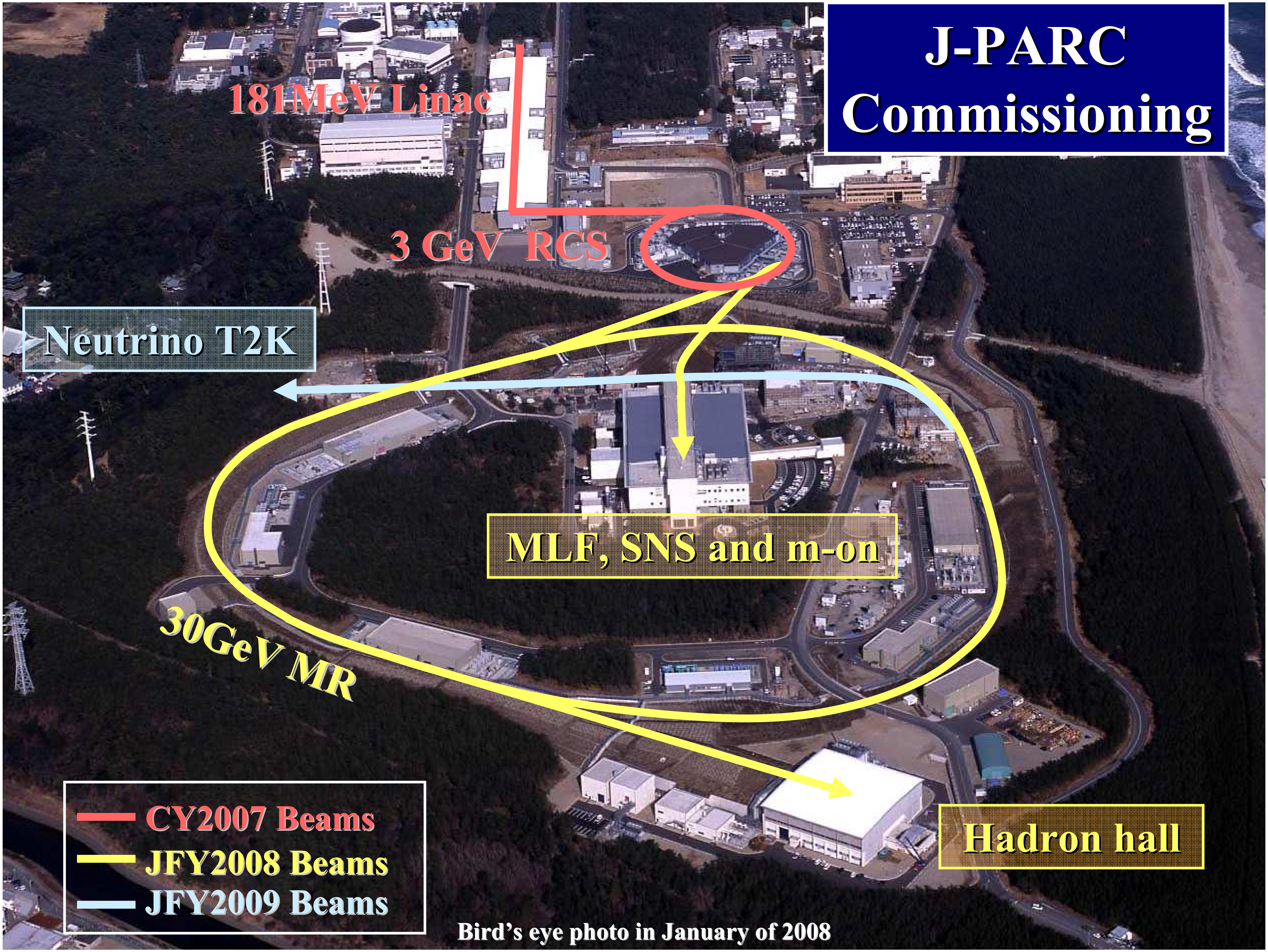
J-PARC Accelerator

Status and Plan

091020 Hitoshi Kobayashi (KEK)

- Introduction
- Linac
  - RFQ and 400MeV energy upgrade
- RCS
- MR
  - 1st step, achieve design performance (0.75MW)
  - 2nd step, KEK Roadmap (1.7MW)

J-PARC Commissioning



Bird's eye photo in January of 2008

RFQ ISSUE

No.1: 30mA-Operational RFQ: ***in operation***

Discharge problem limits power and availability

No.2: 30mA-Back-up RFQ: ***in fabrication***

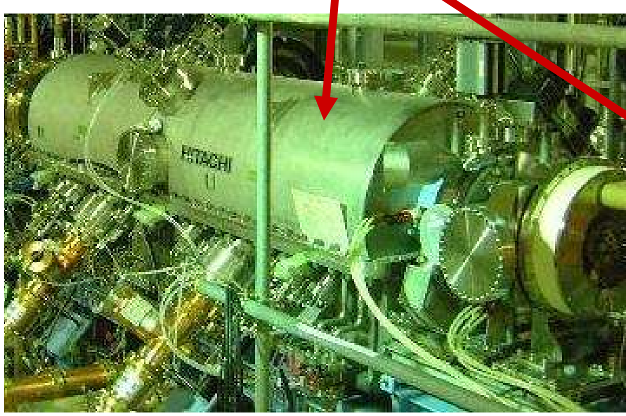
No.3: 50mA-Full spec. RFQ: ***in designing***

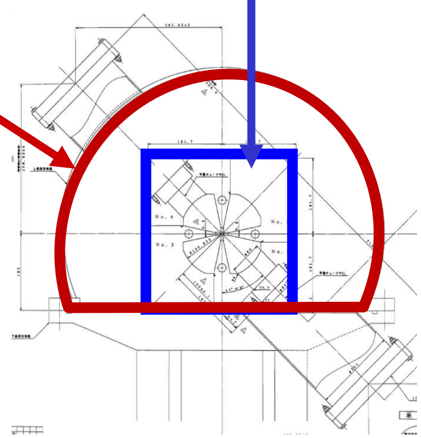
RFQ, in operation (No.1) , Back-up (No.2) and Final version (No.3)

	No.1, in operation	No.2, BACKUP	No.3, FINAL
CURRENT	30mA	30mA	50mA
RF STRUCTURE	IN-VACUUM	DIRECT	DIRECT

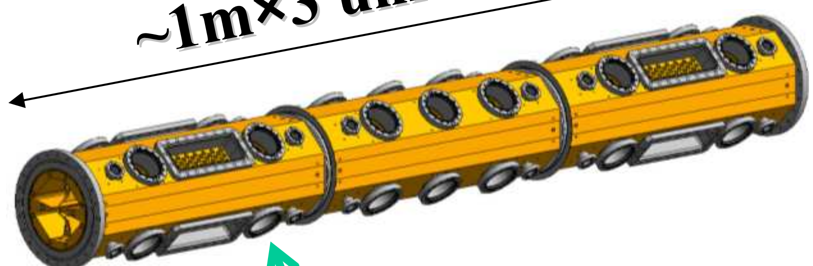
VACUUM VESSEL

RF STRUCTURE





~1m×3 unit = ~3m



Direct evacuation

RFQ discharge problem: Causes and Measures

Estimated causes → **Measures**

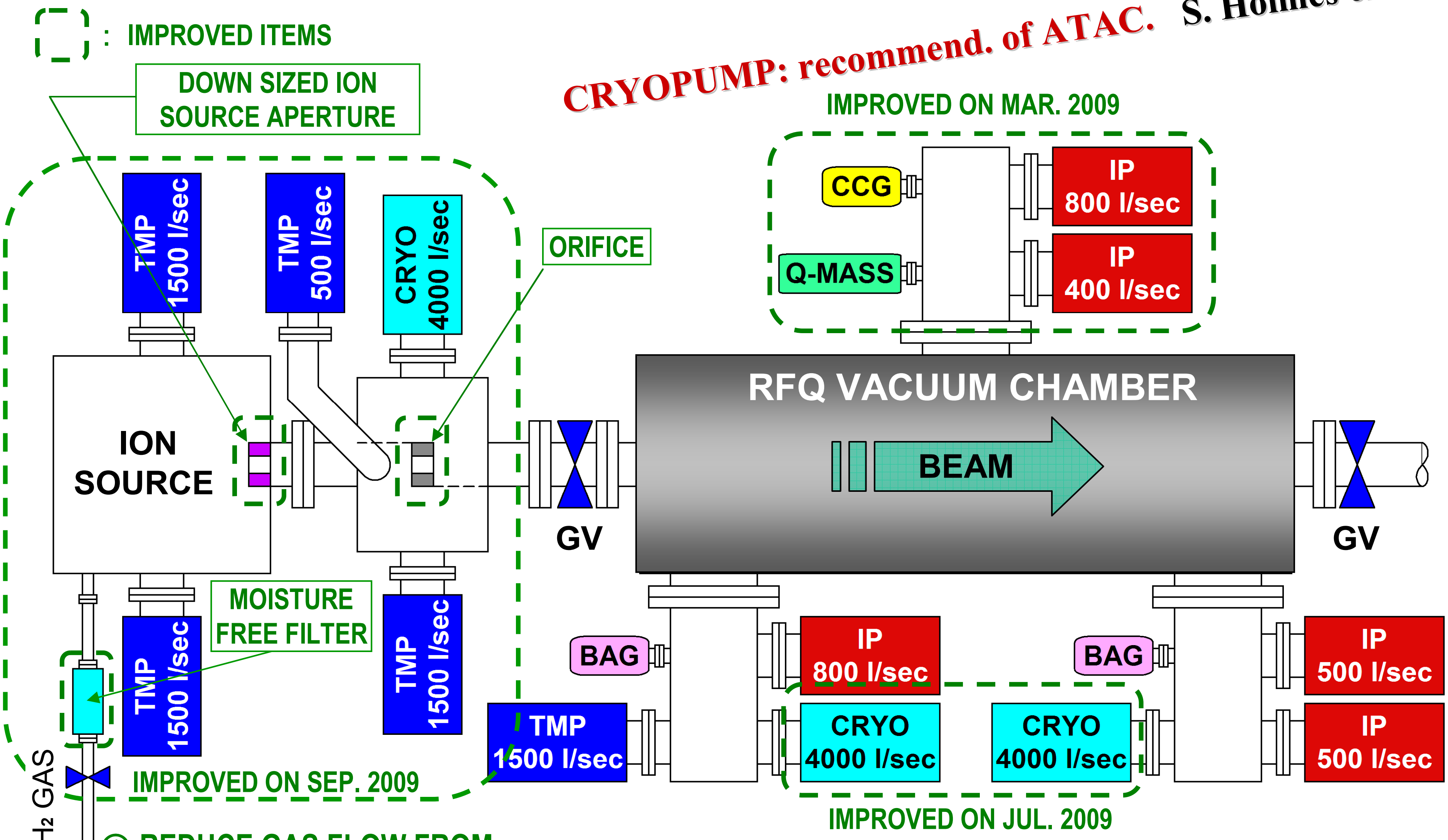
Damage during operation and conditioning →
- Improvement of interlock
- Suppression of not-necessary beams from the ion source
- Gentle conditioning

Poor vacuum properties: poor pressure and accumulation of impurities from LEBT →
- Addition of vacuum pumps, diagnostics
- Degassing by baking
- Oil free system

PUMP SPEED IMPROVEMENT AROUND RFQ

S. Holmes chair

CRYOPUMP: recommend. of ATAC.



① REDUCE GAS FLOW FROM. UPPER STREAM.

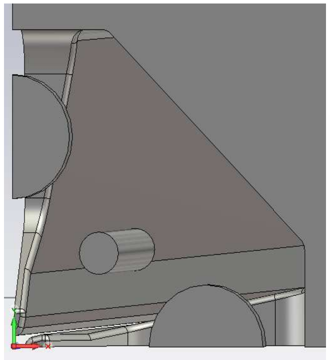
② ADOPT MOISTURE FREE FILTER.

③ OIL FREE ROUGH PUMP SYSTEM.

RFQ PUMP SPEED [l/sec] : 3,300 ➔ 12,500

Become stable ➔ 100kW start in Nov.

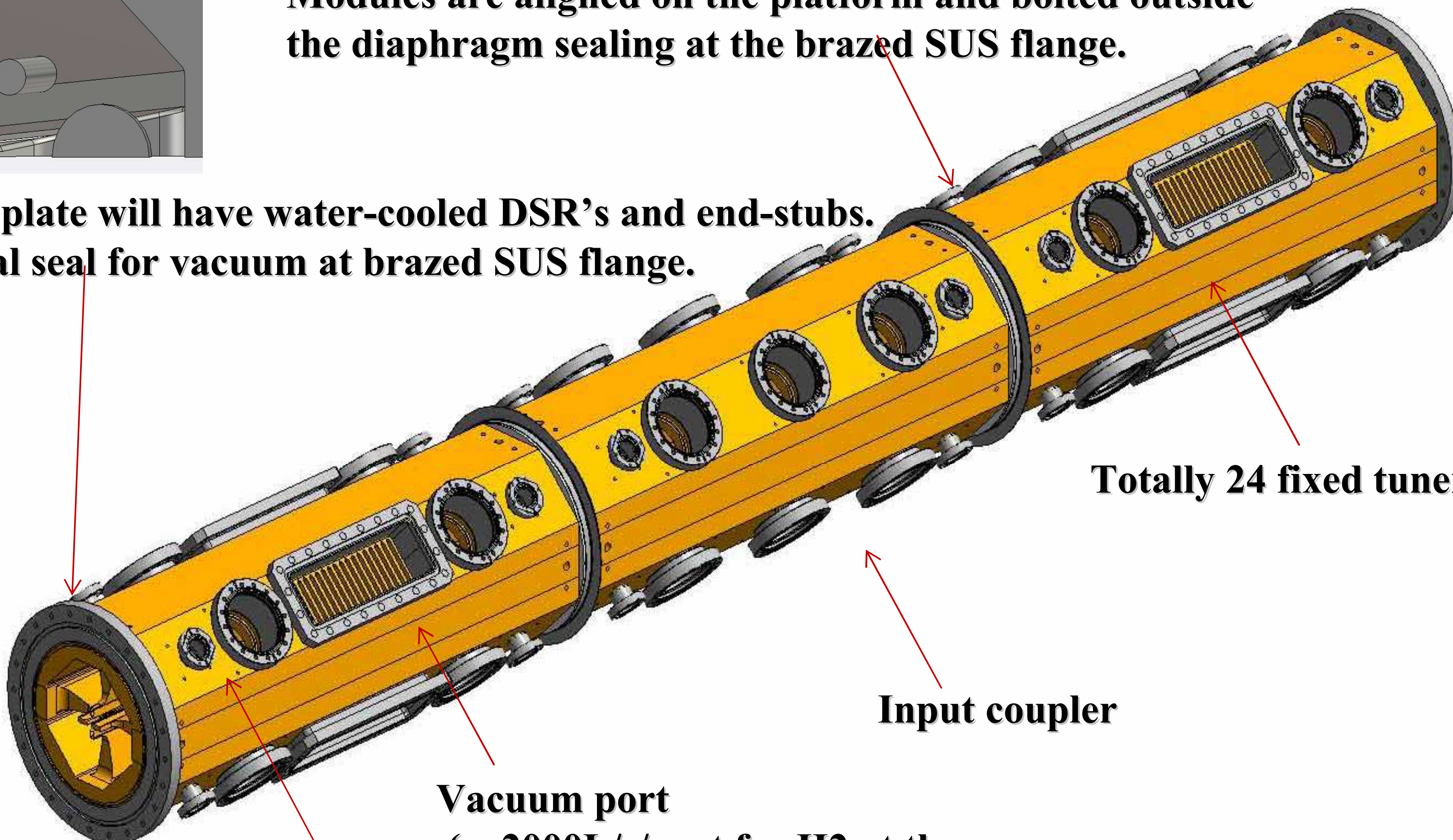
Overall layout of back-up RFQ



Total length: 3.2m, and 3 longitudinal modules are connected.

Modules are aligned on the platform and bolted outside the diaphragm sealing at the brazed SUS flange.

End plate will have water-cooled DSR's and end-stubs.
Metal seal for vacuum at brazed SUS flange.



Totally 24 fixed tuners

Input coupler

Vacuum port
(~2000L/s/port for H2 at the slit)

Monitor port

Design principle for BU-RFQ

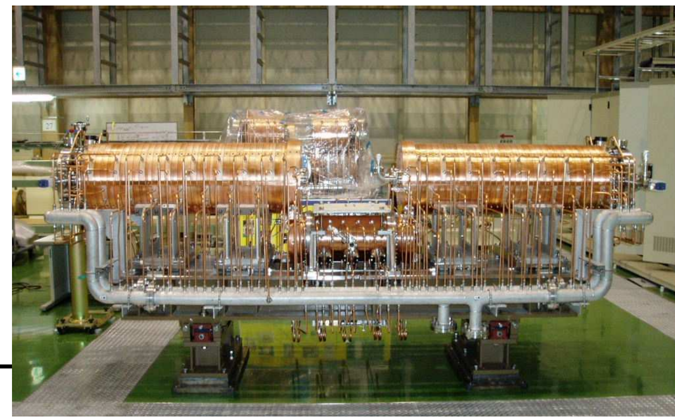
As well as the several measures for the operating RFQ, we are designing and constructing a backup RFQ. The concept is to achieve "stable operation".

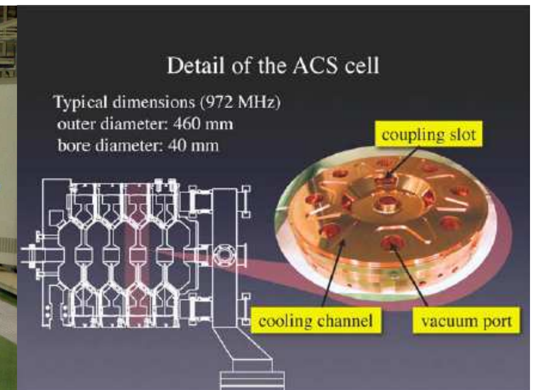
	Present RFQ	BU-RFQ	memo
Material	0.2% Ag doped oxygen-free copper	high-purity oxygen-free copper + HIP (Hot Isostatic Pressing)	Predominated in high field devices Removal of inner defect by HIP
Machining	2D machining with formed bite	NC machining with ball-end mill	Machining test is conducted.
Surface treatment	acid wash	CP or EP (TBD)	Smoothing surface to prevent from discharge
Joining method	Bolted with RF contactors in the vacuum chamber	Vanes and ports are joined in one step brazing	Unifying RF contact and vacuum sealing
Dipole suppressor	PISL's	Dipole Stabilization Rods (DSRs)	Simple structure and low surface electric field

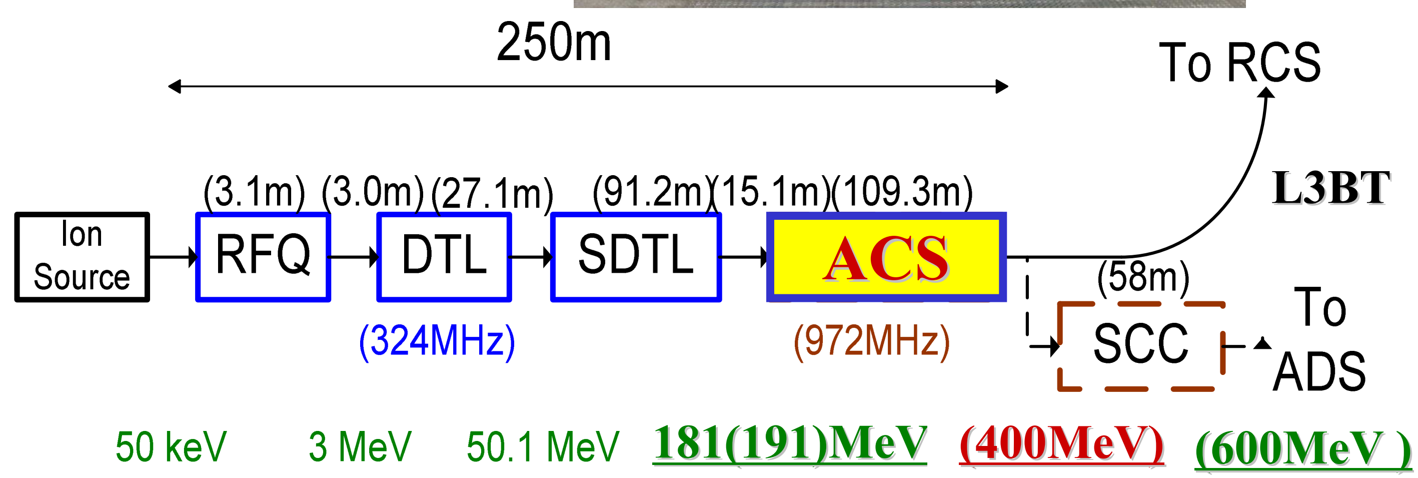
Energy upgrade of the Linac: 181 to 400 MeV

- The current linac energy 181 MeV limits RCS power <600kW
- RCS 400 MeV injection is the necessary condition to achieve RCS 1MW- and MR 750 kW-operation
- The budget for 400 MeV energy upgrade was funded (2008~2011)
- The mass production of ACS (annular coupled structure) for high-β section is well underway

Energy	190.8-400	MeV
Frequency	972	MHz
Section Length	108.3	m
E0	4.1	MV/m
RF pulse width	0.6	ms
Duty factor	3	% max
Number of modules	21	Acceleration
	2	Bunchers
	2	Debunchers

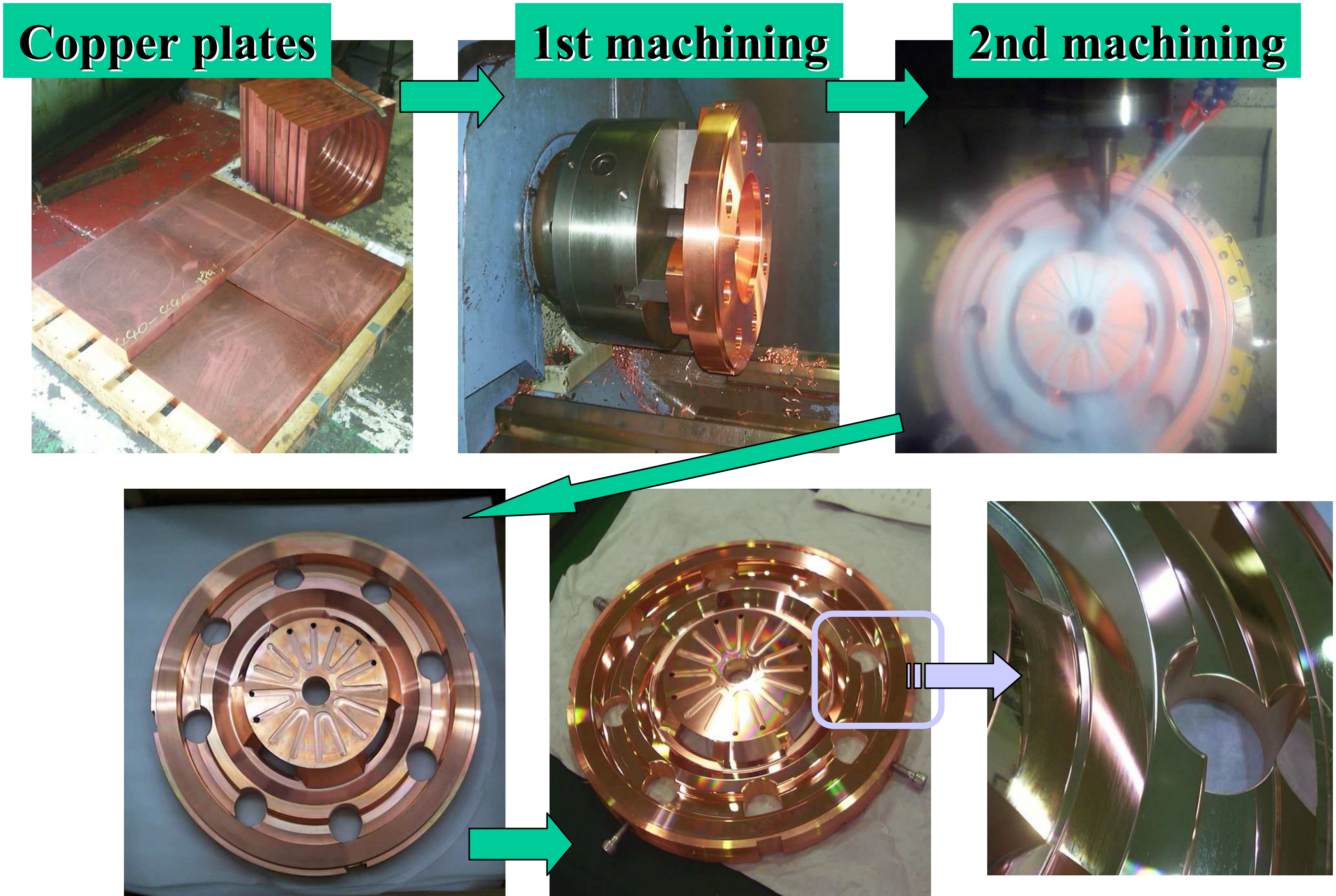




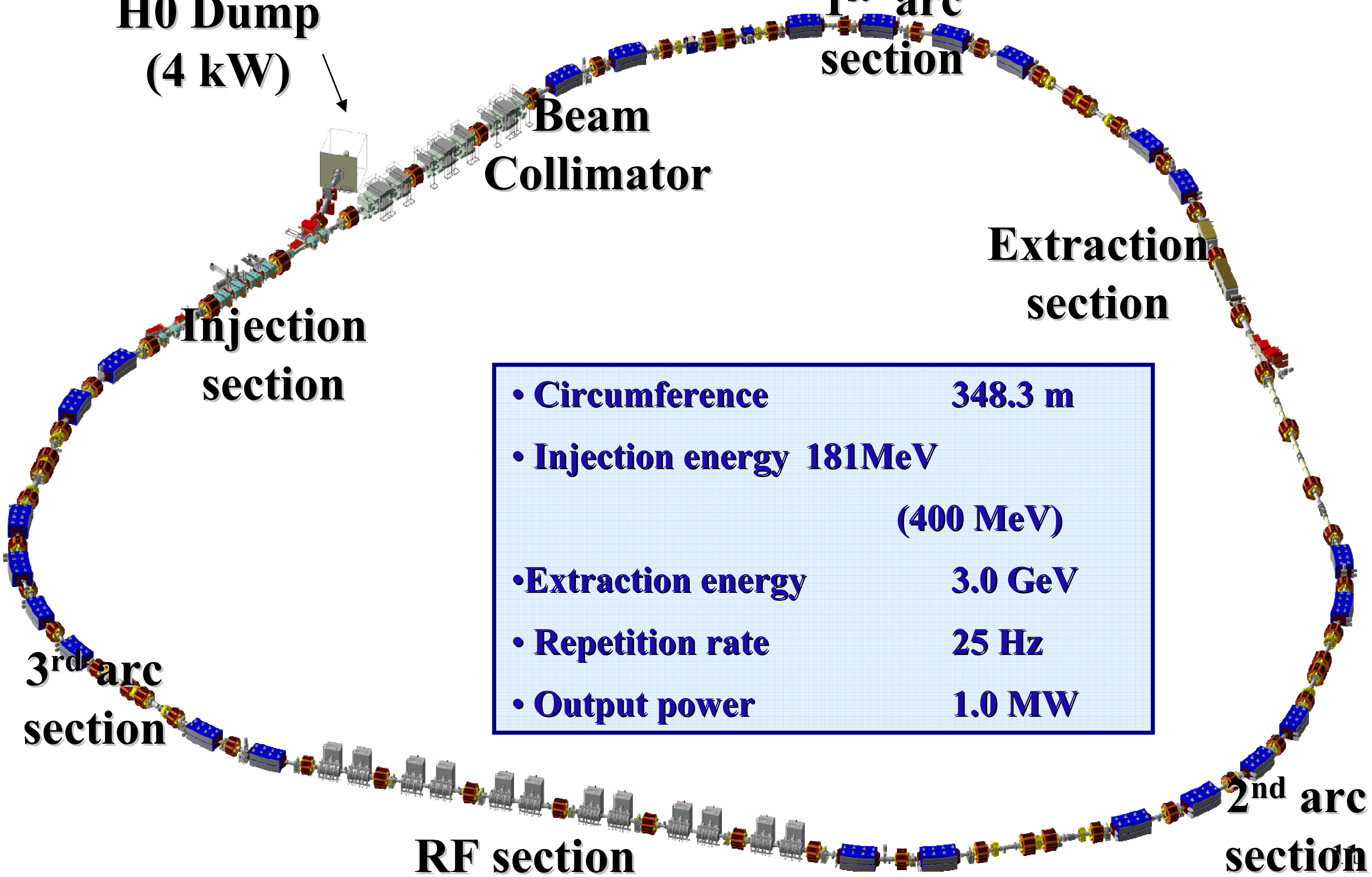


Block Diagram of the Linac

Machining of ACS disks



RCS

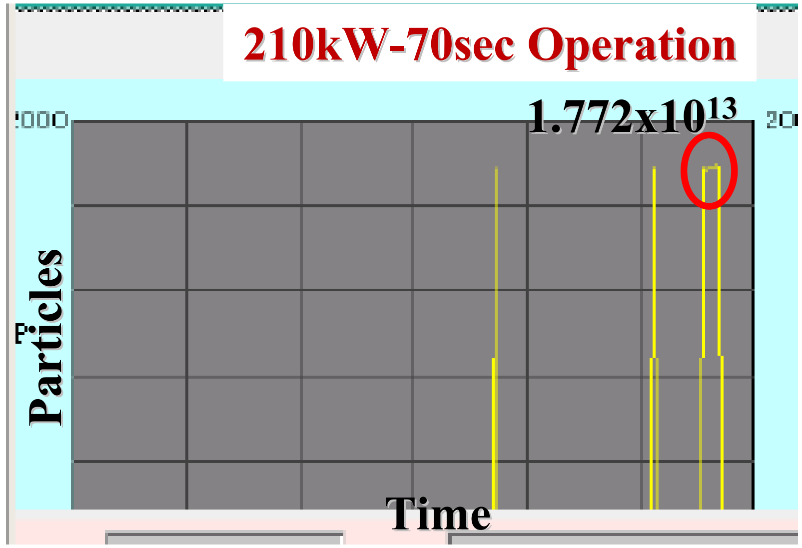


- Circumference 348.3 m
- Injection energy 181MeV (400 MeV)
- Extraction energy 3.0 GeV
- Repetition rate 25 Hz
- Output power 1.0 MW

RCS Status

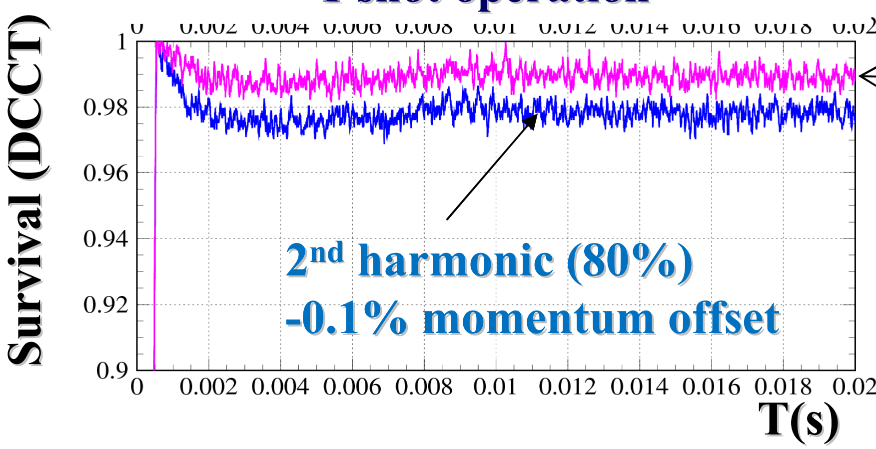
- First beam → Oct. 2007
- High intensity demonstrations Sep.-Dec. 2008
  - ❑ 210kW-70 sec
    (Limit with beam dump capacity)
  - ❑ 310kW- 1 shot Operation
  - ❑ 100kW-1 h Operation for MLF
- Since 2008/12/23 : User Operation (20kW)
  (Limit with RFQ performance)

210kW-70sec Operation



3NBT Current Monitor Signal

1 shot operation



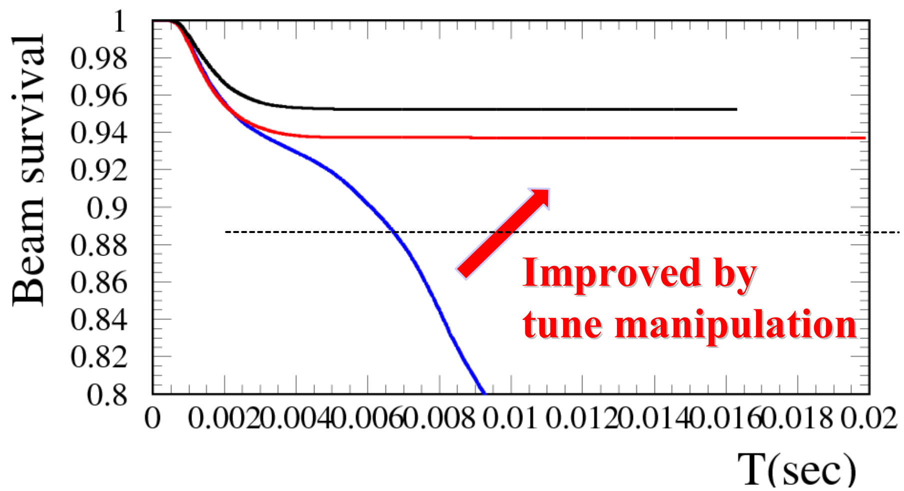
2nd harmonic (80%)
-0.1% momentum offset
Phase sweep -80 to 0 deg

**2.58 x 10^{13} ppp
(310 kW eq.)
at extraction**

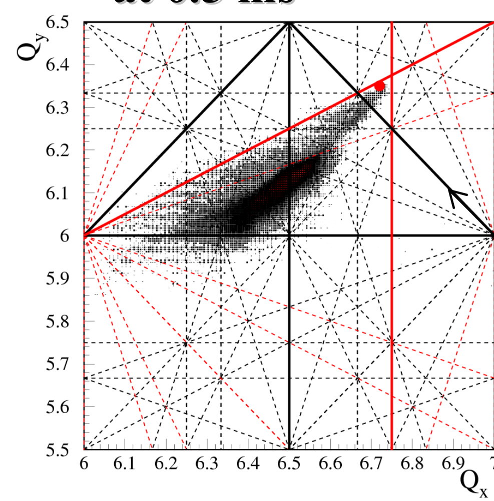
This demonstration is very important progress to realize 1MW for RCS !

Plan of Tune manipulation
to overcome space charge effect

RCS: 0.6 MW
LINAC:
Peak: 30 mA
Pulse width: 0.5 ms



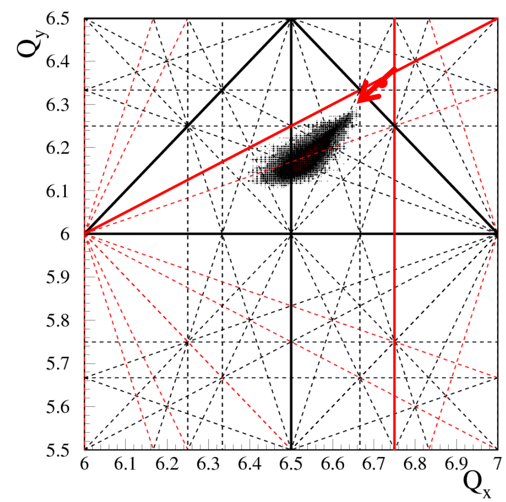
at 0.5 ms



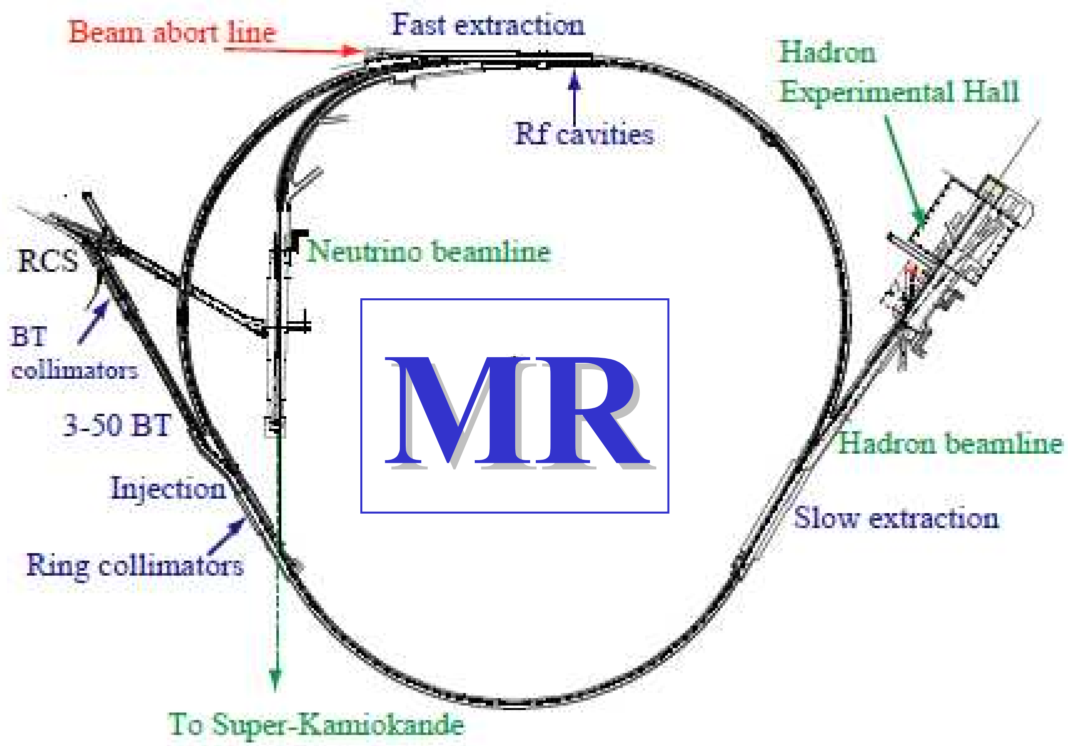
(6.35,6.72)

$Q_x+Q_y=13$ excited by large quadrupole rotation errors

at 8.0 ms



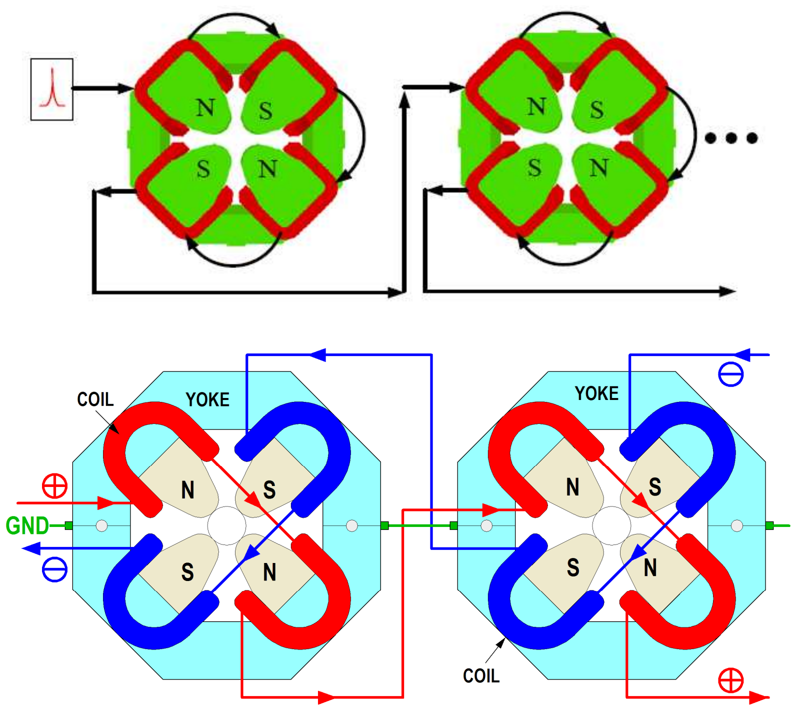
Circumference	1567.5 m
Repetition rate	~ 0.3 Hz
Injection energy	3 GeV
Extraction energy	30 GeV(1st phase)
	50 GeV (2nd phase)
Superperiodicity	3
h	9
Number of bunches	8
Rf frequency	1.67 - 1.72 MHz
Transition γ	j 31.7 (typical)
Number of dipoles	96
quadrupoles	216 (11 families)
sextupoles	72 (3 families)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

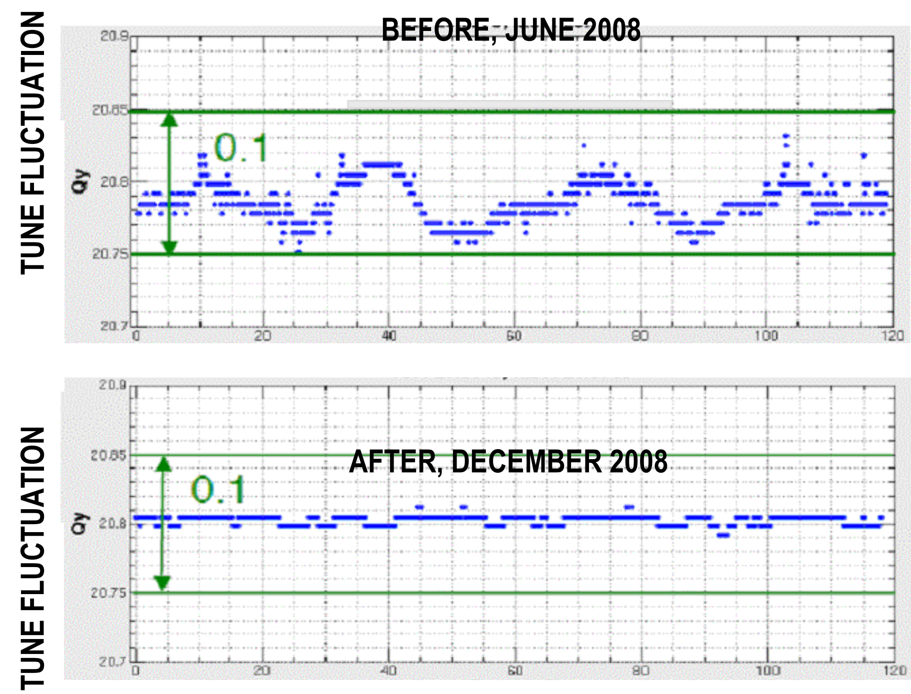


Three dispersion free straight sections of 116-m long:

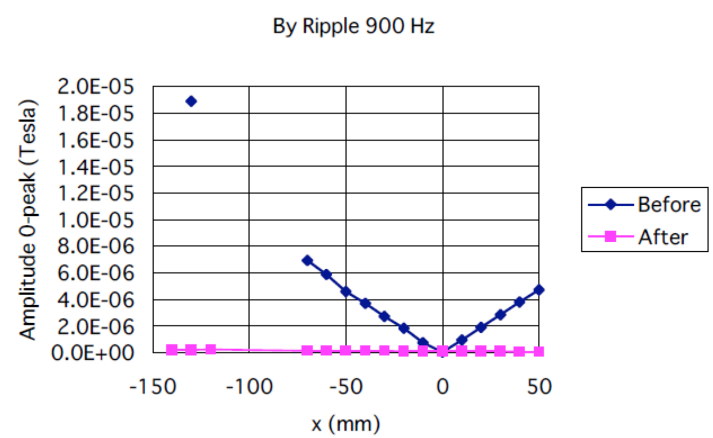
- Injection and collimator systems
- Slow extraction (SX) to Hadron experimental Hall
- MA loaded rf cavities and Fast extraction(FX) (beam is extracted inside/outside of the ring)
  - outside: Beam abort line
  - inside: Neutrino beamline (intense ν beam is send to SK)

Cabling Network improvements



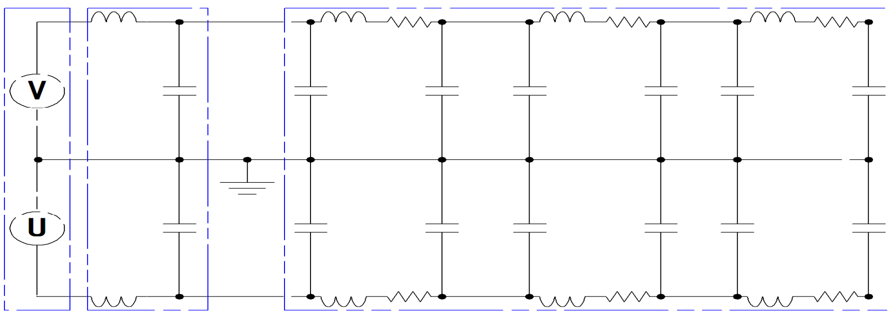


Symmetric configuration:
decouple normal and common mode
Same pole connection:
eliminate magnetic field by common mode



Magnet power supply issue; Symmetry 3 line wiring

Power supply **Network of magnet**



$$\begin{pmatrix} U_1+V_1 \\ I_1+J_1 \\ U_1-V_1 \\ I_1-J_1 \end{pmatrix} = \begin{pmatrix} b_{11} & b_{12} & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & b_{34} \\ 0 & 0 & b_{43} & b_{44} \end{pmatrix} \begin{pmatrix} U_2+V_2 \\ I_2+J_2 \\ U_2-V_2 \\ I_2-J_2 \end{pmatrix}$$

Symmetry:decouple
Common and Normal mode

J-PARC MR:

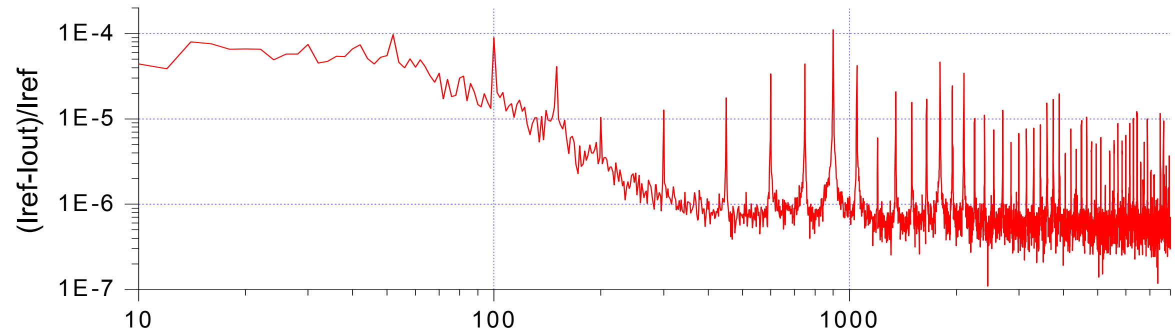
- ❑symmetrical 3-line wiring for Bend, Quad. Sext.
- ❑6-independent power supplies for bending magnet

Two papers by K. Sato and H. Toki

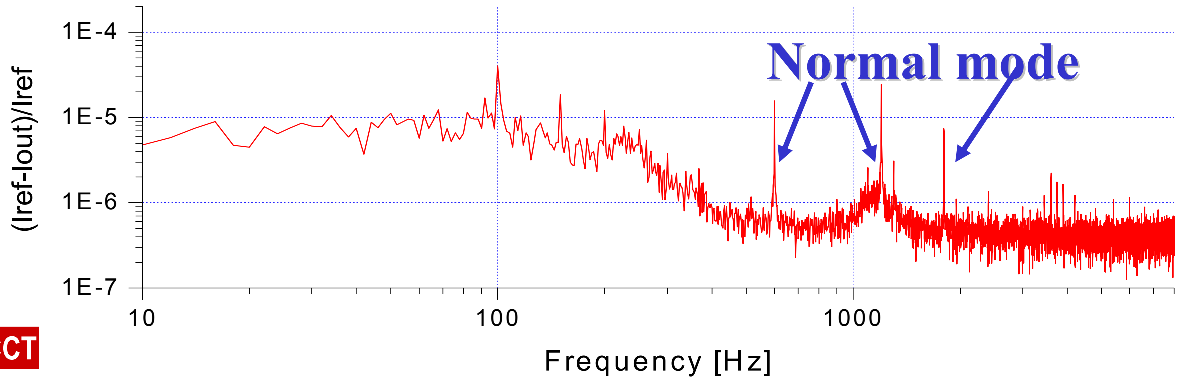
- ❑ Synchrotron magnet power supply network with normal and common modes including noise filtering NIM A565(2006) 351
- ❑Three conductor transmission line theory and the origin of electromagnetic radiation and noise JPSJ Vol.78 No.9(2009)

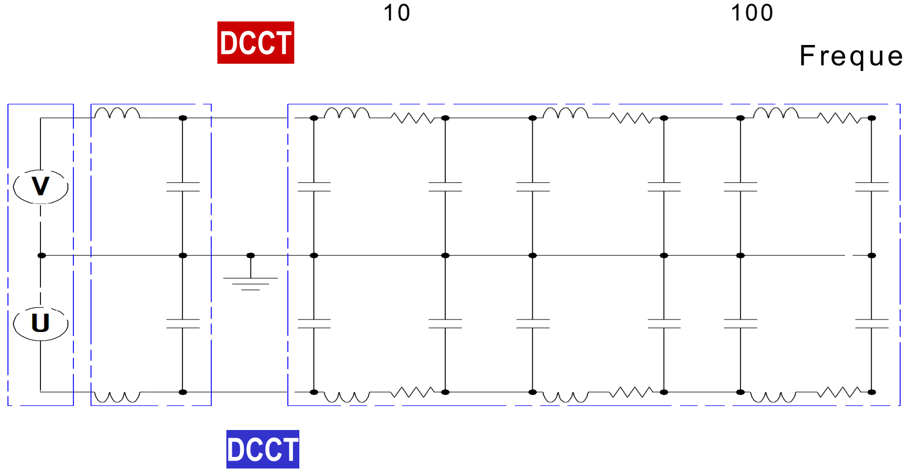
FFT of P-N current

Before symmetry (10/8)

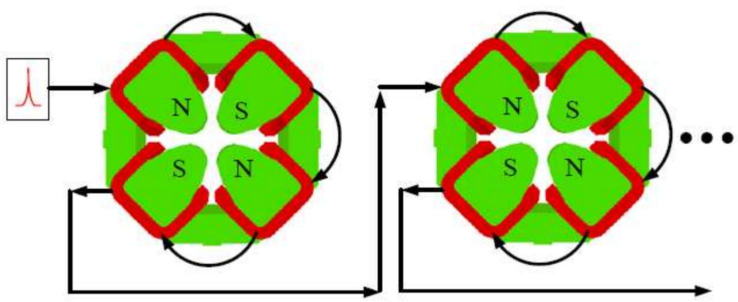


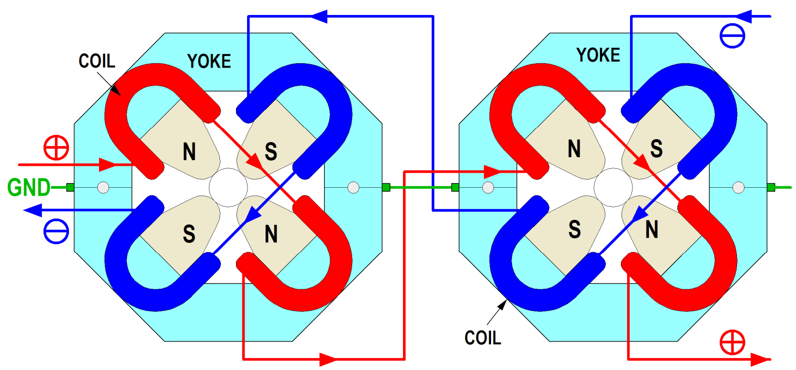
After symmetry (10/29)

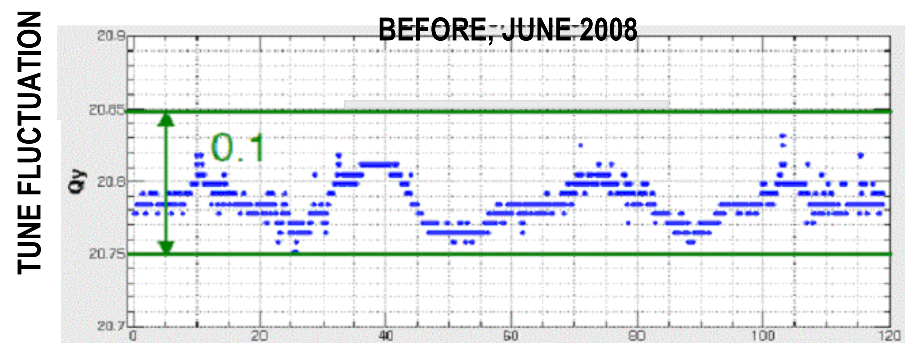


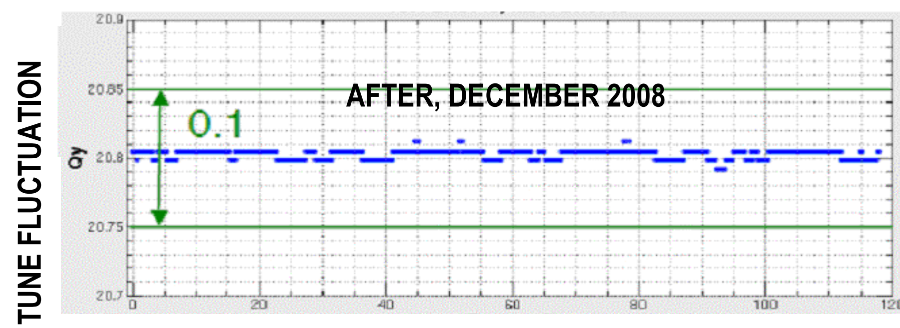


Cabling Network improvements

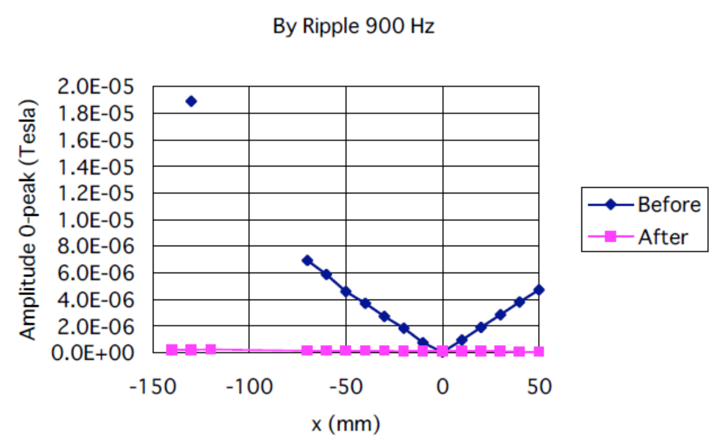




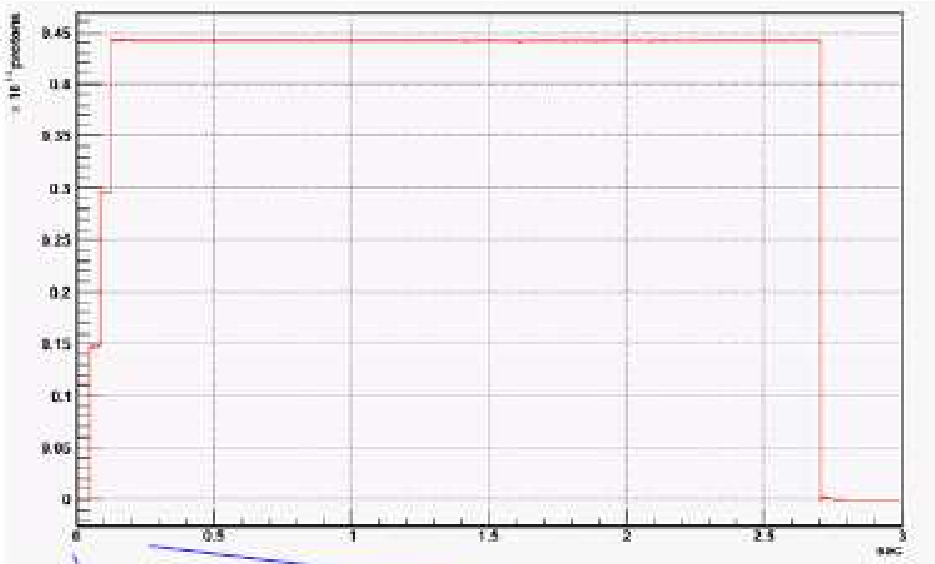




Symmetric configuration:
decouple normal and common mode
Same pole connection:
eliminate magnetic field by common mode



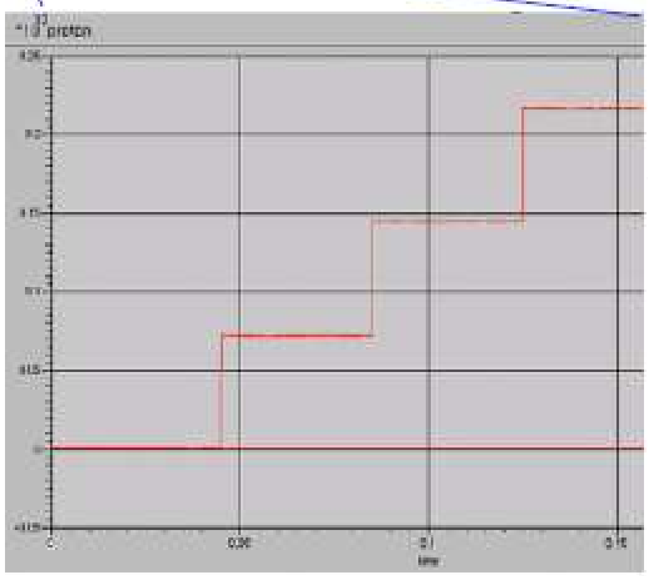
ACCELERATION with 6 bunches

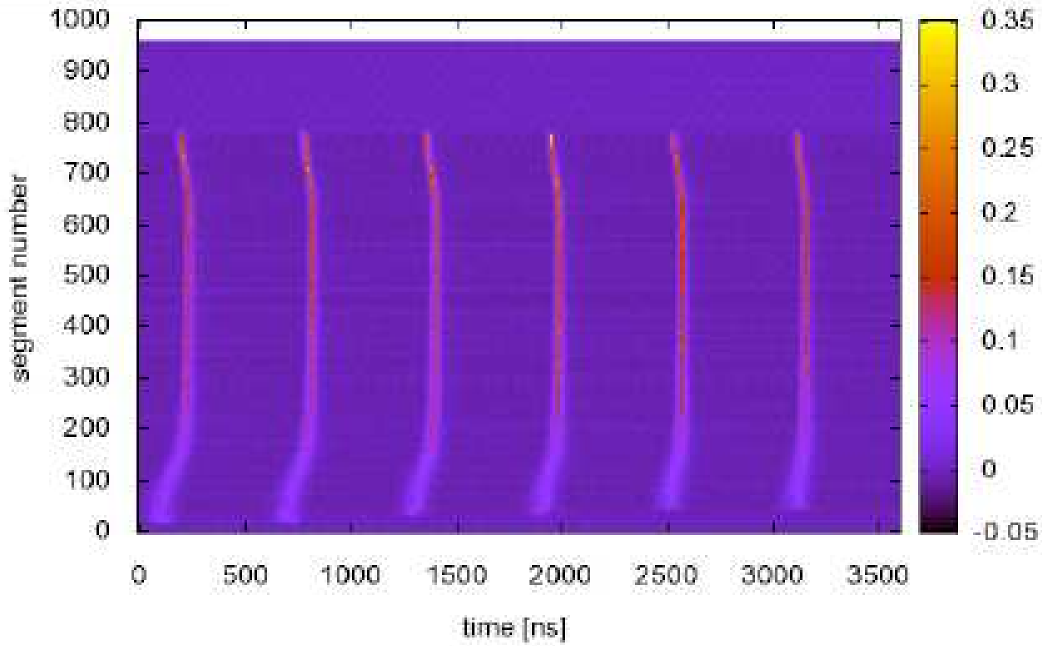


6 bunches, 4.4e12 ppp

3.5 kW (0.17 Hz operation)

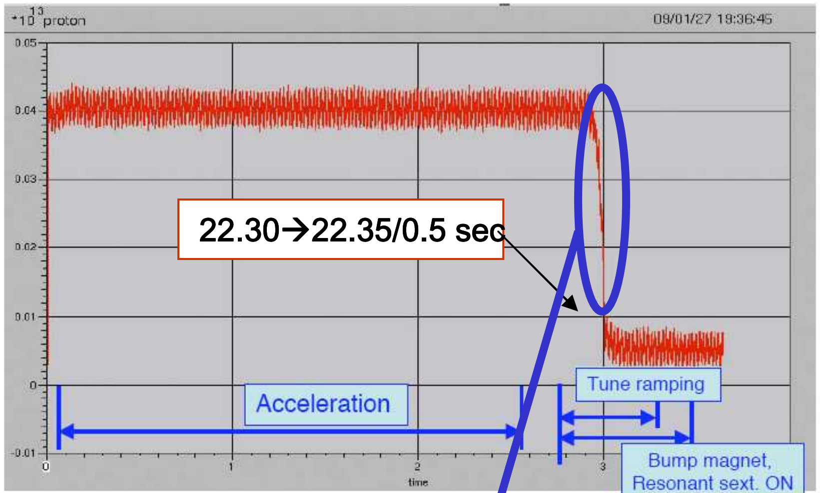
- ➢No transition energy
  - →Imaginary transition γ optics
- ➢Excellent repeatability
- ➢Low Q cavity
  - →Core of magnetic alloy
  - →Easy frequency modulation





Slow Beam Extraction to Hadron Facility

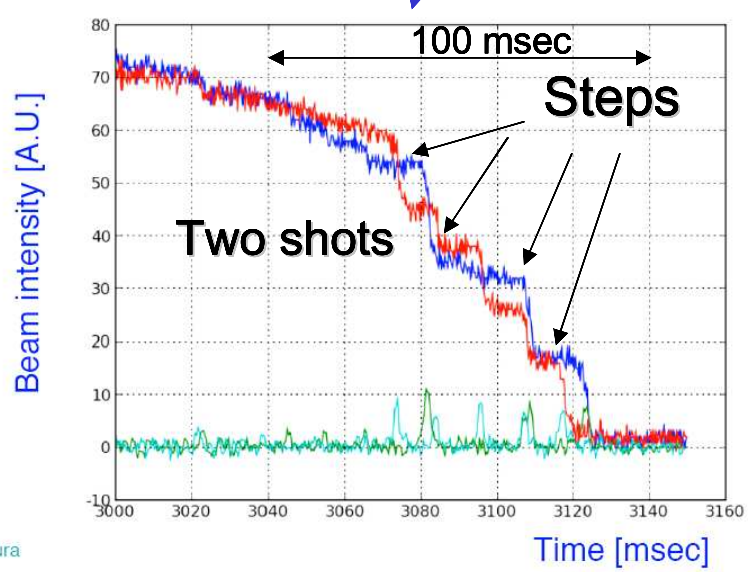
Jan. 27 2009



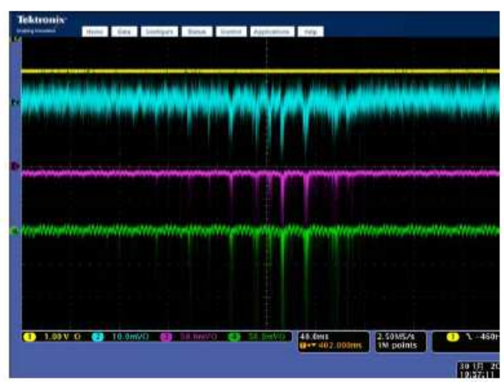
Need more study

- ❑Lower the ripple of Power supply
- ❑Feedback (EQ and RQ)
- ❑"BOSE" feedback

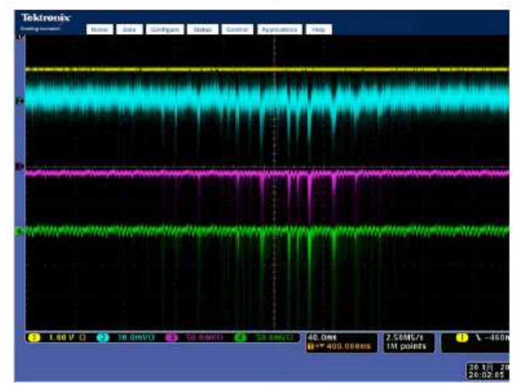
Beam intensity during extraction



RF off, ξ~0



RF off, ξ~-2

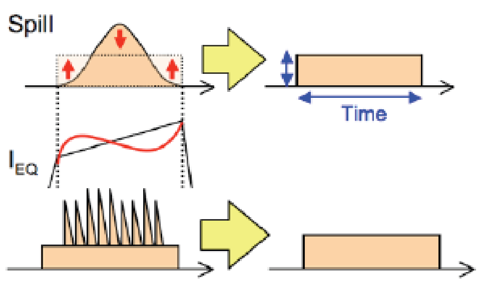


F. Tamura

FEED BACK for SLOW EXTRACTION

Beam Spill Structure

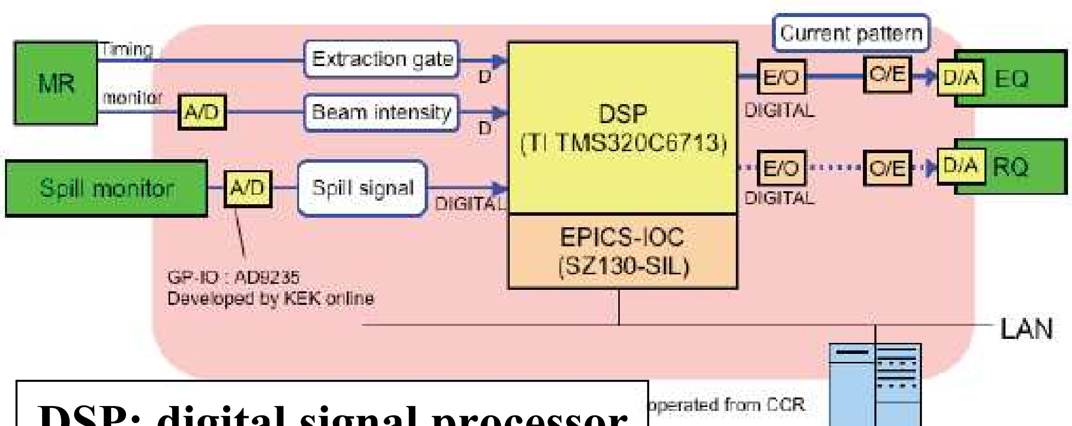
as uniform as possible to reduce multiplicity of secondary beam detection
- coasting beam
  - ---> RF voltage is turned off (rf cavity gap is shorted)
- Longer extraction time (0.2s->2s)
  - ---> longer flat top time and ramping tune slowly
- spill feedback system
  - ---> EQ: shape spill
  - ---> RQ: compensate ripple
  - they will be implemented by next slow extraction run



EQ: Extraction Q ~300Hz

RQ: Ripple compensation Q ~10kHz

Beam Spill Control



DSP: digital signal processor

***"BOSE"* project: Challenge to apply active Cancellation of normal mode noise**

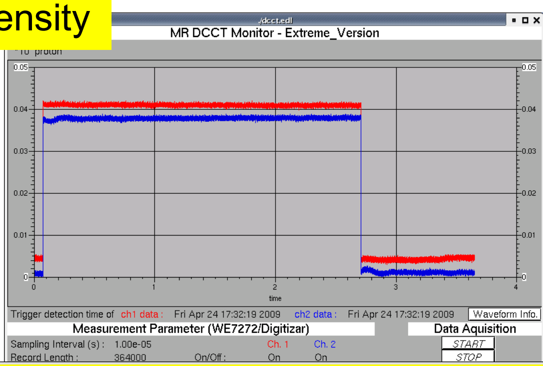
Noise canceling headphones

Fast Beam Extraction to T2K Beam Line

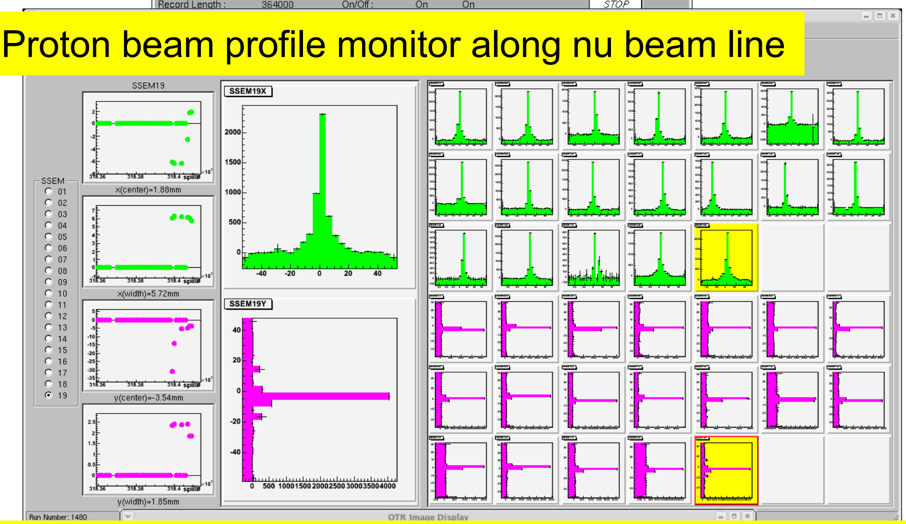
April 23 2009

After ~10 shots for tuning, proton beam hit around target center

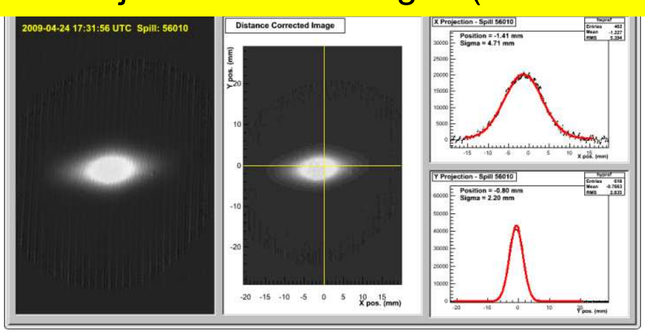
MR intensity



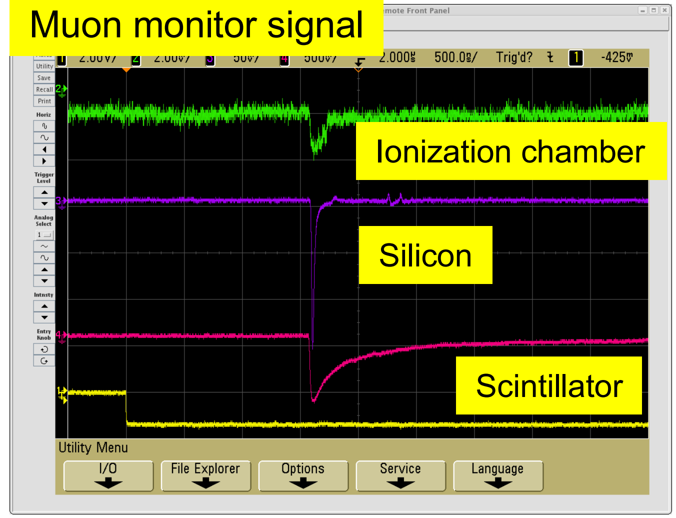
Proton beam profile monitor along nu beam line



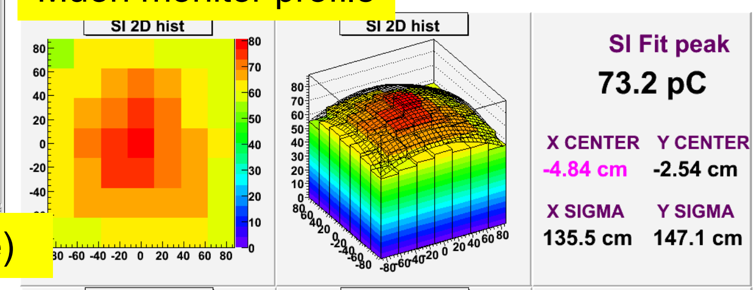
OTR detector just in front of target (fluorescence plate)



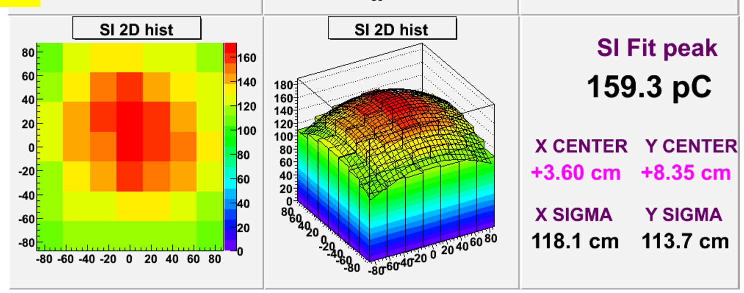
Muon monitor signal



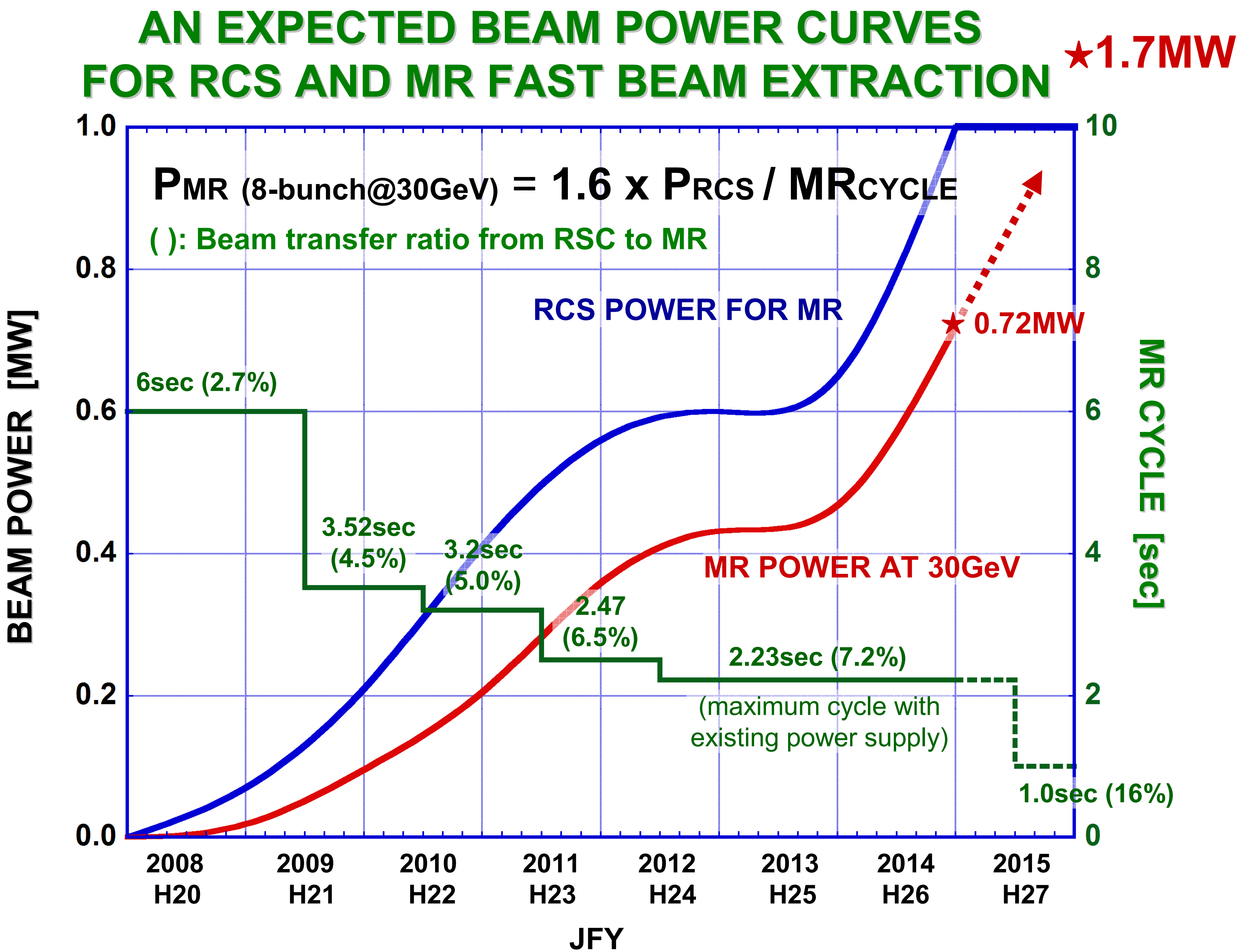
Muon monitor profile

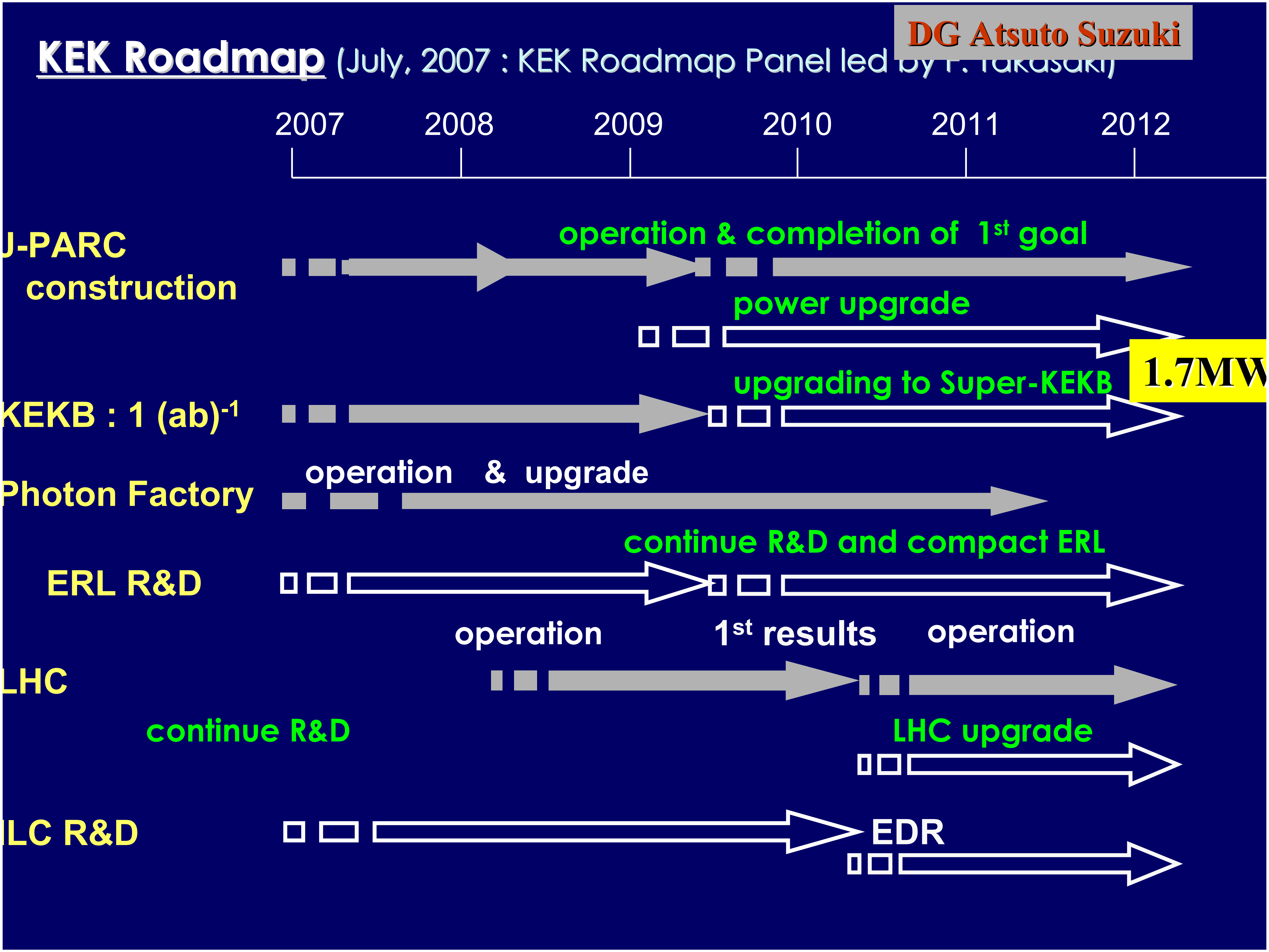


Horn Off



Horn 250kA


AN EXPECTED BEAM POWER CURVES
FOR RCS AND MR FAST BEAM EXTRACTION
★1.7MW
PMR (8-bunch@30GeV) = 1.6 x PRCS / MRCYCLE
( ): Beam transfer ratio from RSC to MR
RCS POWER FOR MR
★ 0.72MW
6sec (2.7%)
3.52sec
(4.5%)
3.2sec
(5.0%)
MR POWER AT 30GeV
2.47
(6.5%)
2.23sec (7.2%)
(maximum cycle with
existing power supply)
1.0sec (16%)
BEAM POWER [MW]
MR CYCLE [sec]
1.0
0.8
0.6
0.4
0.2
0.0
10
8
6
4
2
0
2008
H20
2009
H21
2010
H22
2011
H23
2012
H24
2013
H25
2014
H26
2015
H27
JFY



KEK Roadmap (July, 2007 : KEK Roadmap Panel led
DG Atsuto Suzuki
2007
2008
2009
2010
2011
2012
J-PARC construction
operation & completion of 1st goal
power upgrade
1.7MW
KEKB : 1 (ab)-1
upgrading to Super-KEKB
Photon Factory
operation & upgrade
ERL R&D
continue R&D and compact ERL
LHC
operation
1st results
operation
continue R&D
LHC upgrade
ILC R&D
EDR

Technology choice to achieve maximum beam power

- Beam energy is 30GeV instead of 50 GeV (original design)
- Compact, symmetric and standardized magnet power supply systen
- High gradient RF system

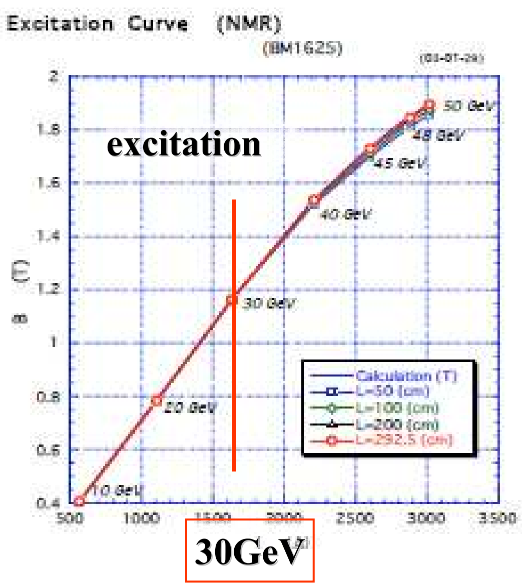
Fermilab Main Injector upgrade：PAC03

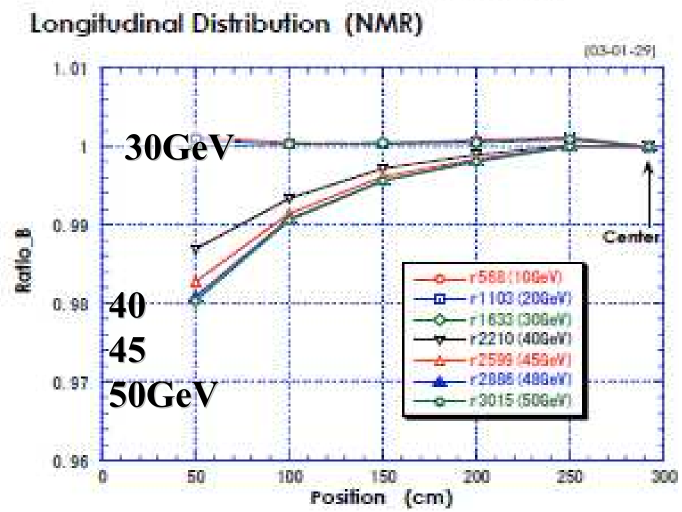
2 MW UPGRADE OF THE FERMILAB MAIN INJECTOR*

W. Chou# for the Proton Driver Study II Group, FNAL, Batavia, IL 60510, USA

Beam power does not depend on energy

(Beam energy) x (rep. Rate)=constant



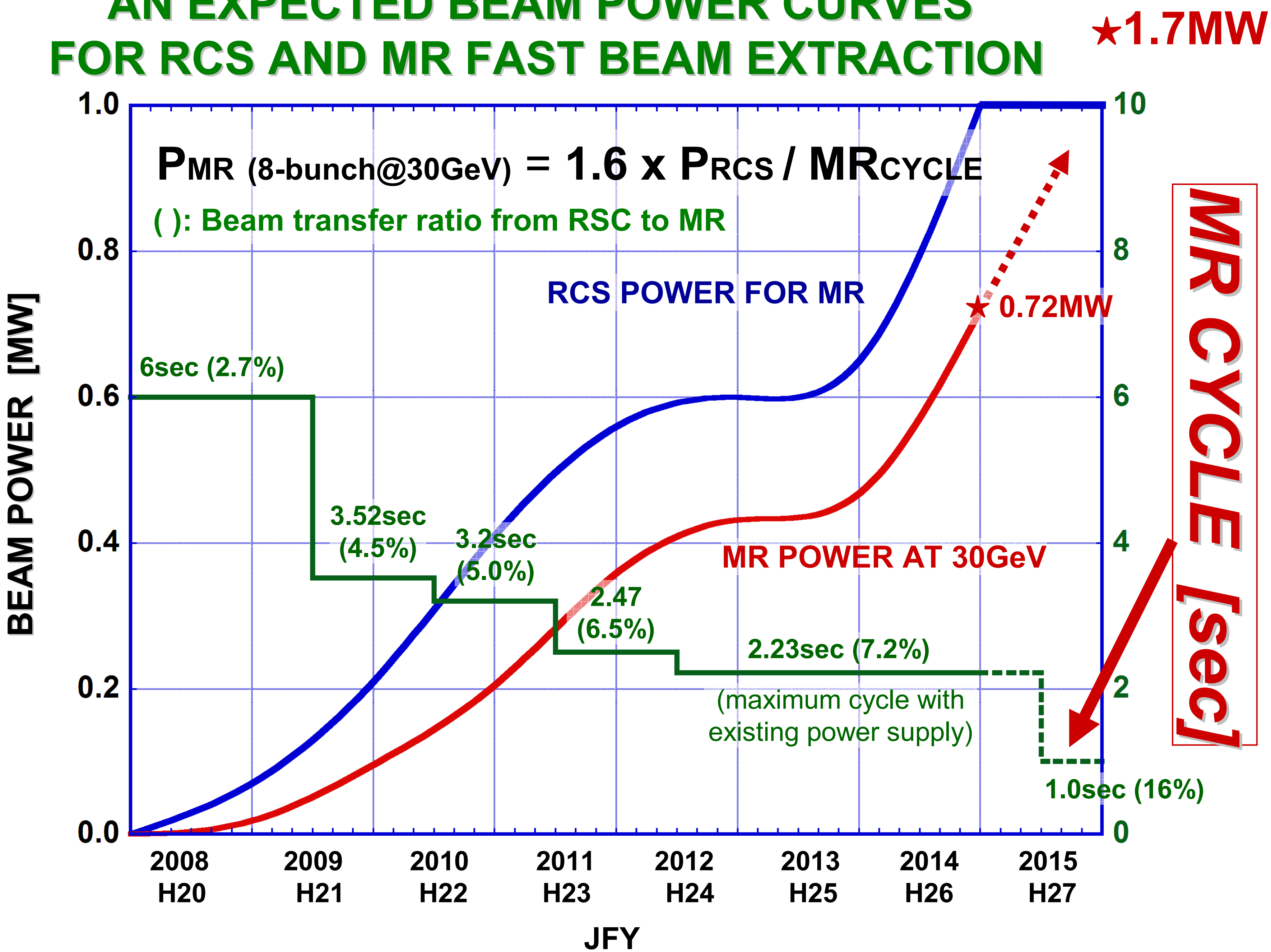


MR magnet

>30 GeV

Saturation starts

AN EXPECTED BEAM POWER CURVES FOR RCS AND MR FAST BEAM EXTRACTION



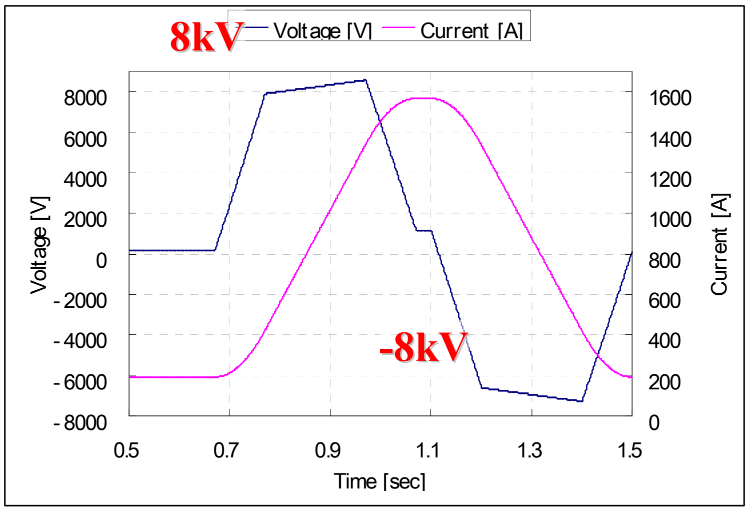
High Rep. Rate for 1.7 MW

standard PS for B & Q mag.

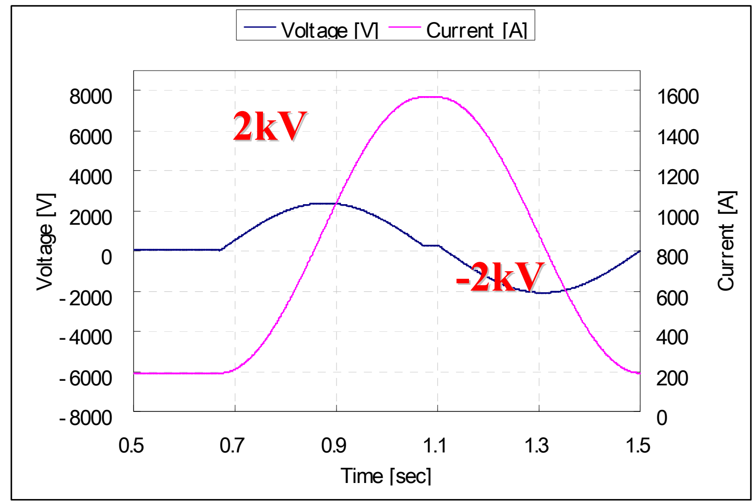
Rep. Rate:1Hz for BM

電流と電圧

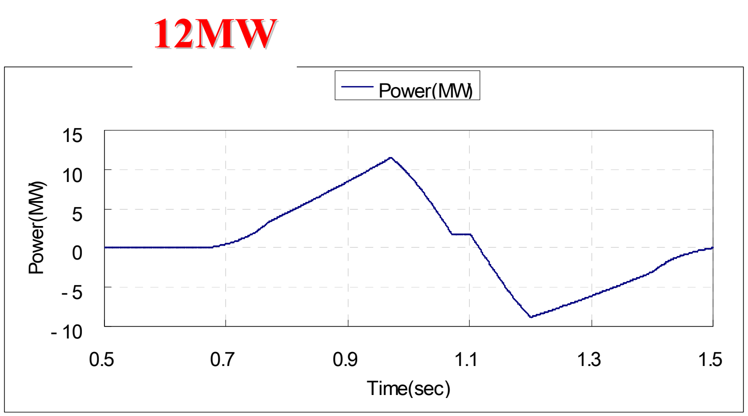
Present: 16 magnets/1 PS

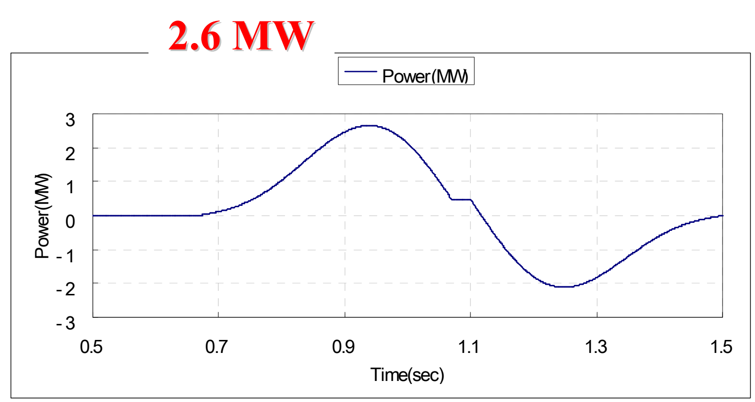


High Rep. Rate: 4 magnets/1 PS



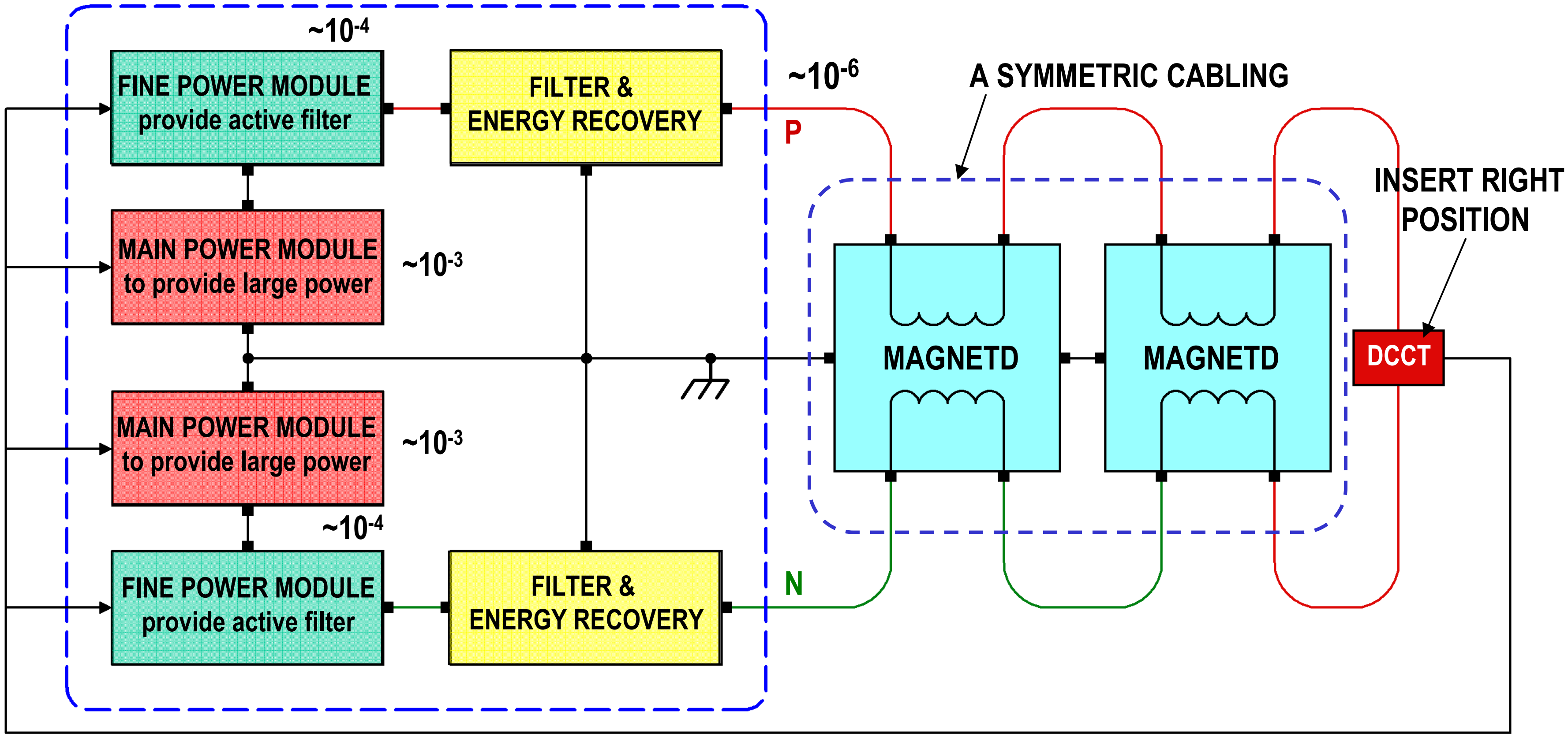
電力



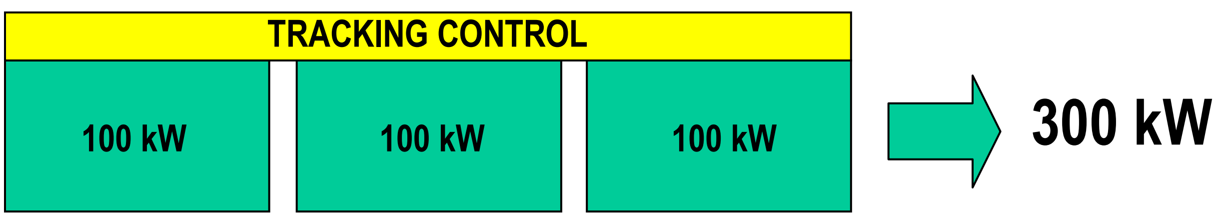


A STANDARD POWER SUPPLY

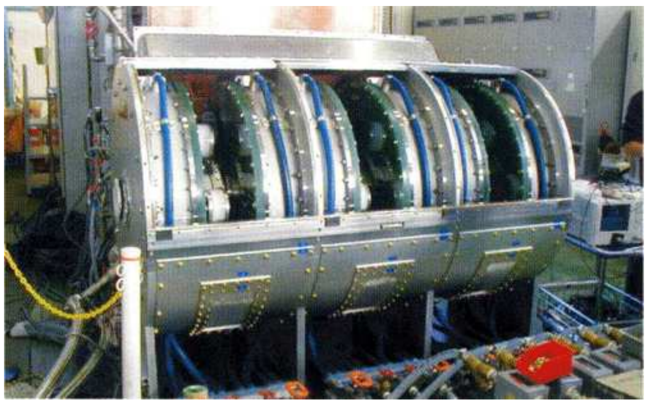
A SYMMETRIC POWER MODULE CIRCUIT AND A SYMMETRIC CABLING CAN BE REDUCE COMMON MODE NOISE FOR MAGNETIC FIELD.



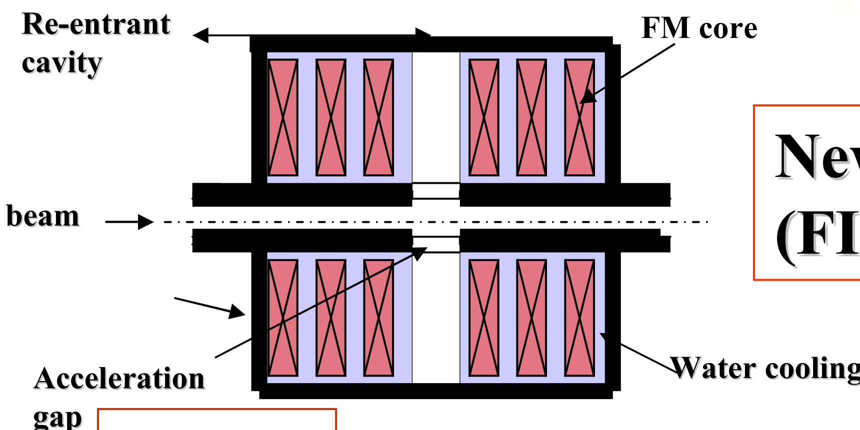
EXAMPLE FOR THREE PARALLEL OPERATION



RF acceleration structure at MR



50GeVシンクロトロン



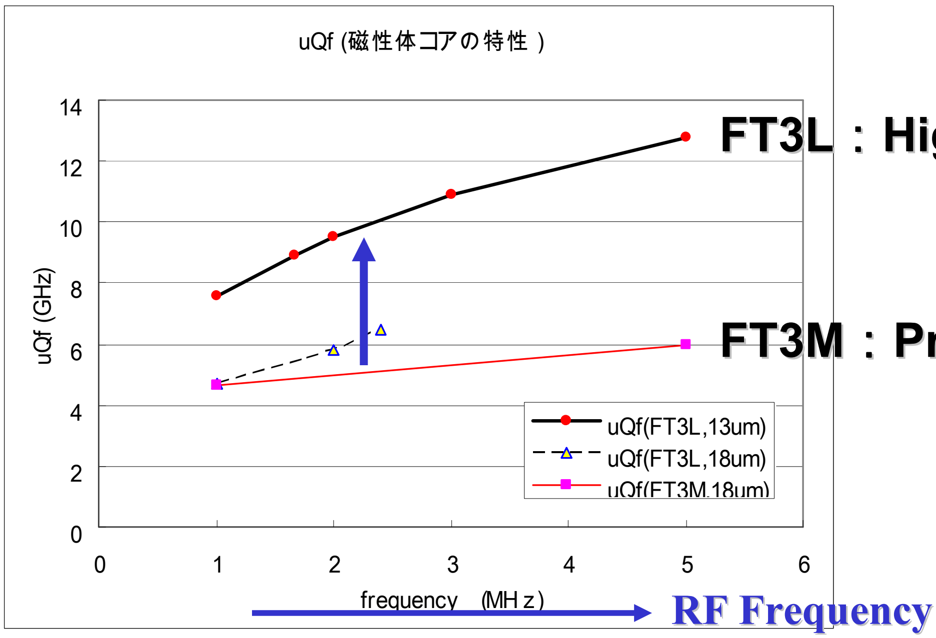
15kV/gap

New material→magnetic alloy (FINEMET of Hitach metals)

High Impedance Core for 1.7 MW

C.Ohmori

- High Impedance Core: ＦＴ３Ｌ (New type
  - Magnetic field is applied during nano-crystallize.
- Re-design of Cavity: number of accelerating gap will be increased



For higher acceleration:

❑Number of accelerating cavity

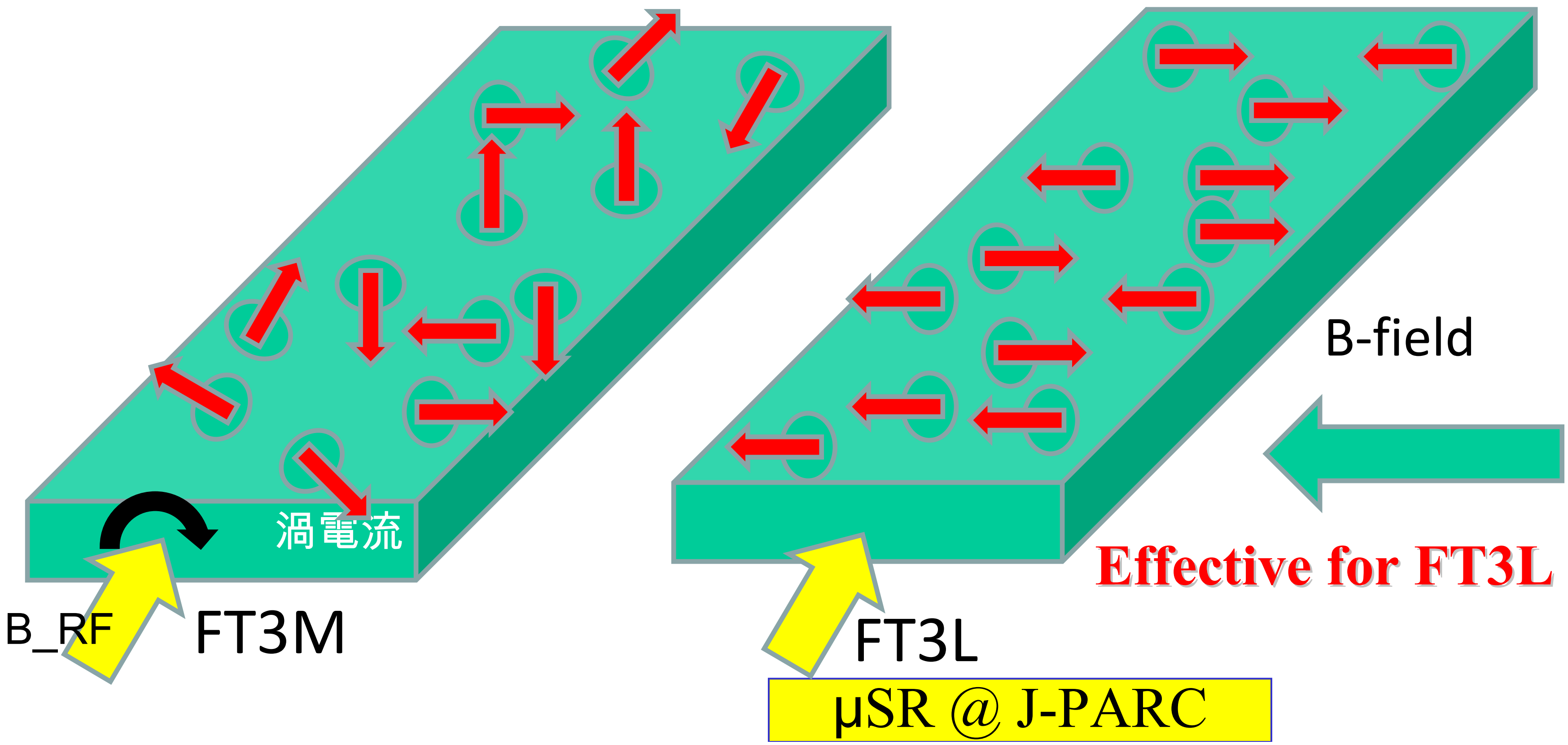
❑Energy gain of each cavity

High Impedance Core

C.Ohmori

- FT3M：crystallize without magnetic field. Random easy magnetization axis
- FT３L：crystallize with magnetic field. Uniform easy magnetization axis

Thickness of core material is also important parameter

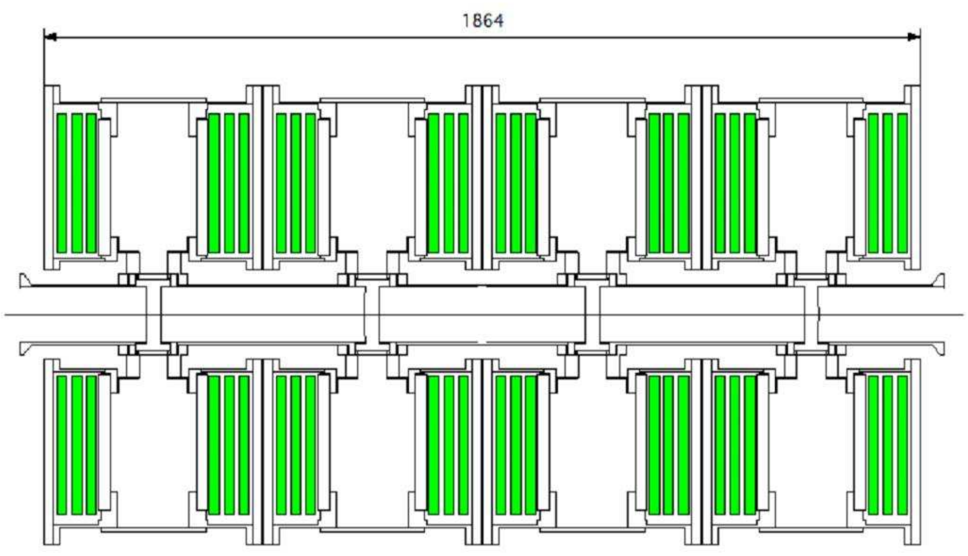


Conceptual Design of Cavity

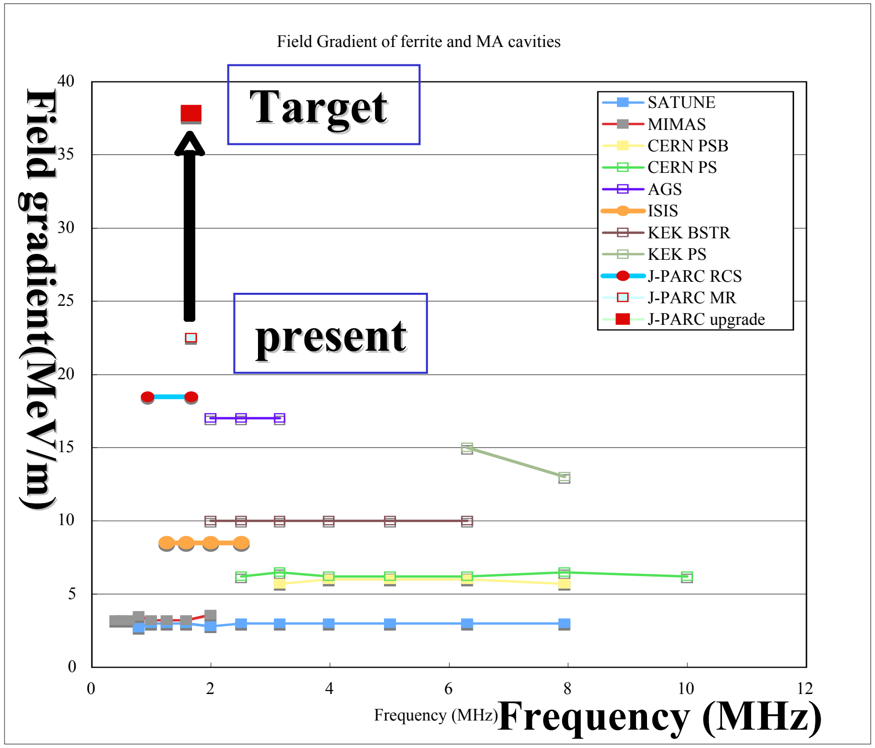
C.Ohmori

9unit X 60kV = 540kV （fundamental）
3unit X 66kV = 200kV （higher harmonics）

- ❑ Accelerating field: 22.5 kV/m→35 kV/m
  - ❑ Number of acc. Gap: 3→ 4
  - ❑ Thickness of core: 35mm → 25mm
- ❑ Present power supply will be available



4-Gap 70-kV Cavity



Summary

- Higher power operation in 2010
  - RCS 300kW
  - MR >100kW
- 400MeV Linac energy upgrade is essential
  - RCS 1 MW
  - MR 750 kW
  - Installation in 2012
- R&D toward KEK Road map (MR 1.7 MW)
  - Magnet power supply
    - Compact, symmetric and standardized system
  - High gradient RF system