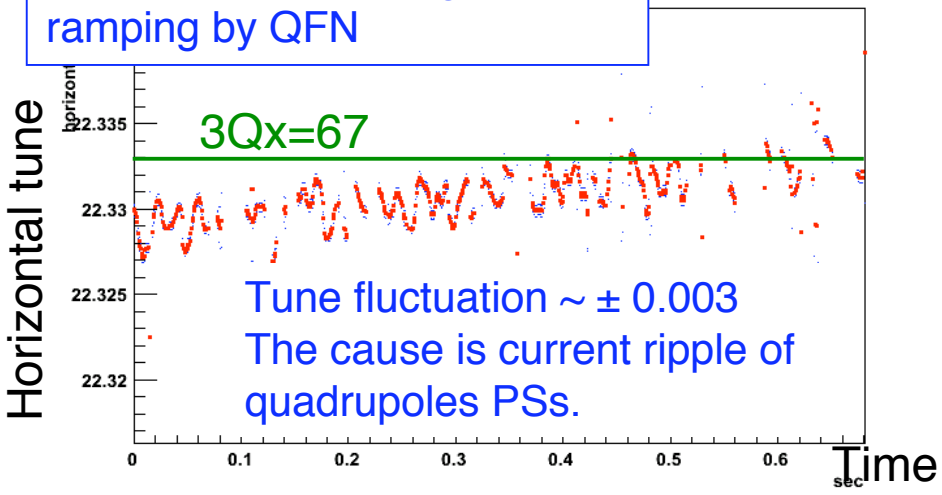
FT: 0.7-2.63 sec



Tune ramping by QFN:
(22.30, 20.78) -> (22.35, 20.78)

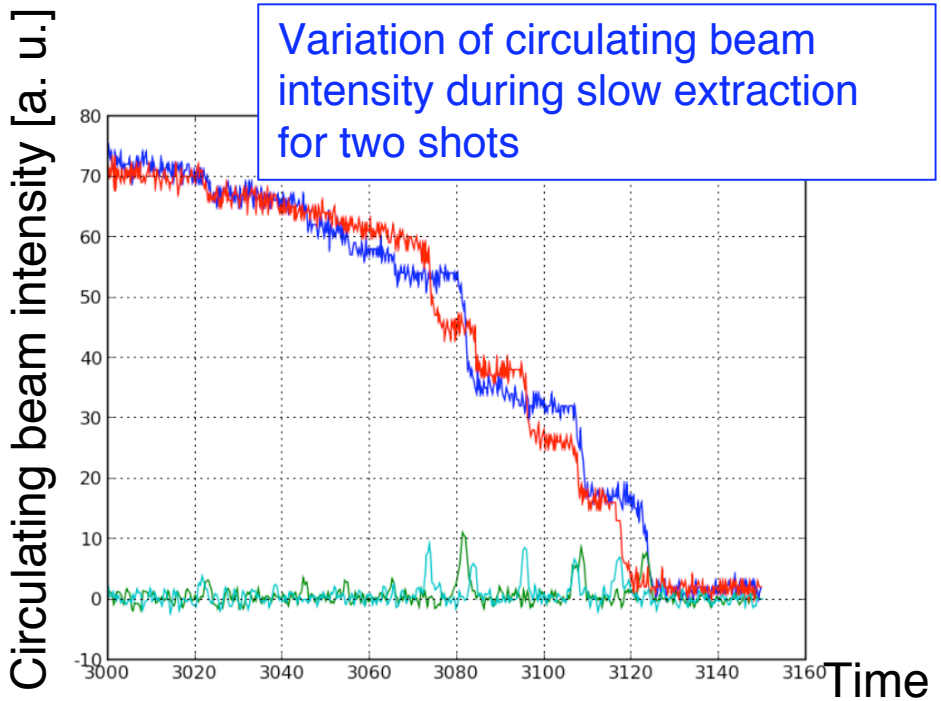


Measured tune during the tune ramping by QFN



Tune fluctuation ~ ± 0.003
The cause is current ripple of quadrupoles PSs.

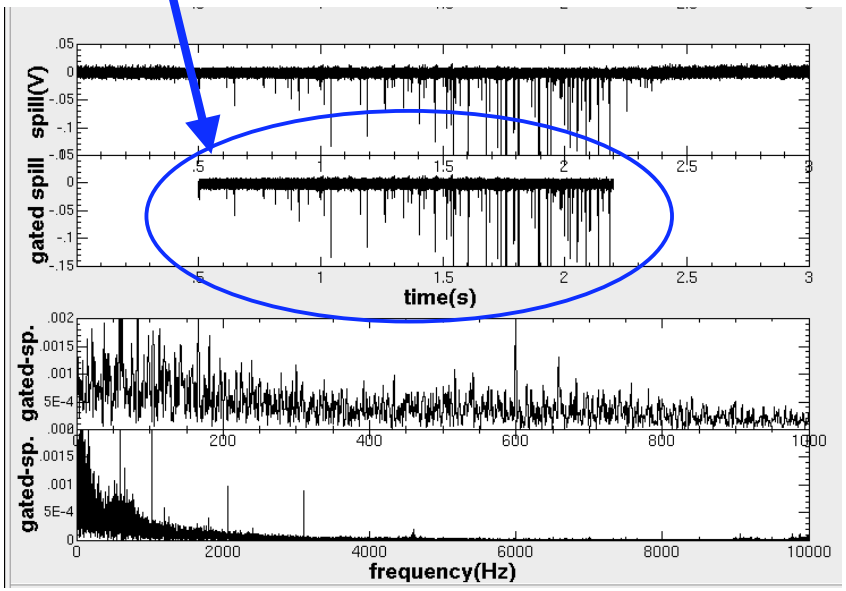
Variation of circulating beam intensity during slow extraction for two shots



Because of the tune fluctuation, the circulating beam decreases in the step-like shape

Spill monitor signal in HD beam line

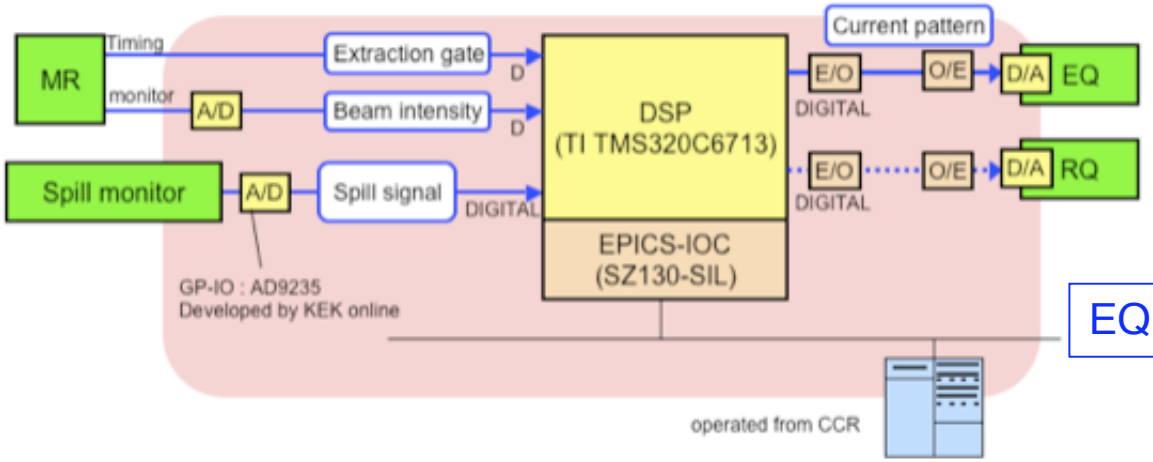
Extracted beam has many sharp peaks.



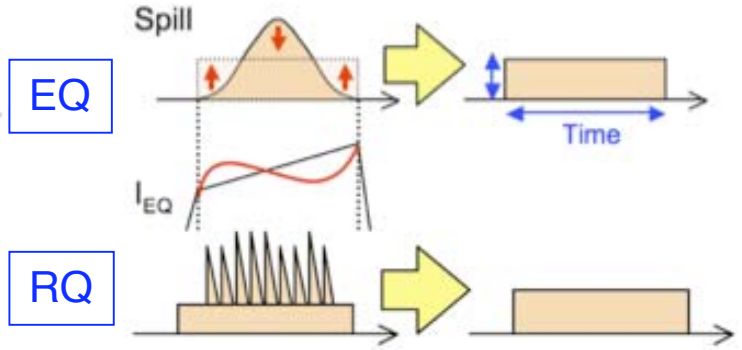
$$Duty = \frac{\left(\int_0^T Idt\right)^2}{\int_0^T dt \int_0^T I^2 dt} \qquad \sim 1\ \%$$

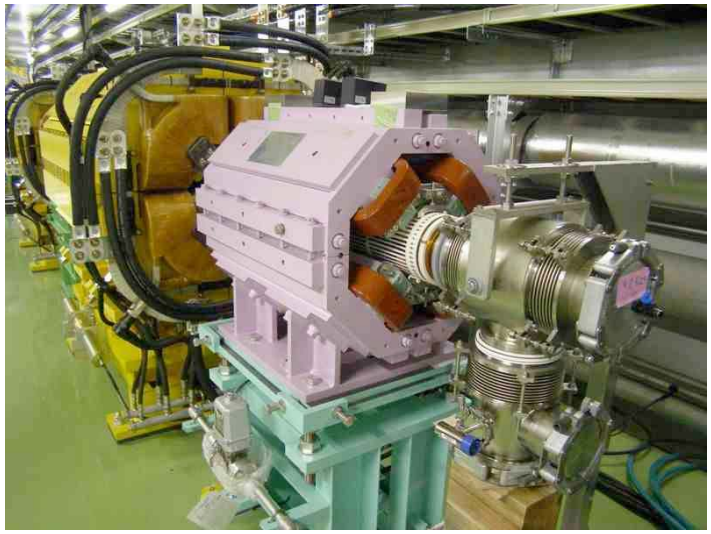
Improvement of spill structure

Spill feedback using EQ, RQ and DSP system was installed in the 2009 summer shutdown

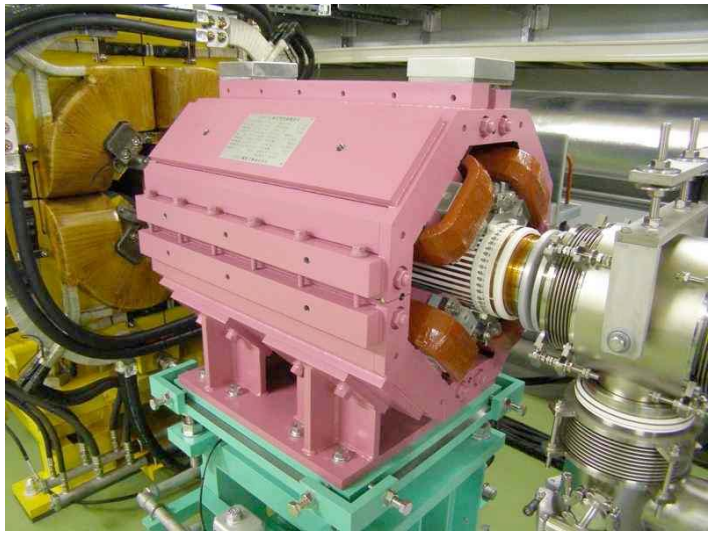


Beam spill signal is fed into the DSP system and current pattern of the correction is sent to PSs of feedback quadrupoles.





EQ: for constant spill structure (< 100 Hz)

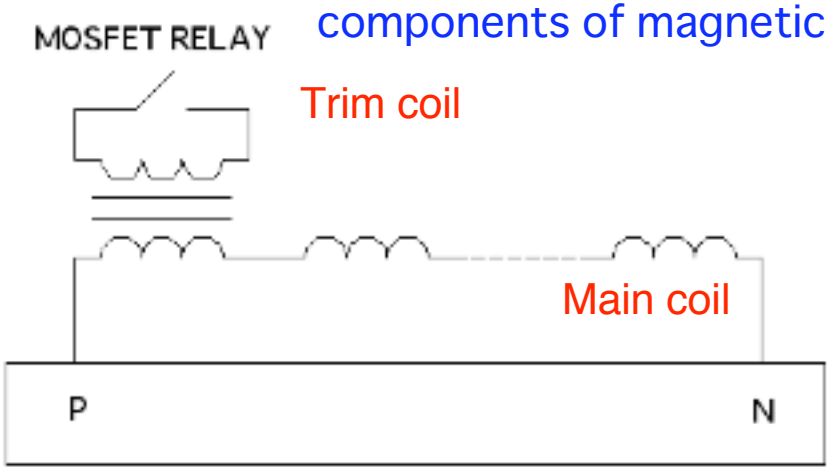


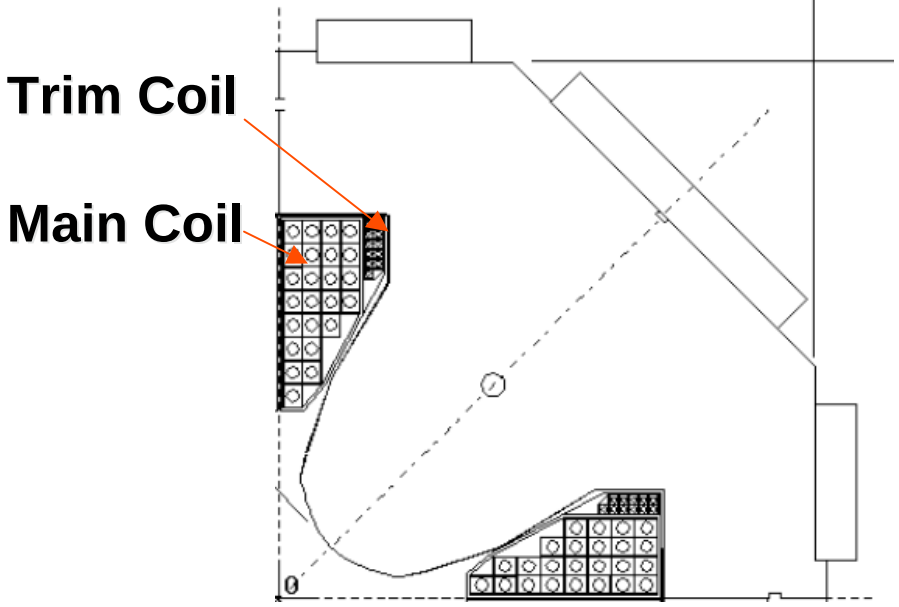
RQ: for ripple compensation (< 3 kHz)

Ripple reduction using trim coil of quadrupoles

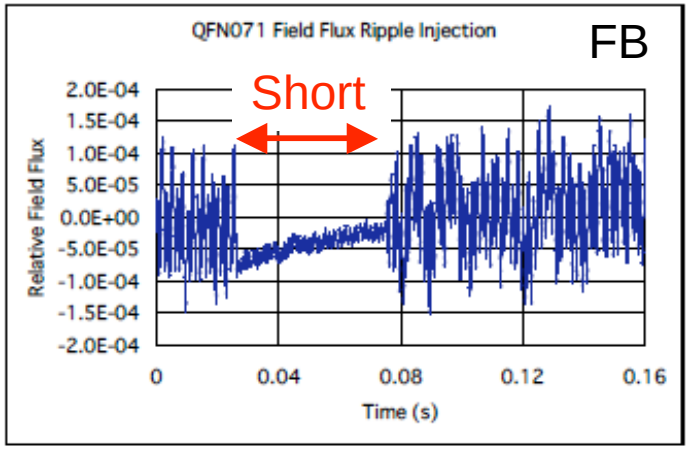
All the quadrupoles has trim coils. We set MOSFET RELAY to the trim coil circuit.

Trim coil short using MOSFET RELAY reduces the AC components of magnetic field

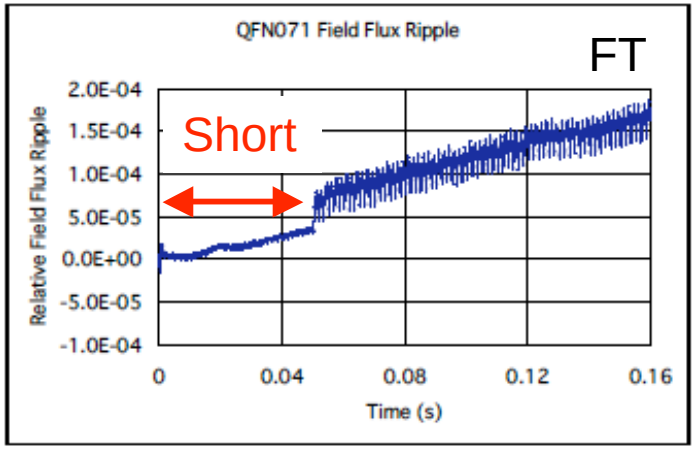




Injection
Ripple(p-p)
Open
3.1×10-4
Short
3.9×10-5



Flat top
Ripple(p-p)
Open
4.4×10-5
Short
9.1×10-6

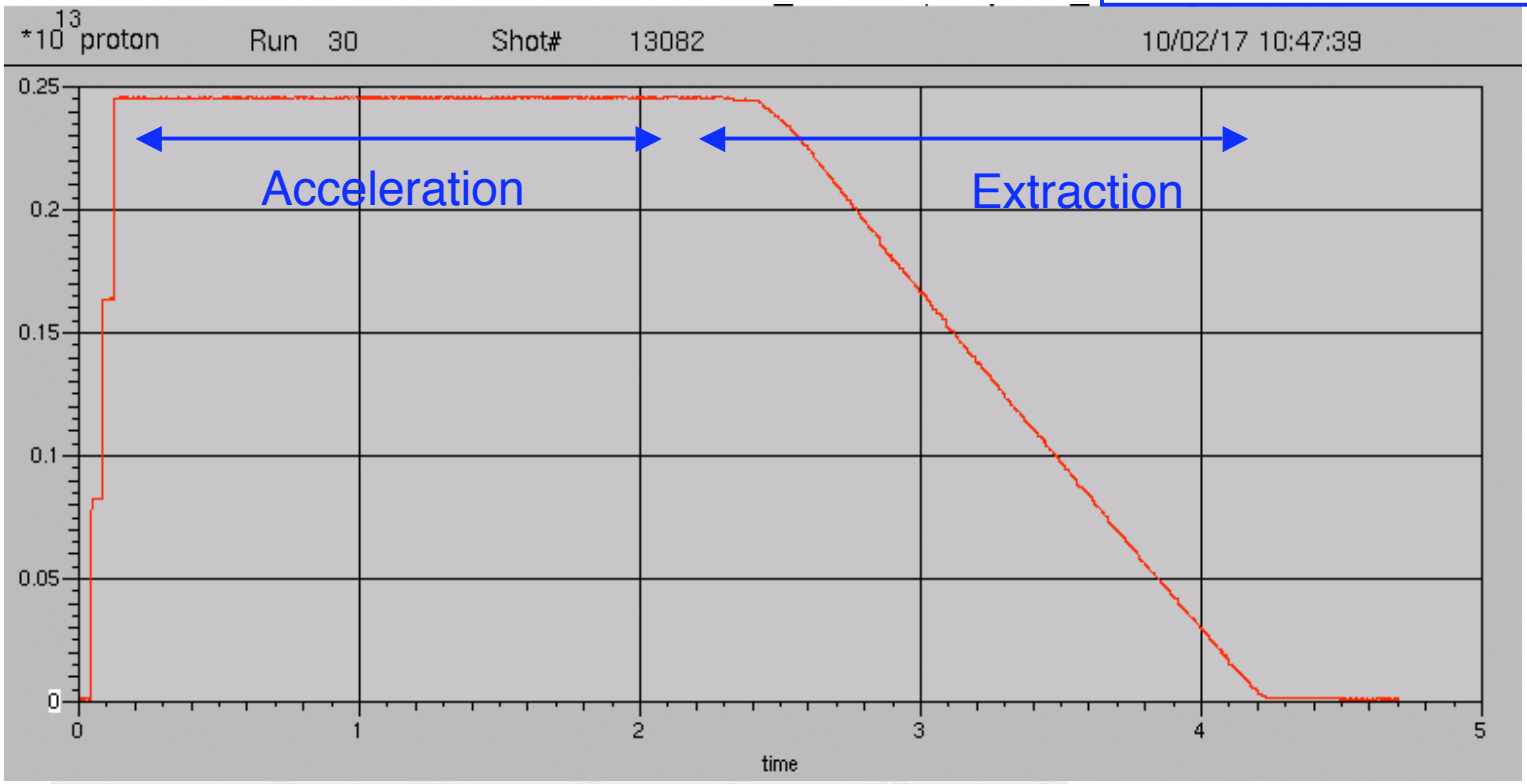


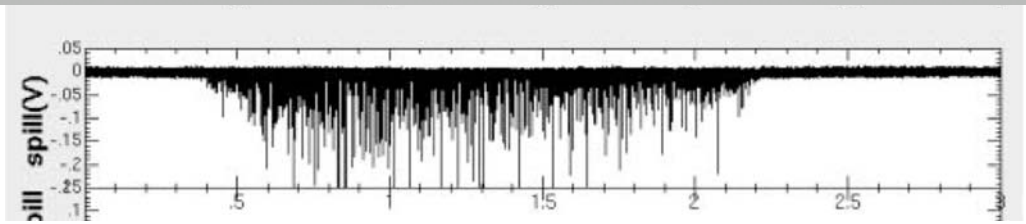
Ripple ~1/6

Operation for users in hadron experimental facility

With spill Feedback EQ/RQ+trim coil short

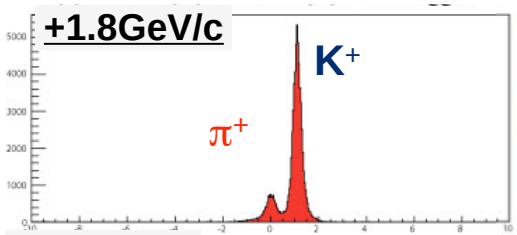
2.4 e12 ppp
(1.9 kW at 6 sec cycle)

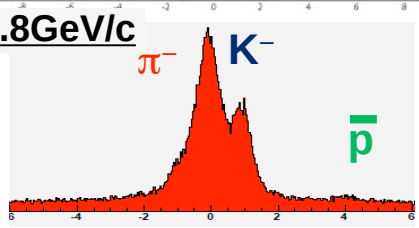




Duty of the spill
Improved from 1 % to 11 %

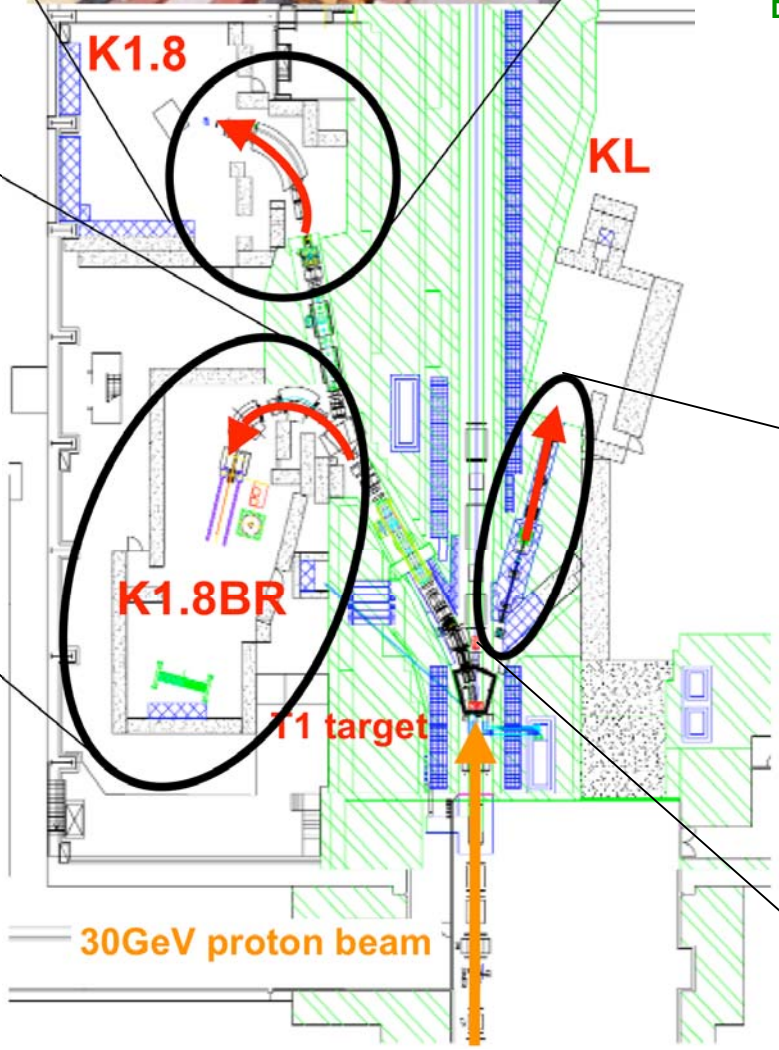
Estimated extraction efficiency ~ 98.5 %

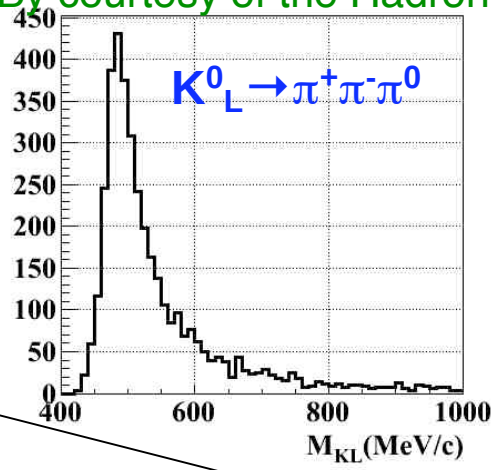


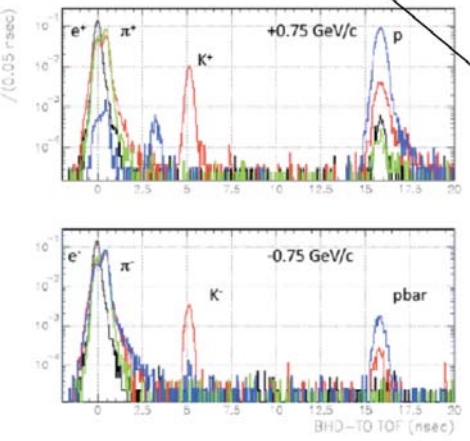


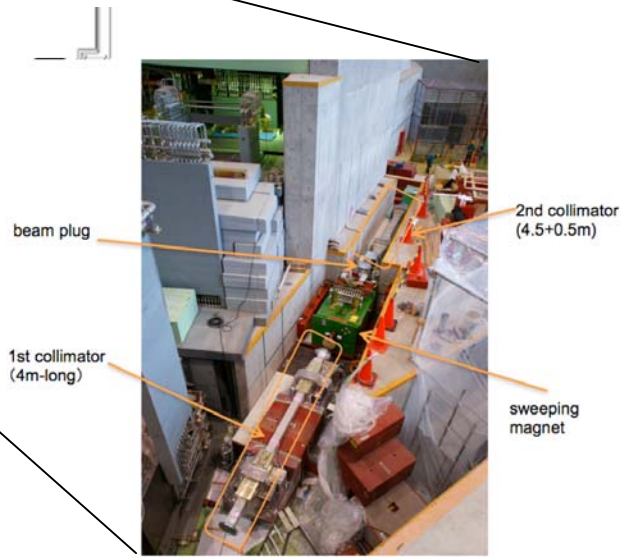
We have observed charged and neutral kaons in the secondary beam lines (**K1.8BR**, **K1.8** and **KL**) of Hadron Experimental Hall.

By courtesy of the Hadron Gr.



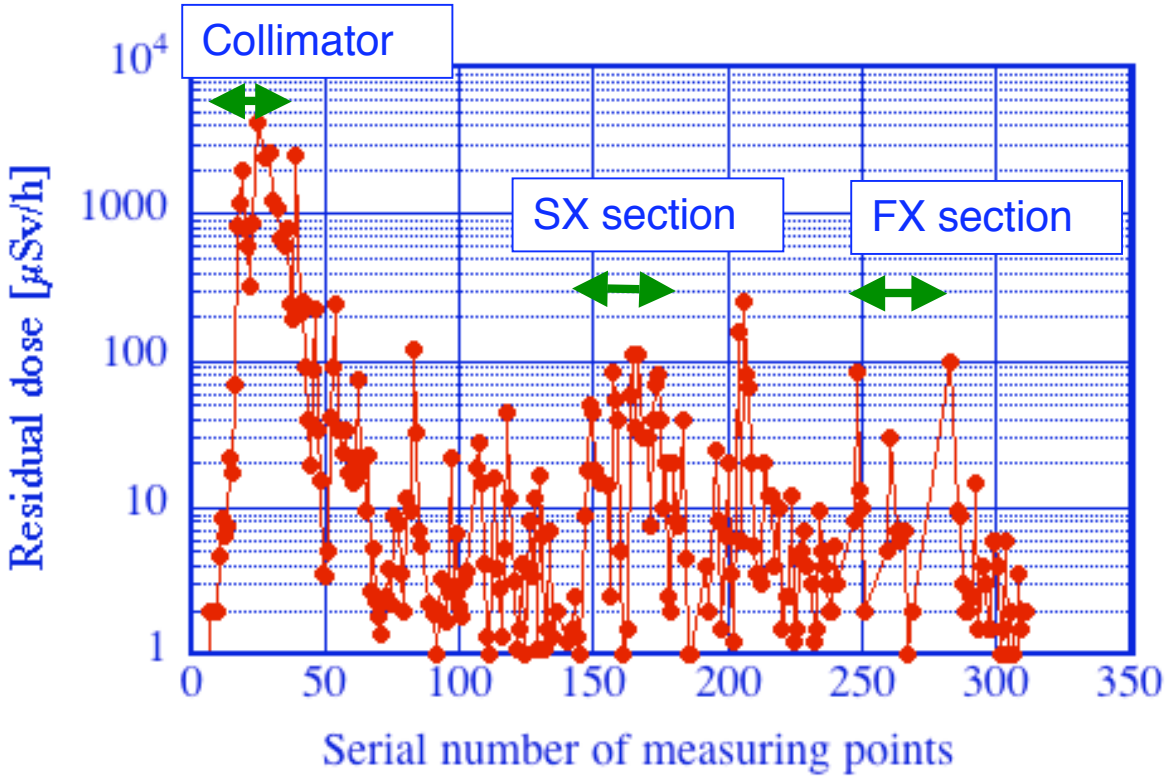






Residual activation after RUN#30

After the 2010 February RUN (RUN#30):
Total deliver time to HD is 122 hrs. (5 days) : 1 kW(106.5 hrs.), 2 kW (2 hrs.), 1.5 kW (13.5 hrs.)
Total deliver time to NU is 72 hrs. (3 days) : 18 kW(19 hrs.), 27 kW (21 hrs.), 31 kW (32 hrs.)
Survey: 4 hours after stop of beam delivery to NU, measured by contact on the beam ducts.
(7days after stop of delivery to HD)



- High activation is localized in collimator section.
- The residual activation in SX section 1 week after beam stop is less than 100 μSv/h on contact.
(The guide line of activation max. is 1 mSv/h to allow hands on maintenance.)

Summary

The RCS has started to deliver the 120 kW beam to the MLF since Nov. 2009.

Recent achievements of the MR operation:

Fast Extraction (FX)

-Beam delivery to the NU beam line : 40 kW in max.

Physics data taking started in January and 1st neutrino event in SK on Feb. 24.

-High power demonstration : 100 kW equivalent operation

7.2~7.4e13 ppp : the world record of ppp in synchrotron

Slow Extraction (SX)

-Beam delivery to the HD beam line : 2.6 kW in max.

-Tuning for higher extraction efficiency: ~ 98.5 %

-Improvement of time structure of beam spill.

Duty of the spill is ~11 % in users operation.

Plan for JFY2010

FX:

- Beam delivery of 40 - 100 kW or higher to T2K experiment
- New FX kicker system with faster rise time (# of bunches : 6 -> 8)
- Operation with 2nd harmonics cavity

SX:

-Beam delivery of 5 kW to HD users

-For higher extraction efficiency :

Dynamic bump scheme will be adopted from 2010 Autumn RUN

- For improvement of spill structure :

Main PS tuning to reduce 600 Hz ripple

Feedback with RF noise

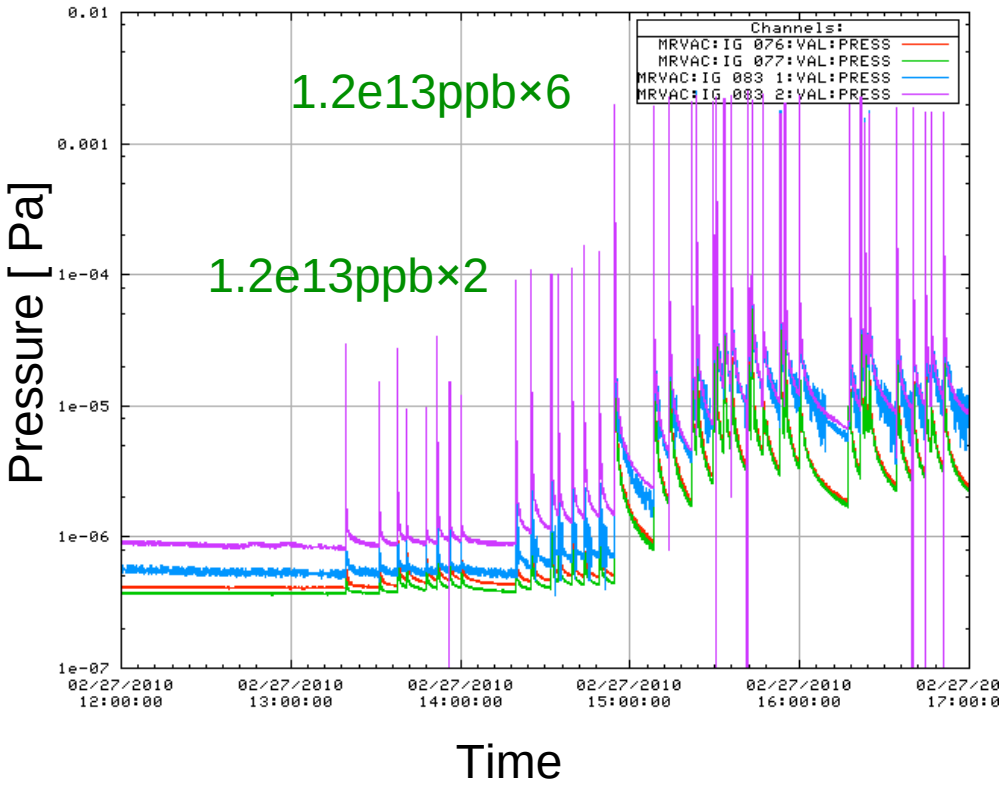
Ripple cancellation system

Thank you for your attention

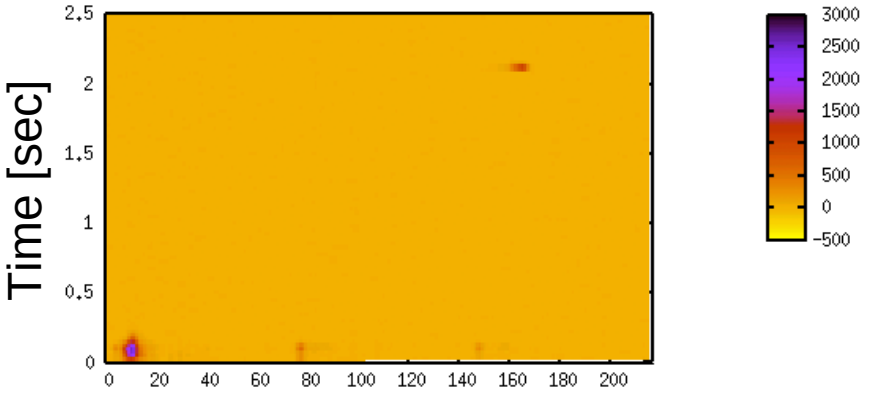
Backup slides

Correlation between pressure rise and beam loss

The most significant pressure rise is observed in the SX section.

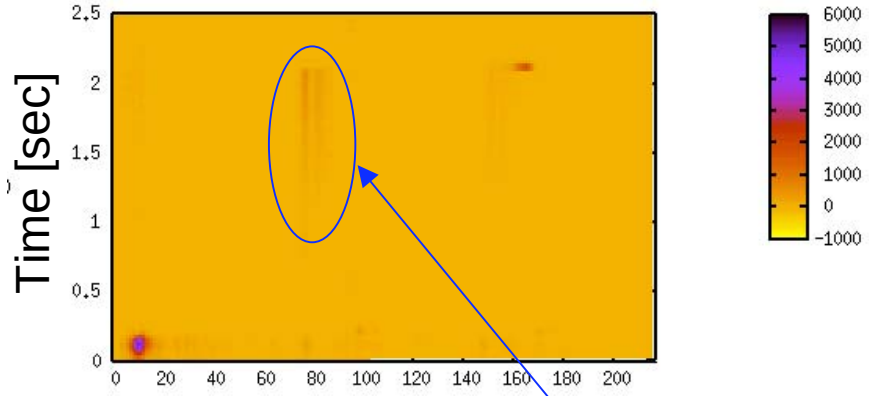


1.2e13ppb×2



No beam loss during acceleration

1.2e13ppb×6 (100 kW eq.)



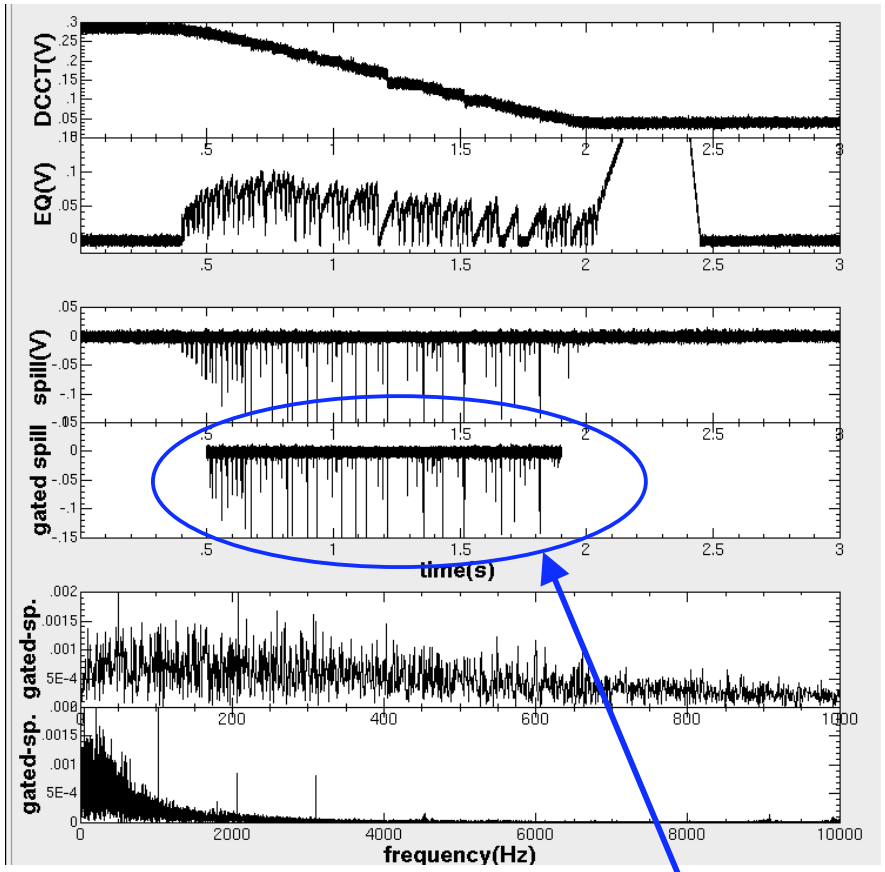
Beam loss at SX section

An expected loss from pressure of 1e-3 Pa:
~ 1e8 particles/sec (C equivalent)
Measured loss is ~1e9.

The cause of beam loss may be pressure rise.
-> Continuous operation may decrease the loss

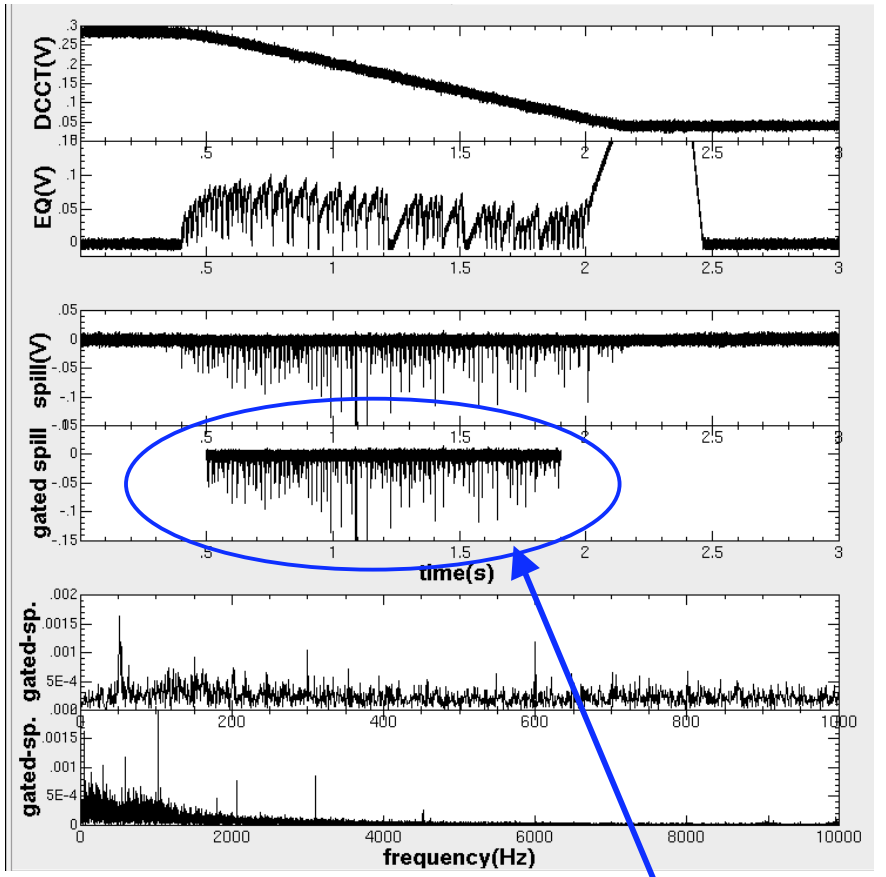
Extraction with the spill feedback system

With EQ



Duty ~ 3 %

With EQ/RQ

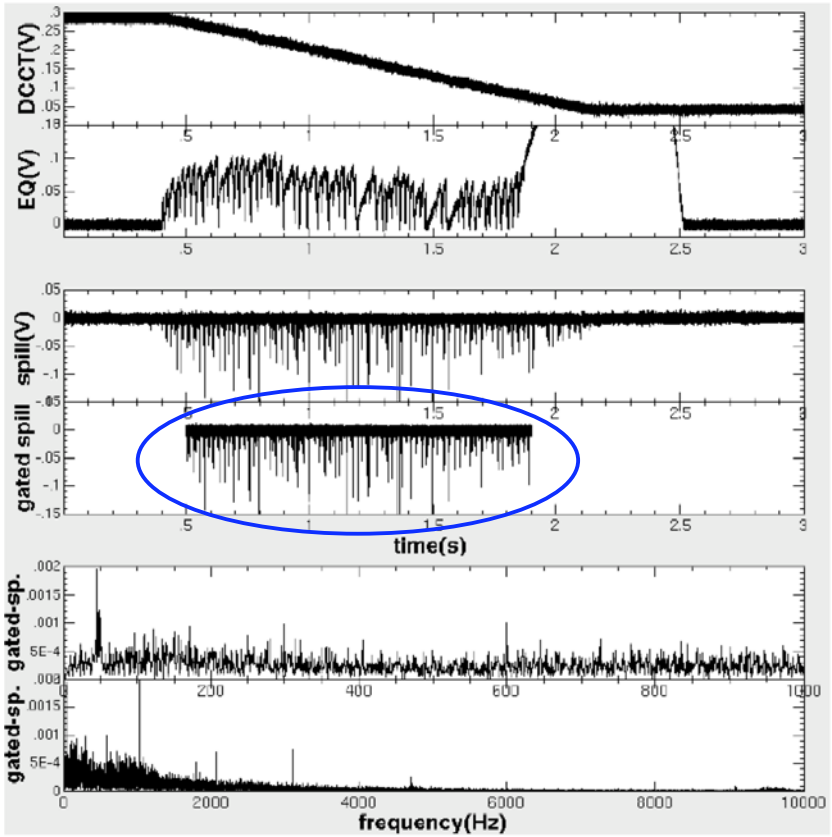


Duty ~ 6 %

Extraction with EQ/RQ + coil short

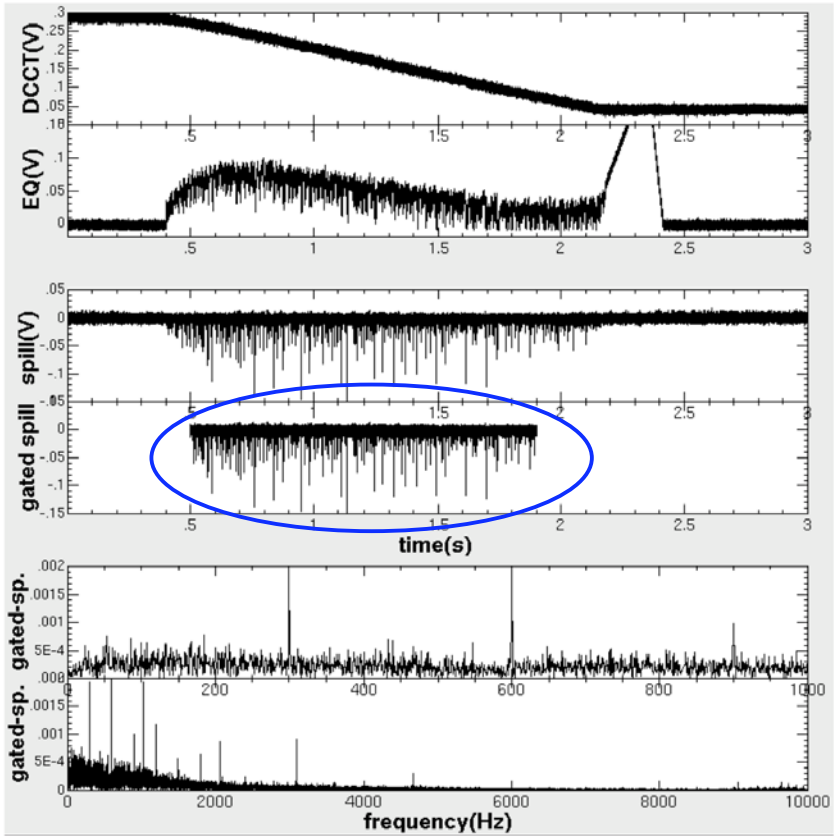
Trim coils of 117 quadrupoles of six families (QFN,QDN,QFX,QDX,QFR,QDR) are shorted at FT

Without coil short



Duty 6.6%

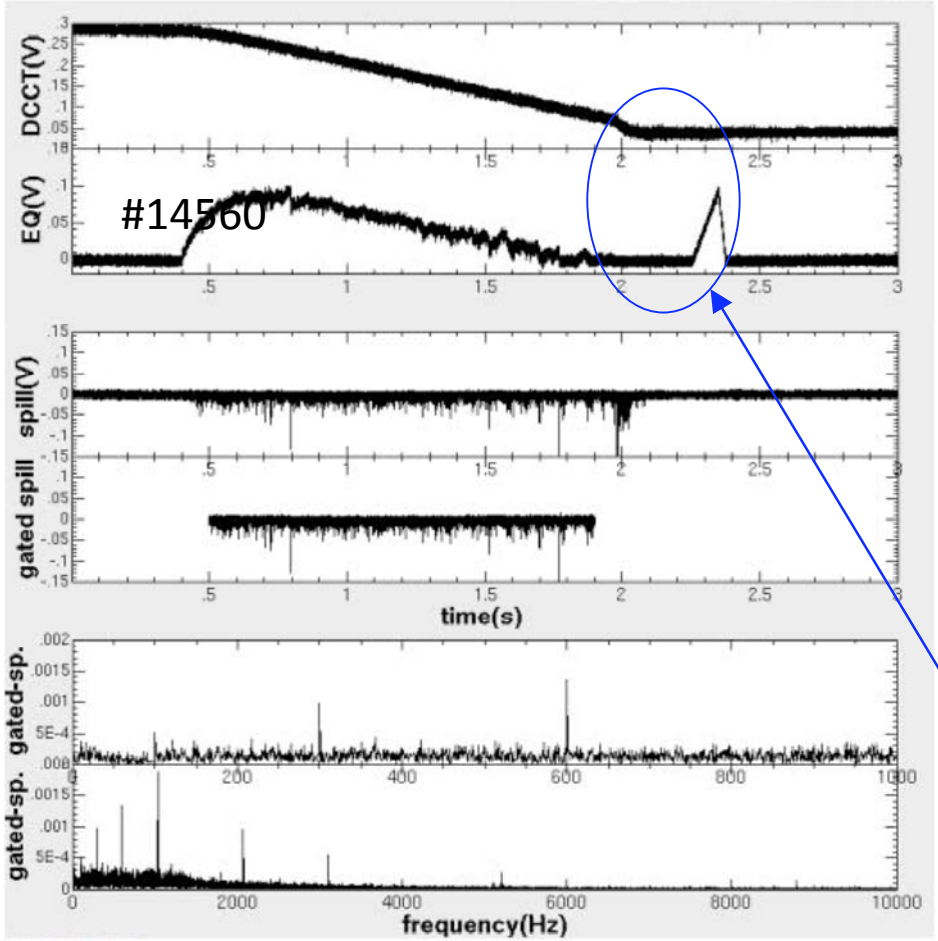
With coil short



Duty 8.4%

After additional tuning of EQ/RQ, the duty improved ~11 % with auxiliary coil short.

Extraction with EQ/RQ +Coil short + transverse RF noise



fc=5.033877MHz(h=26)
1kHz width
Full power (IkW)
EQ, RQ ON
EQ_A3: x10

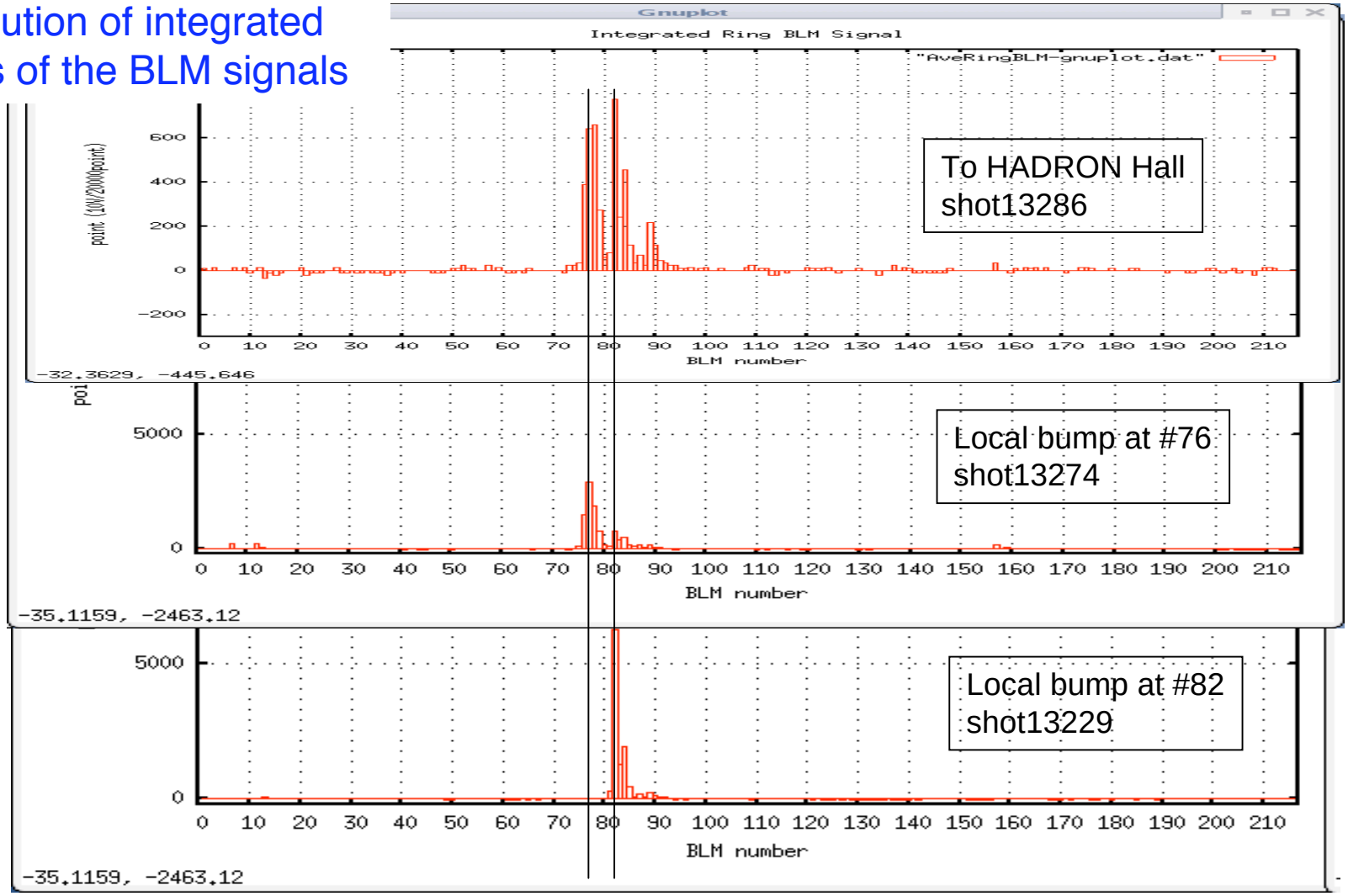
RF OFF duty 9% (#14532)
RF ON duty 15% (#14560)
(gate 0.5-1.9s)

When the RF noise switches on, the EQ feedback does not work in the spill end. Investigation of the reason and more tuning are necessary for the users RUN.

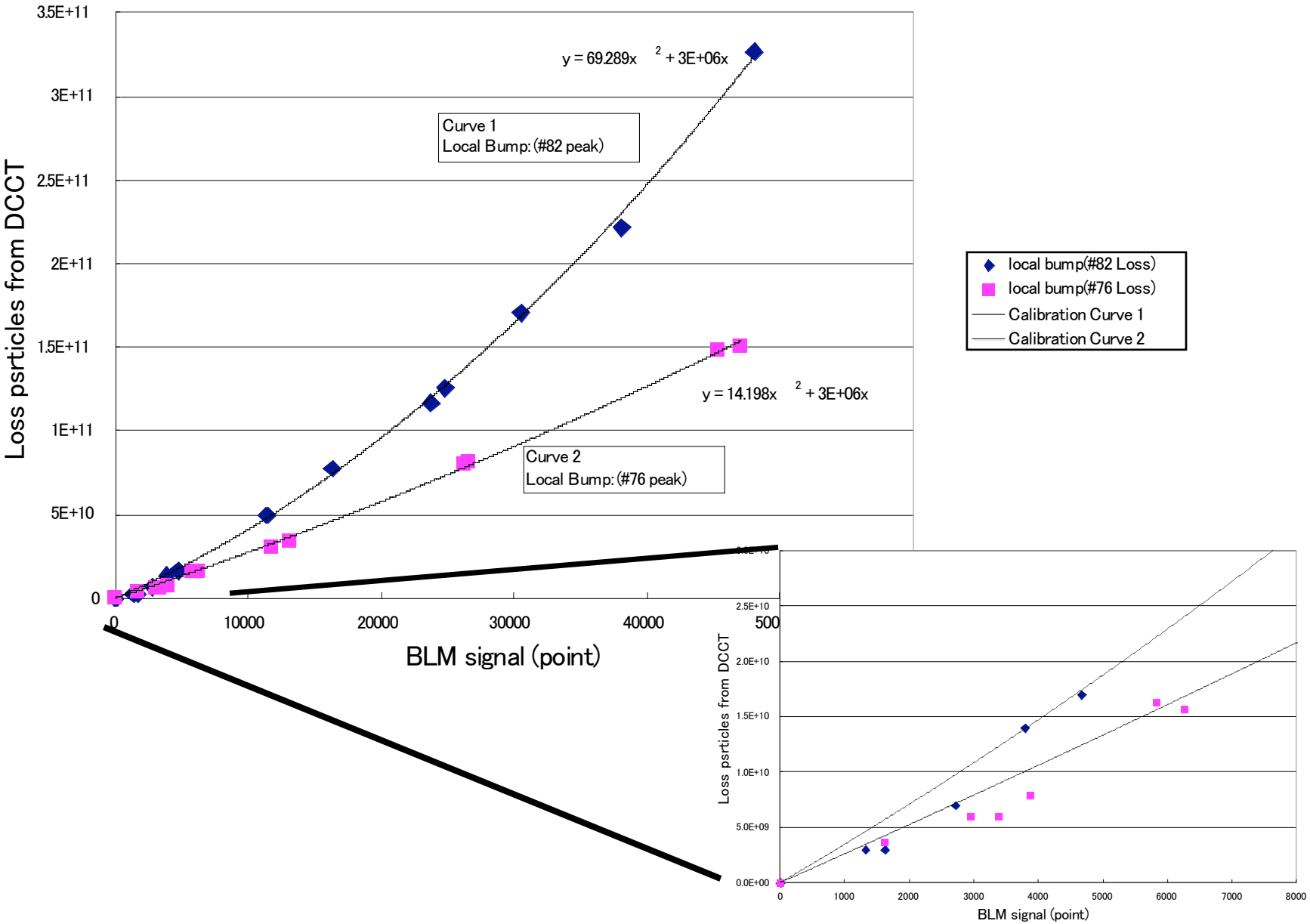
Calibration of BLMs

Beam loss distribution similar to the SX loss was made using steering magnets

Distribution of integrated counts of the BLM signals



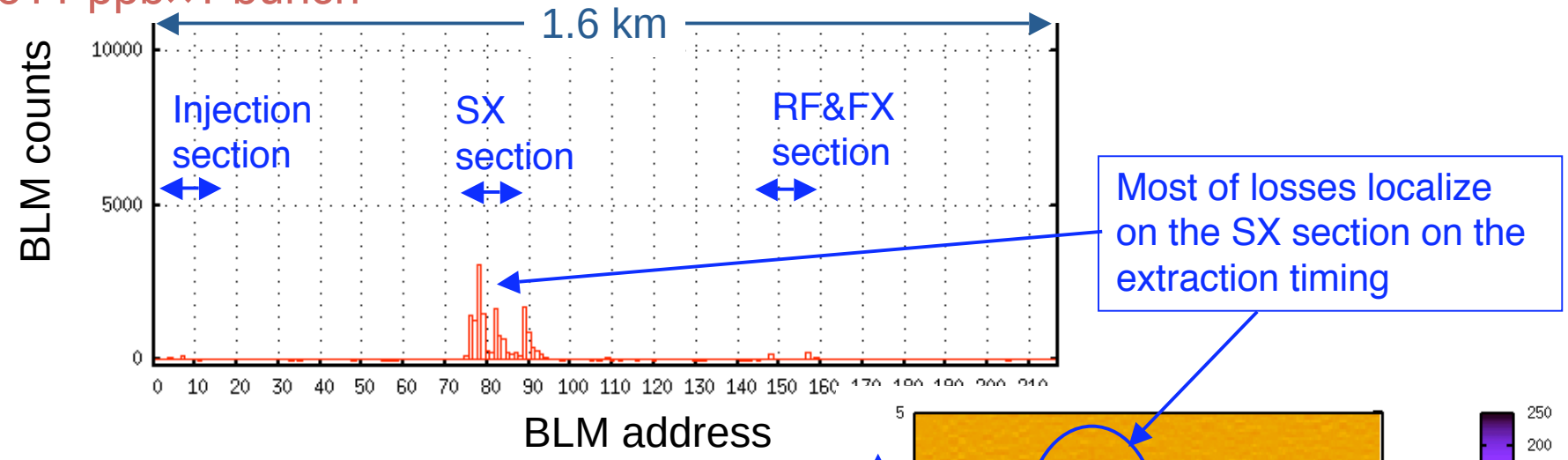
SX line BLM calibration (Bias=1.3kV)



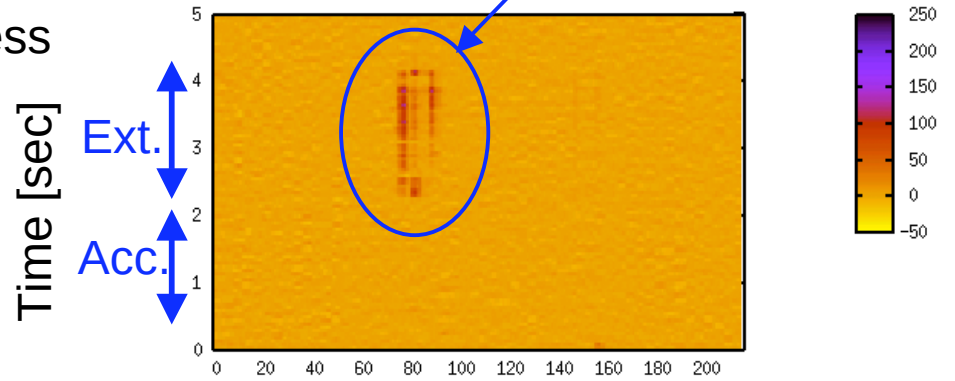
Beam loss and extraction efficiency

For high extraction efficiency:
- Bump orbit tuning
- Position adjusting of ESS's and Magnetic septa
- Tuning of resonant sextupole strength

4e11 ppb×1 bunch



Most of losses localize on the SX section on the extraction timing



Estimated extraction efficiency from the BLM counts : ~ 98.5 %

It is consistent with the efficiency measured by SEC in HD beam line (~ 100 % with 10 % error)

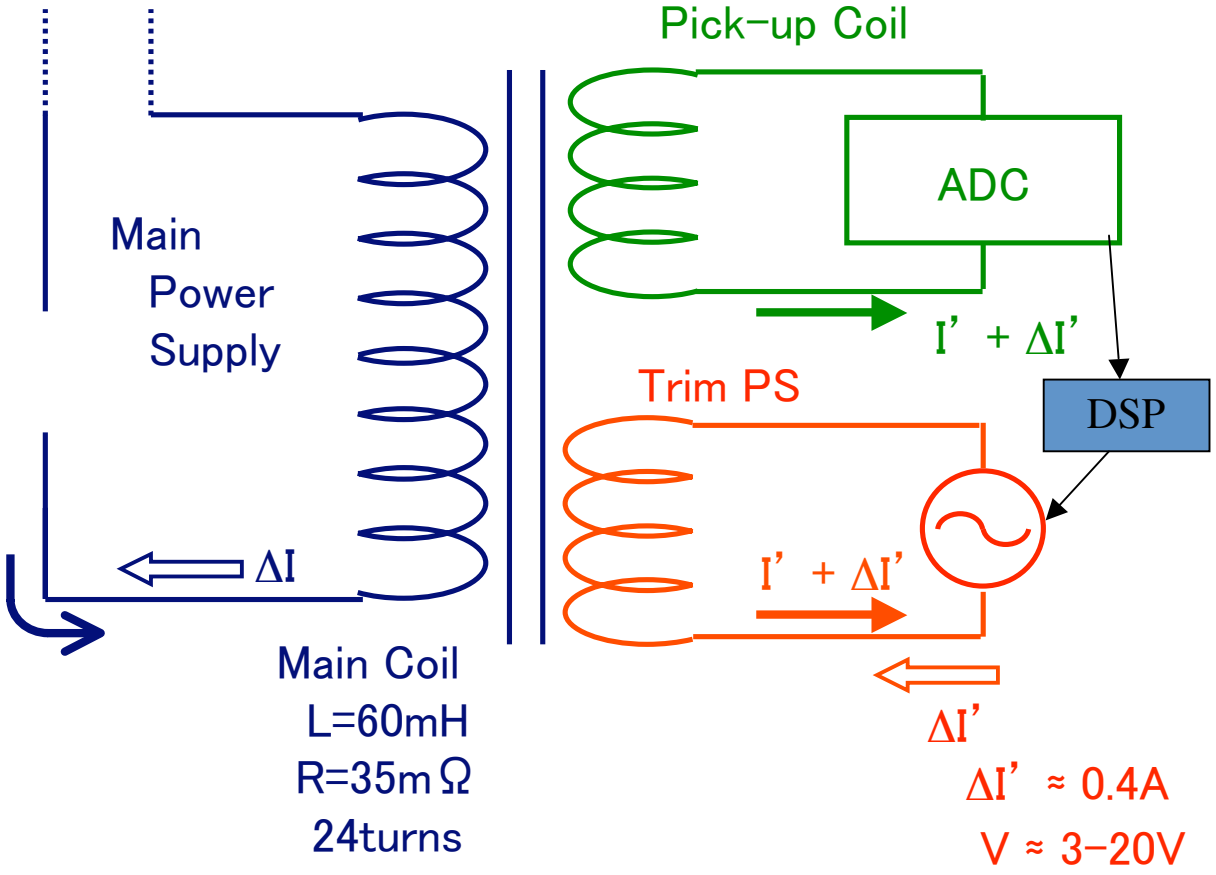
Ripple cancellation system

All the quadrupole magnets have trim coils.

An additional pickup coils set on the magnet poles to measure the field ripple.

-> A DSP system gives the ripple cancellation signal to the trim coil.

Noise canceling headphones



Measure the ripple

↓

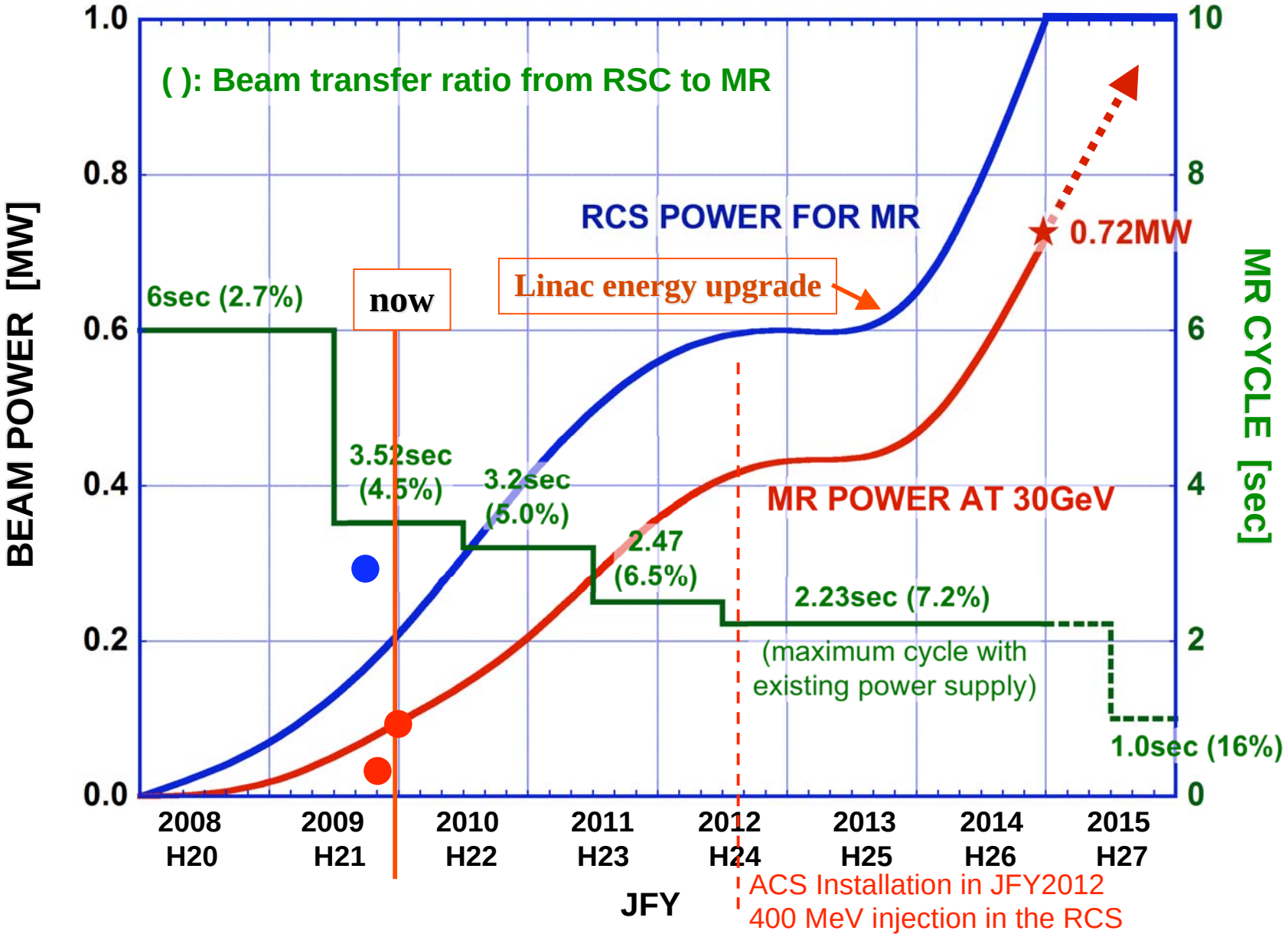
Feed-back/
Feed-forward

↓

Ripple cancellation
using Trim Coil

Power upgrade plan for the fast extraction

For 8 bunches, 30 GeV at MR: $P_{MR}=1.6 \times (P_{RCS}/T_{MR})$



Power upgrade plan of SX (under discussion)

Power and spill after the summer shutdown

	Beam intensity			Spill structure	
JFY	Key components	Users operation [kW]	Accelerator study [kW]	Key components	Duty [%]
2010	Dynamic bump	5	10	Feedback system Ripple canceller	15+α
2011	SX collimator	10	20	RQ Power supply	30
2012	Ti chambers Local shields	20	30		> 30
2013		30	> 30		
2014		> 30			