Accelerator System
for
J-PARC Project

(Japan Proton Accelerator Research Complex)

Workshop

"Neutrino Super Beams, Detectors and Proton Decay"

March, 3~5, 2004

BNL

KEK Masayuki Muto

J-PARC Project is;

to construct an accelerator facility supplying the proton beam with the beam power of 1MW at 3GeV and 750kW at 50GeV, and

to construct experimental facilities using these beams for accelerator-driven transmutation experiment (*Linac beam*), materials & life science (*3GeV Beam*), nuclear & particle physics and neutrino experiment (*50GeV Beam*).

The Accelerator System consists of;

1) 400 MeV Linac
2) 3 GeV Proton Synchrotron (RCS)
3) 50 GeV Proton Synchrotron (MR).

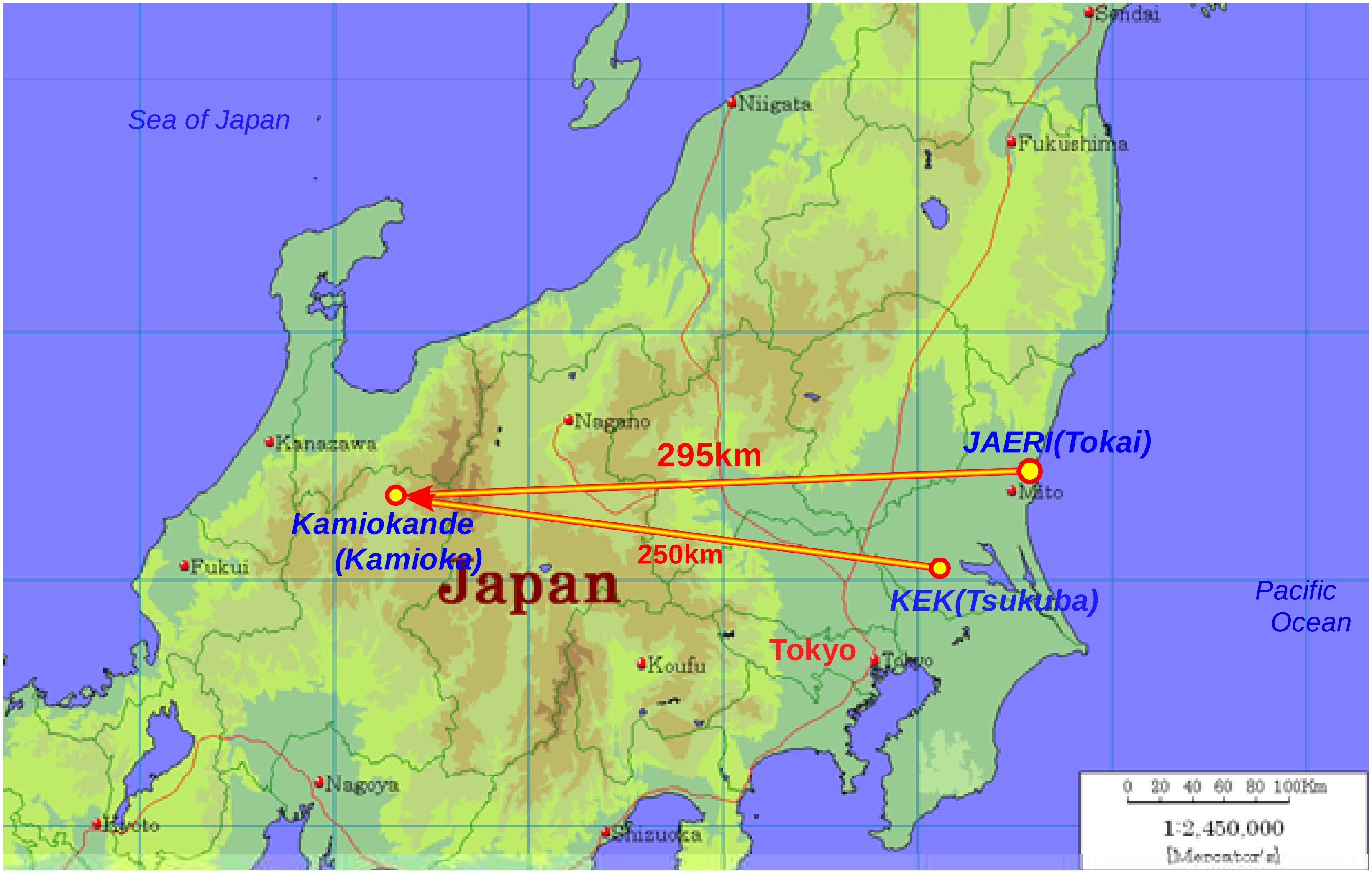
Construction Teem is;

formed with members from *KEK* and *JAERI*.

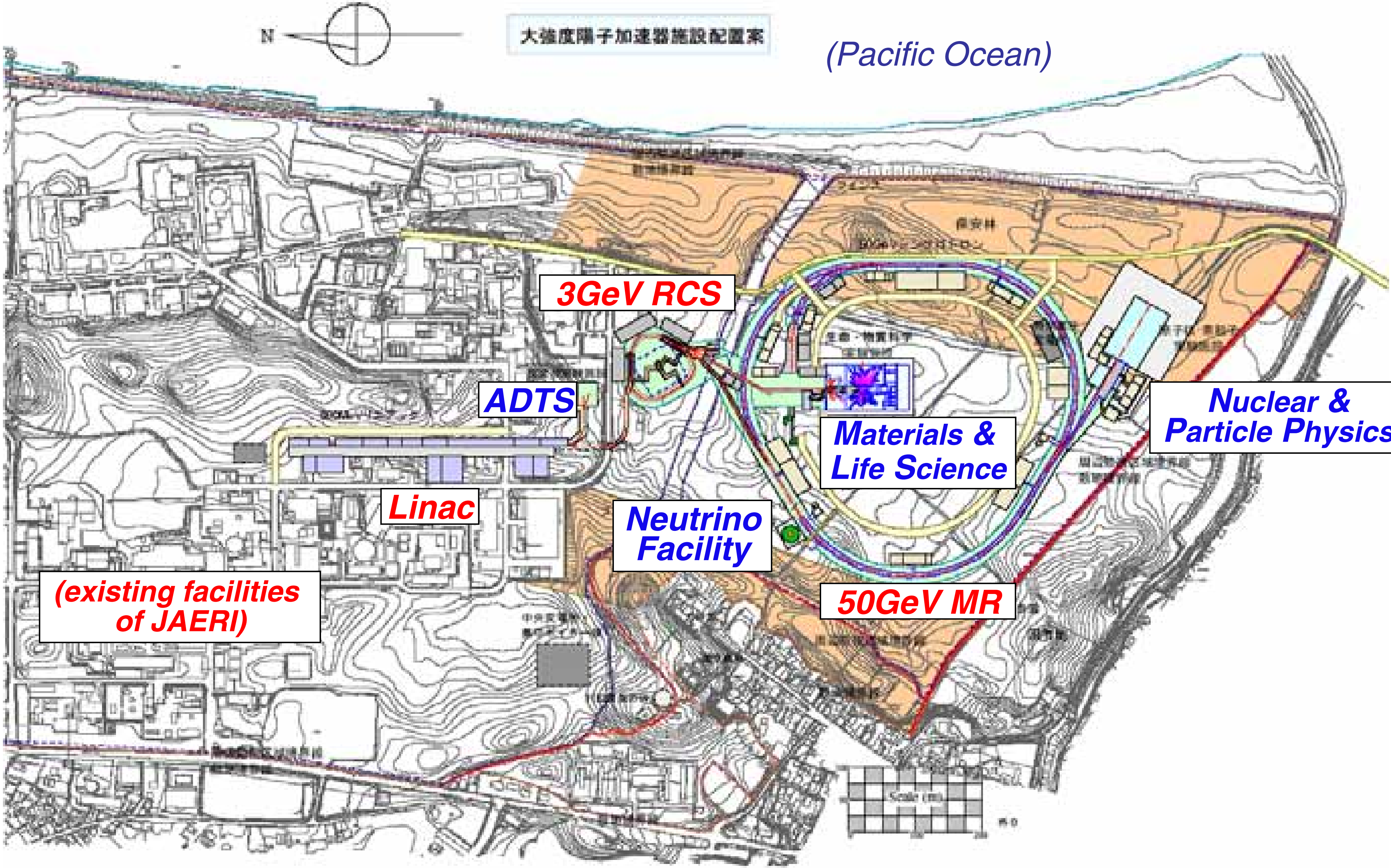
Construction Site is;

the JAERI Tokai Institute.

Location of J-PARC in Japan



Plan View of J-PARC Site



Main Parameters of Accelerator (1)

Linac

Ions	H^-
Energy for RCS	400 MeV
for ADTS	600 MeV (with SCC. Phase II)
Peak Current	50 mA
Average Current	1.25 mA (before chopping)
	0.7 mA (after chopping)
Beam Pulse Length	500 ms
Repetition Rate	50 Hz
Total Length	249 m (up to 400 MeV)
	340 m (up to 600 MeV)

Main Parameters of Accelerator (2)

3 GeV Synchrotron (RCS)

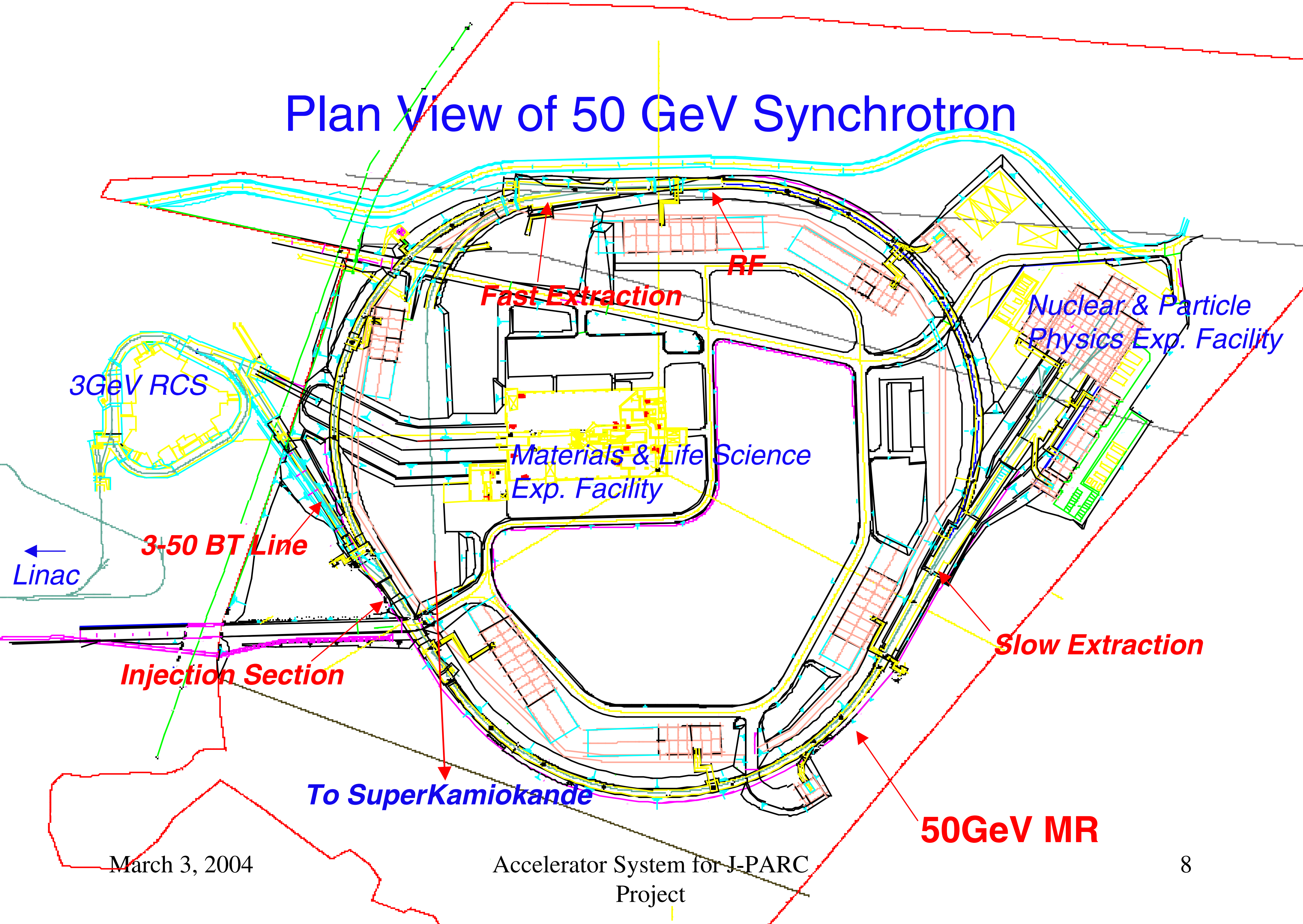
Energy	3 GeV
Beam Intensity	8.3×10^{13} ppp
Repetition	25 Hz
Average Beam Current	333 μA
Circulating Beam Current	9~12.4 A
Beam Power	1 MW
Circumference	348.3 m
Bending Magnet Field	0.27~1.1 T
Quadrupole Magnet Gradient (max)	4.6 T/m
RF Frequency	1.36~1.86 MHz
RF Voltage per Cavity	42 kV (11 cavities, 3 gaps/cav.)
Harmonic Number	2

Main Parameters of Accelerator (3)

50 GeV Synchrotron (MR)

Energy	50 GeV
Beam Intensity	3.3×10^{14} ppp
Repetition	0.3 Hz
Average Beam Current	15 μA
Circulating Beam Current	19~25 A
Beam Power	0.75 MW
Circumference	1567.5 m
Bending Magnet Field	0.143~1.9 T
Quadrupole Magnet Gradient	(max) 18 T/m
RF Frequency	1.67~1.72 MHz
RF Voltage per Cavity	47 kV (6 cavities, 3 gaps/cav.)
Harmonic Number	9

Plan View of 50 GeV Synchrotron



Slow Extraction (under designing)

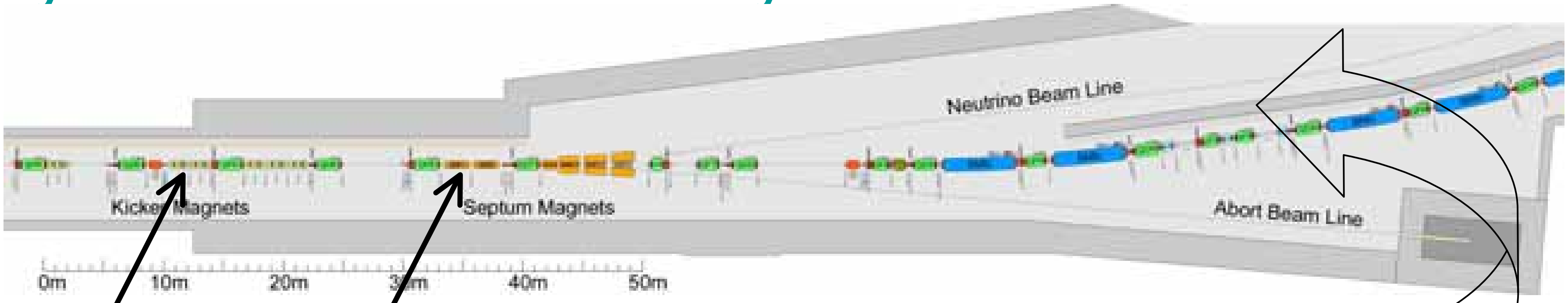
Method: third integer resonance extraction

(1 ESS + 3 sets of SM + 4 Bump Magnets + 8 RSM's)

ESS:	
Voltage	170 kV for 50GeV
Gap	25 mm (6.8 MV/m)
Length	1500 mm
Septum Magnet;	
Num. of SM	3 sets, 8 magnets
SM1(2magnets)	0.114T, 1.5m
SM2(3magnets)	0.374T, 1.5m
SM3-1	1.35T, 2.3m
SM3-2	1.64T, 2.3m
SM3-3	1.64T, 2.3m
Bump Magnet:	(not fixed)
Resonance Sextupole Mag;	
Num. of RSM	8

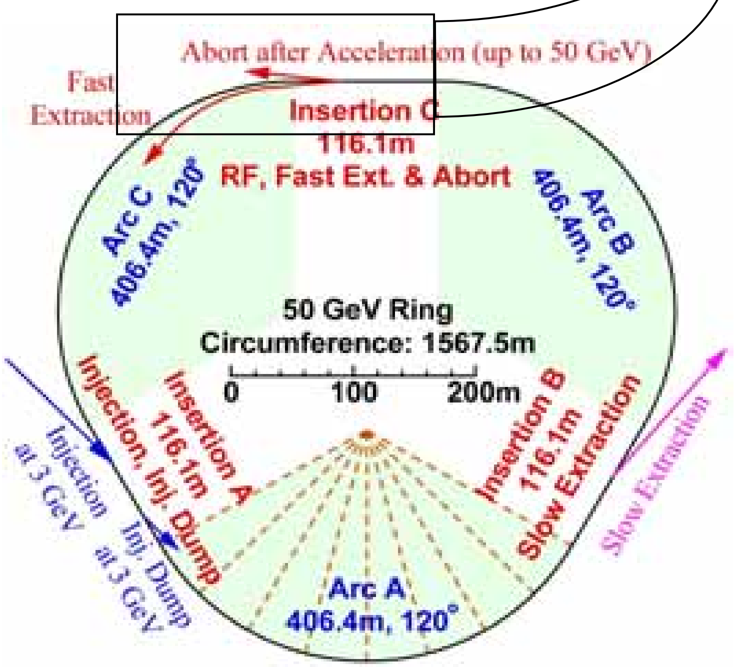
Fast Extraction

Layout of fast extraction system



6 kickers

8 pairs of septa



Fast extraction system has two functions;

<to extract beam to neutrino experimental beam line,

<to abort beam in emergency as hardware trouble during acceleration.

To meet this requirements;

- for fast extraction, kickers and septa bend a beam inward.
- for beam abort, the same kickers and septa bend a beam outward.

⇒ *bipolar kickers and septum magnets*

- to abort a beam anytime during acceleration, bending strength of kickers and septa has to be synchronized with beam momentum.
  - Excitation of septum follows the same pattern of ring magnets.
  - Excitation of kicker is always maximum. Bend angle is adjusted by a number of kickers turned on.

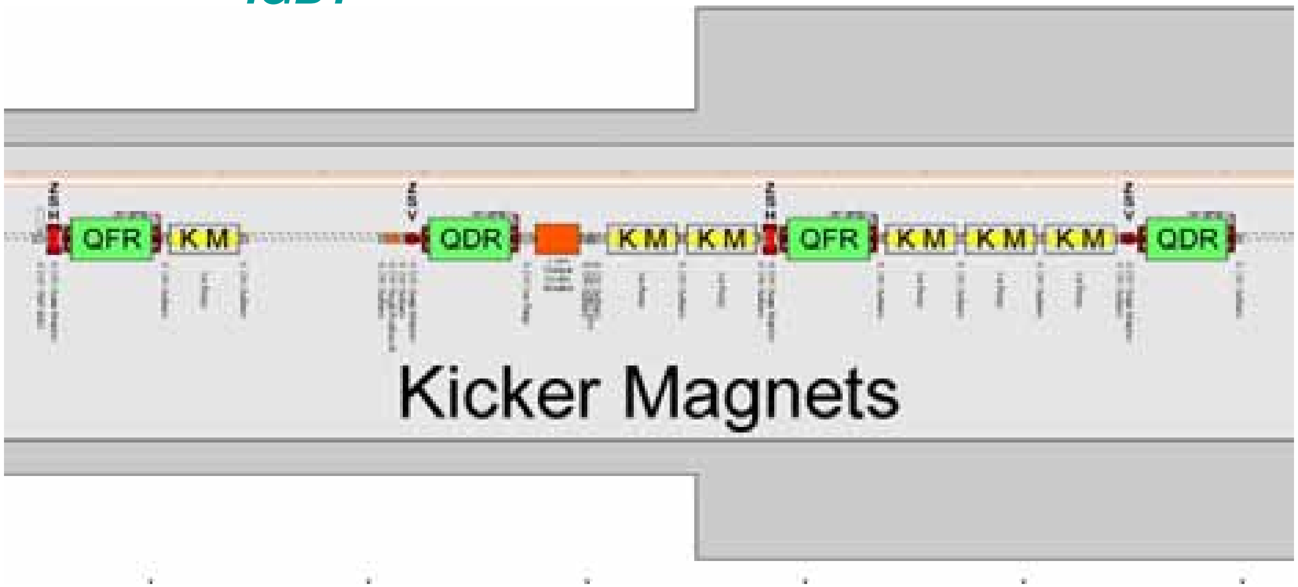
Kicker Magnet

Magnet

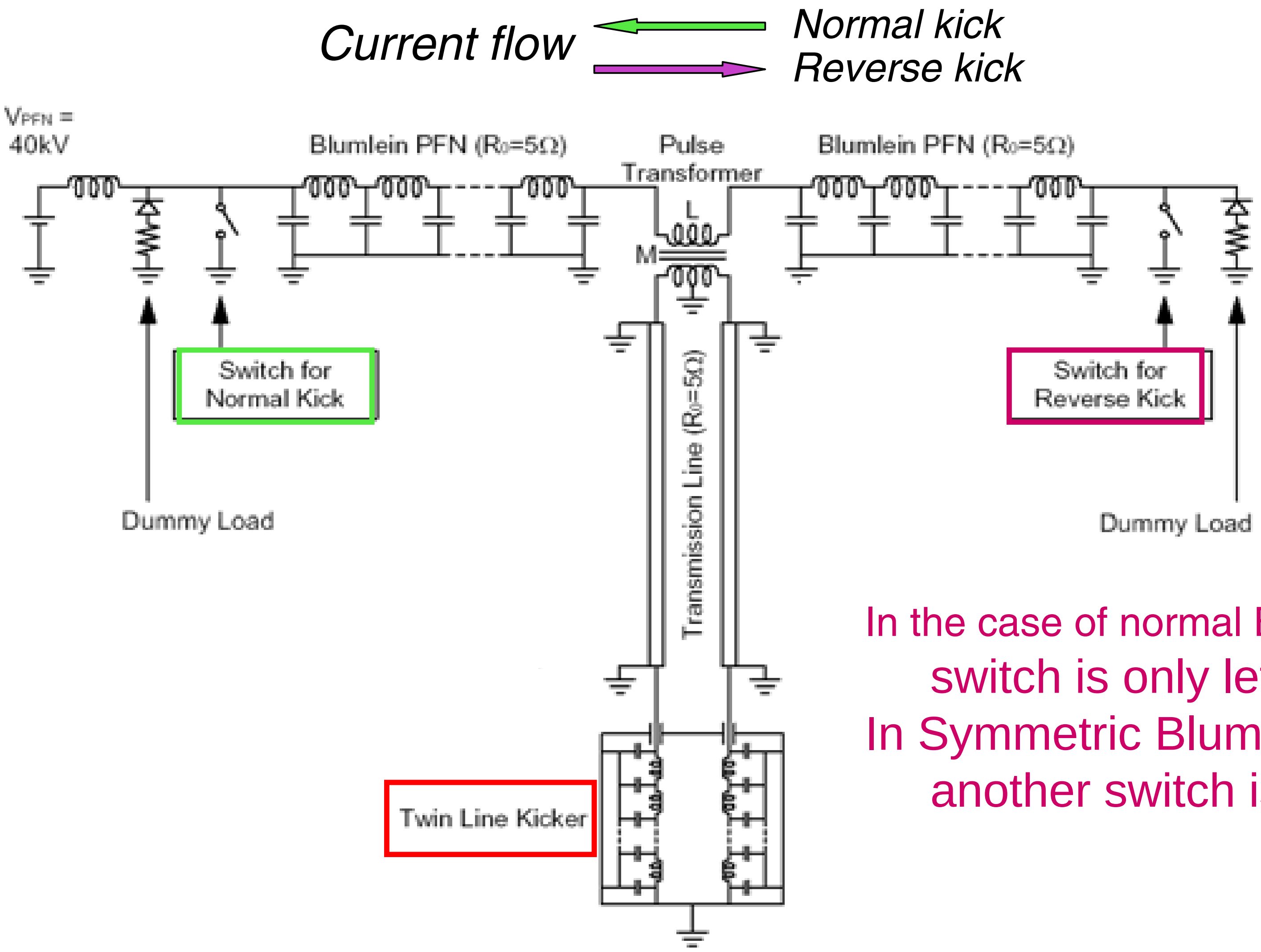
Number of Kicker Magnet	6
Magnetic Field (max)	1 kG
Deflection Angle	0.88 mrad (x 6)
Rise-up Time	< 1.1 μs
Flat-top Time	> 4.3 μs
Core Material	Ferrite
Aperture	100 x 100 mm^2

Power Supply

Type	***Symmetric*** Blumlein PFN ⇨ *bipolar operation*
PFN Voltage	40 kV
PFN Current	8000 A
Switching Element	***IGBT***

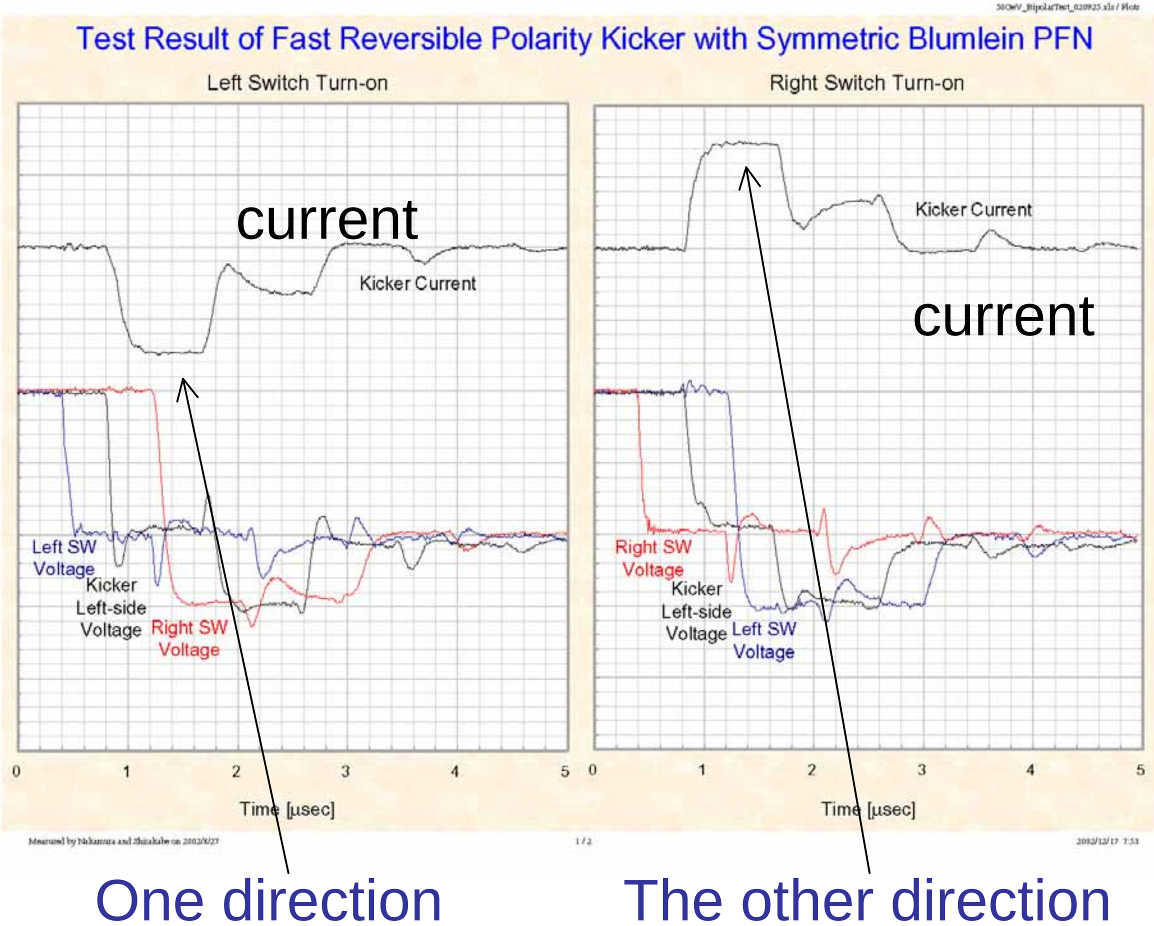


Symmetric Blumlein PFN Circuit



In the case of normal Blumlein PFN,
switch is only left side.
In Symmetric Blumlein PFN,
another switch is added to right side.

Experimental proof



Small-scaled model test shows it works as expected.

IGBT switching module

Parameters of IGBT switching

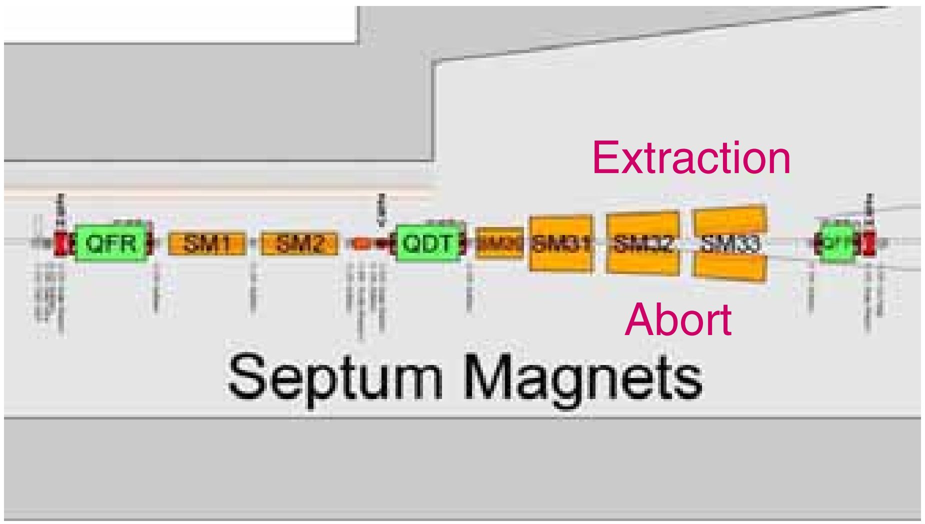
Turn-on rise time	160 ns
Operation voltage	40 kV
Operation current	8 kA
Series # in module	48
Parallel #	3

Test of the module will start soon.

Septum Magnet

Magnet

- Four sets of low field normal septa in vacuum
  (*SM1-1, SM1-2, SM2-1, SM2-2*)
- Two sets of ***Bipolar septum*** (*SM30, SM31*)
- Two sets of high field normal septa (*SM32, SM33*)
- Ceramic coating of coil (plasma powder spraying)



Name and installation order of SM

(abort line)		(extraction line)
SM1-1A		SM1-1E
SM1-2A		SM1-2E
SM2-1A		SM2-1E
SM2-2A		SM2-2E
	SM30	
	SM31	
SM32A		SM32E
SM33A		SM33E

SM30,SM31: used in common

Parameters of Septum Magnet for Fast Extraction

Magnet	Length (mm)	Field (T)	Angle (mrad)	Septum (mm)	Current (A)	Turns	Aperture (Hmm x Wmm)
SM1-1 ~SM2-2	875	0.427	2.2	7	6031	4	71, 80
SM30	1225	1.38	9.93	30	4484	48	98, 120
SM31	1660	1.66	16.3	43	4095	30	93, 110
SM32A, 33A	1900	1.66	18.6	62	4447	30	101. 140
SM32E, 33E	1900	1.66	18.6	62	4477	18	61, 140

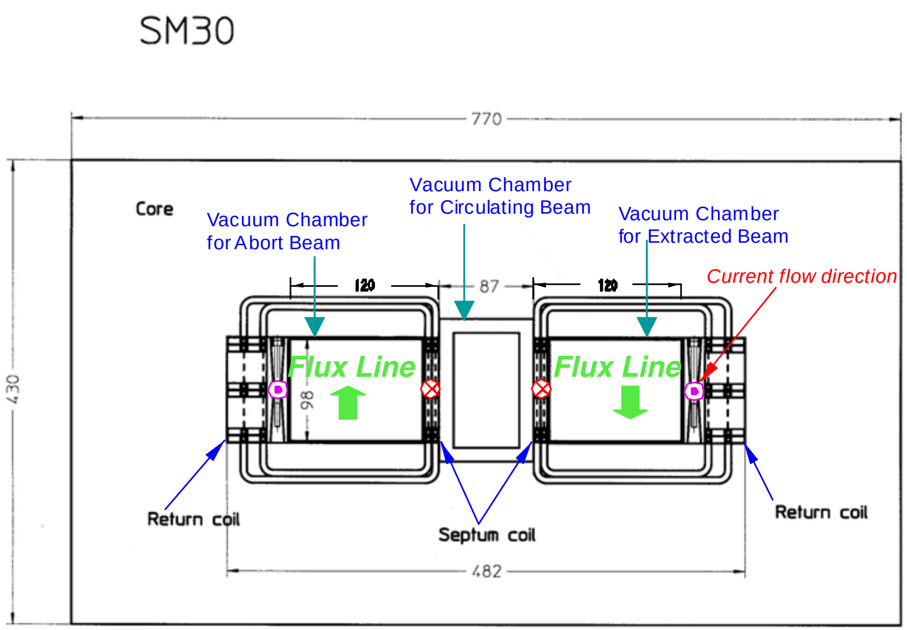
Bipolar Septum Magnet (SM30, SM31)

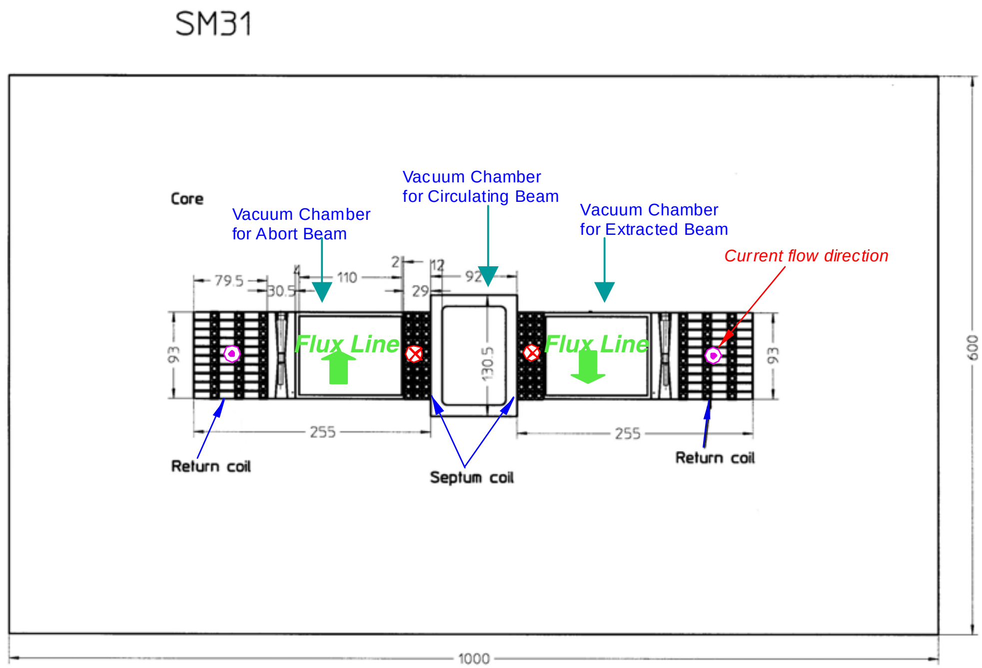
Design principle is same for both magnets.

> in one magnet core system, 3 apertures are formed,

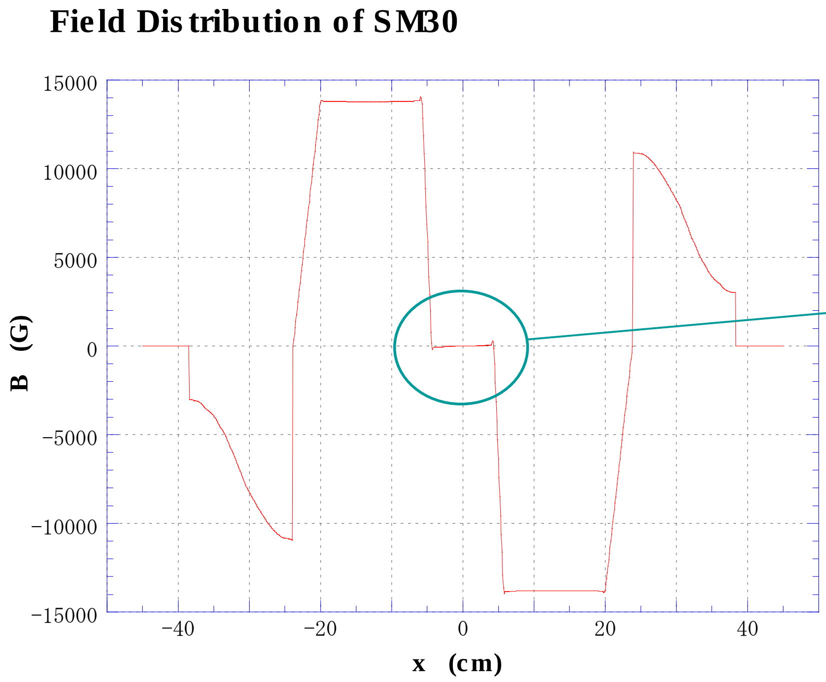
> to fix septum coils is very easy.

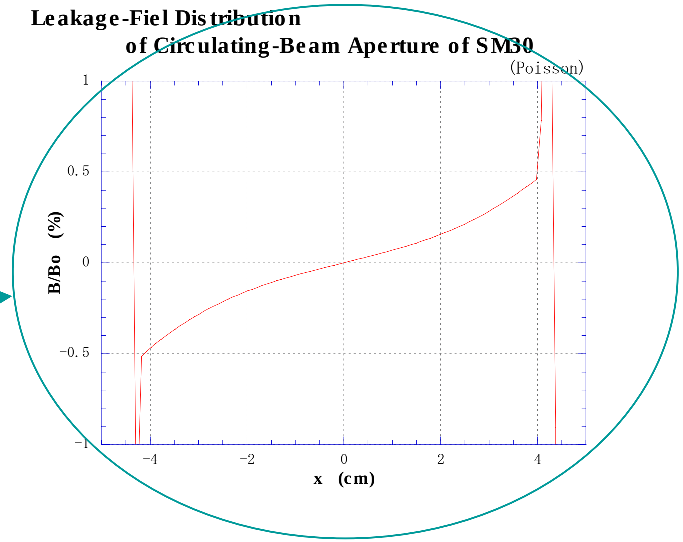
→ How is the stray field in the circulating beam aperture?

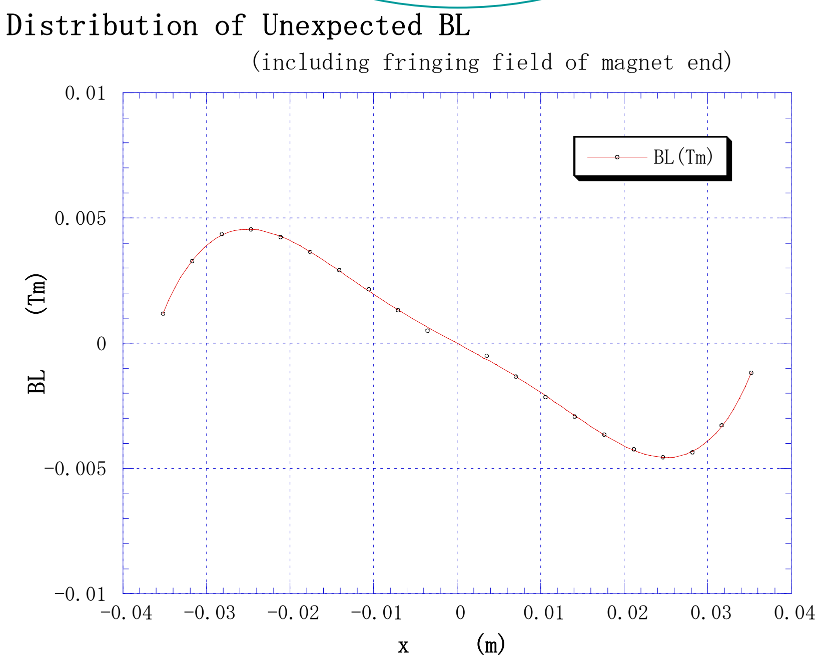




Field Distribution of SM30







The effect of BL production of stray field in the circulating beam aperture and magnet ends is negligible.

Two Problems concerning Beam Power

1. 50GeV MR is operated with the energy of 40GeV during an early period of operation start.

   50 GeV operation needs Fly Wheel Generator (FWG) because high electric power (170 MWp-p) induces fluctuation of line voltage and frequency without it. +-2.4% at 154 kV

   40 GeV operation reduces peak power to 100 MWp-p.
   +-0.8% at 154 kV

   Phase I: 40 GeV
   Phase II: 50 GeV with FWG
   (note: 50 GeV with lower duty is possible at Phase I)

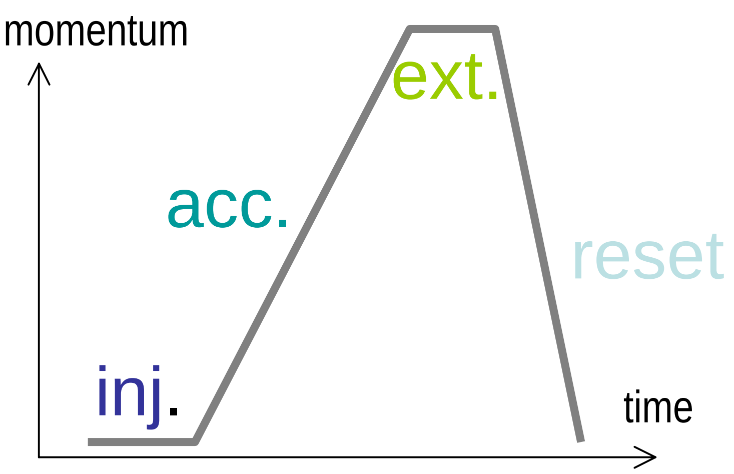
2. 400MeV Linac is operated with the energy of 180MeV during an early period of operation start. Then the RCS beam power is reduced to 60%. (0.6MW)

Operation Modes of 50GeV MR

slow extraction mode

inj.	0.17 s
acc.	1.9 s
ext.	0.7 s
reset	0.87 s

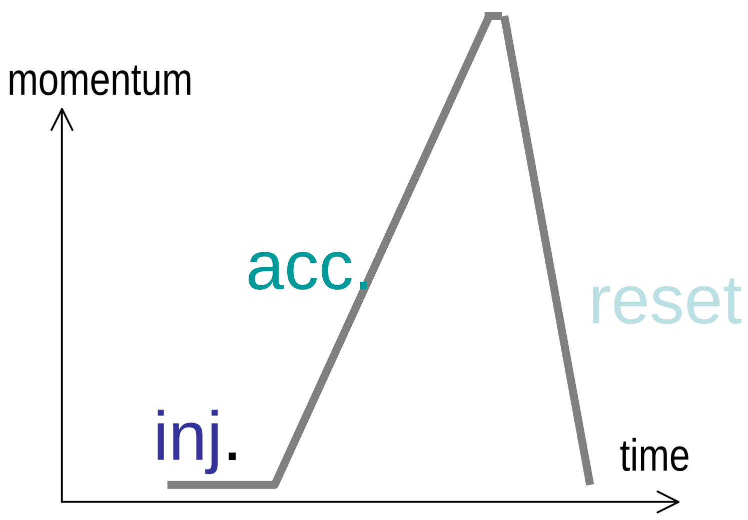
Energy (max) 30GeV



fast extraction mode

inj.	0.17 s
acc.	1.9 s
ext.	0.1~0 s
reset	0.87 s

Energy (max) 40GeV



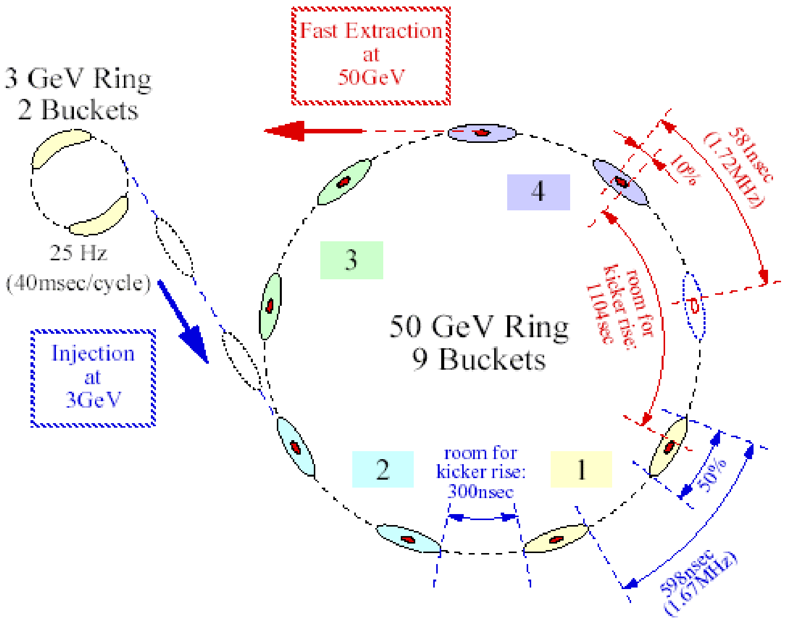
Beam Power (for fast extraction)

RCS current	bunch/ bucket	energy	cycle time	MR current	beam power	note
333 mA	8 / 9	50 GeV	3.64 s	15 μA	0.75 MW	Final goal
333 mA	8 / 9	40 GeV	3.64 s	15 μA	0.6 MW	Lower energy
333 mA	8 / 9	40 GeV	2.94 s	18 μA	0.72 MW	Shorten flattop
200 mA	8 / 9	40 GeV	2.94 s	11 μA	0.44 MW	Lower RCS current (x 0.6)
200 mA	8 / 18	40 GeV	3.08 s	10 μA	0.4 MW	Alternative injection scheme
200 mA	15 / 18	40 GeV	3.38 s	18 μA	0.72 MW	Alternative injection scheme with full bunches

Alternative Injection Scheme for 180MeV Linac Beam

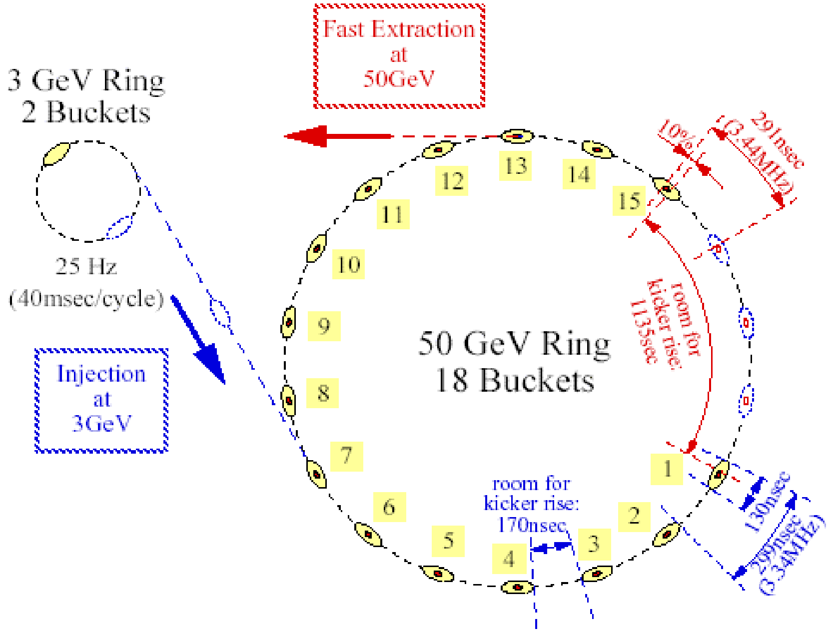
400MeV linac

Injection/Fast Extraction Scheme for the 50 GeV Ring



180MeV linac

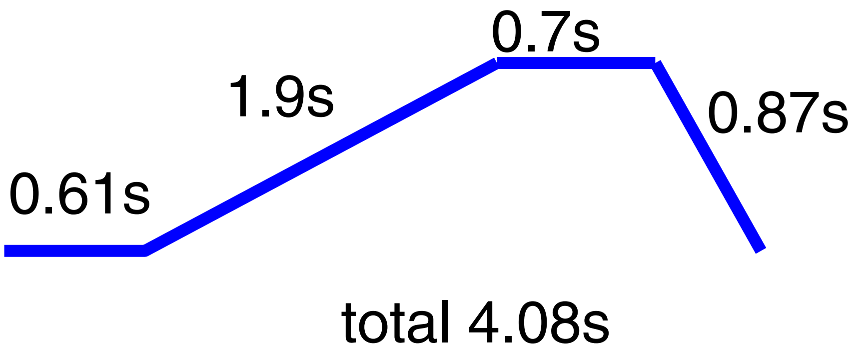
Injection/Fast Extraction Scheme for the 50 GeV Ring



Injection time	**120ms**	**→ 540ms**
RF frequency	**1.67-1.72 MHz**	**→ 3.34-3.44 MHz**
Injection kicker rise time	**300ns**	**→ 170ns**
Injection kicker flat top	**900ns**	**→ 130ns**

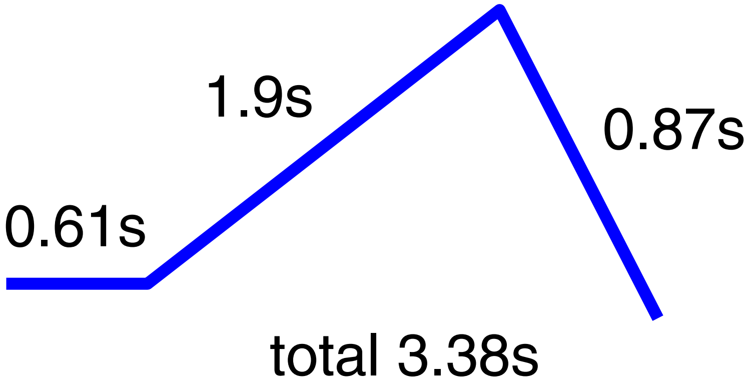
180MeV Linac case (15batches/15bunches)

slow extraction 30GeV



beam current: $f \times 24\mu A$
beam power: $f \times 0.73MW$

fast extraction 40GeV

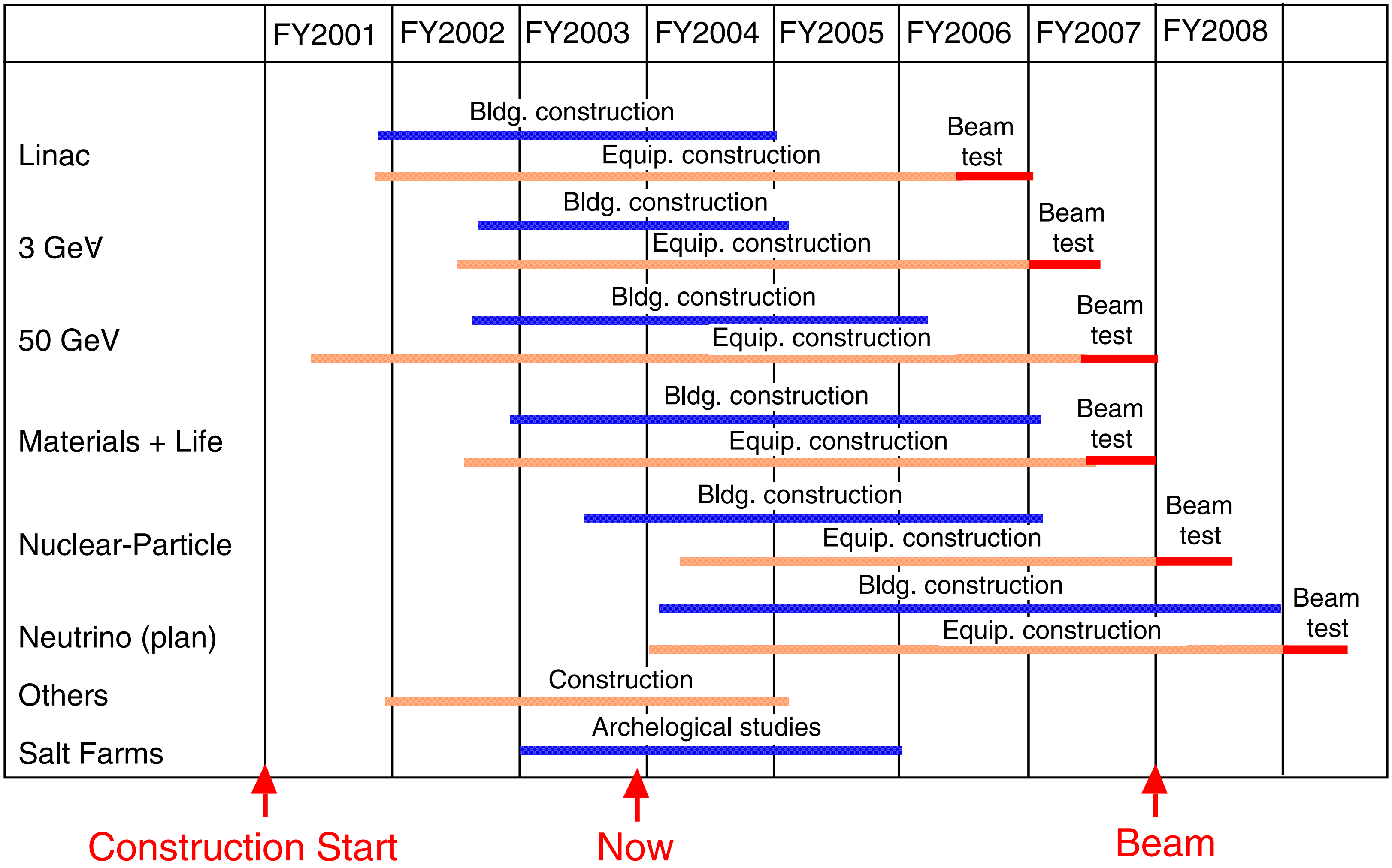


beam current: $f \times 29\mu A$
beam power: $f \times 1.17MW$

f: ***RCS beam intensity ratio between 181MeV/400MeV including a factor reduced by beam loss at MR long injection time***

Construction Schedule

Construction Schedule



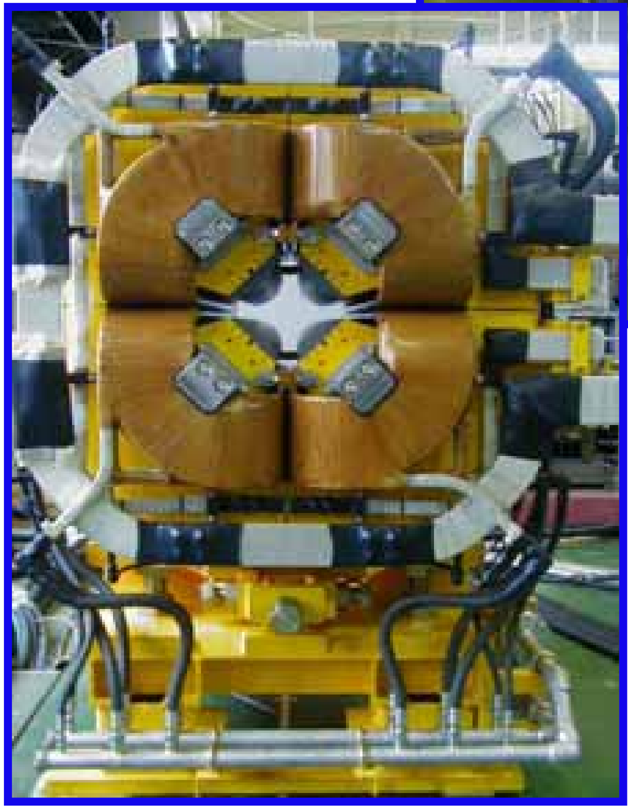
The linac energy of 400MeV is expected to be recovered by FY2010.

Status of Hardware

More than 70% of components are already ordered.

Magnet

Quadrupole

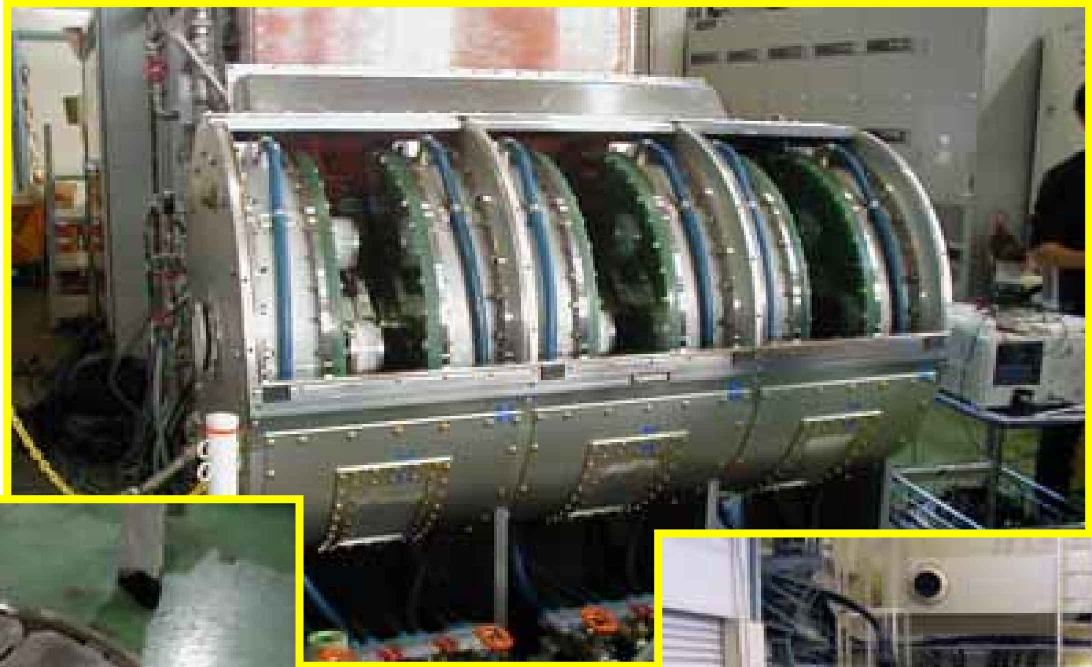


Power supply

Dipole

RF

MA core w/ diagonal cut



Power supply

Steering Magnet and Beam Position Monitor

Steering magnets
and
Power supply

Beam position
monitor

Beam transport line and dump

Iron for dump

B and Q for BT

Vacuum chamber

for bending magnet

for straight section


Ancient Salt Farm
December, 2003