50- GeV Proton Synchrotron

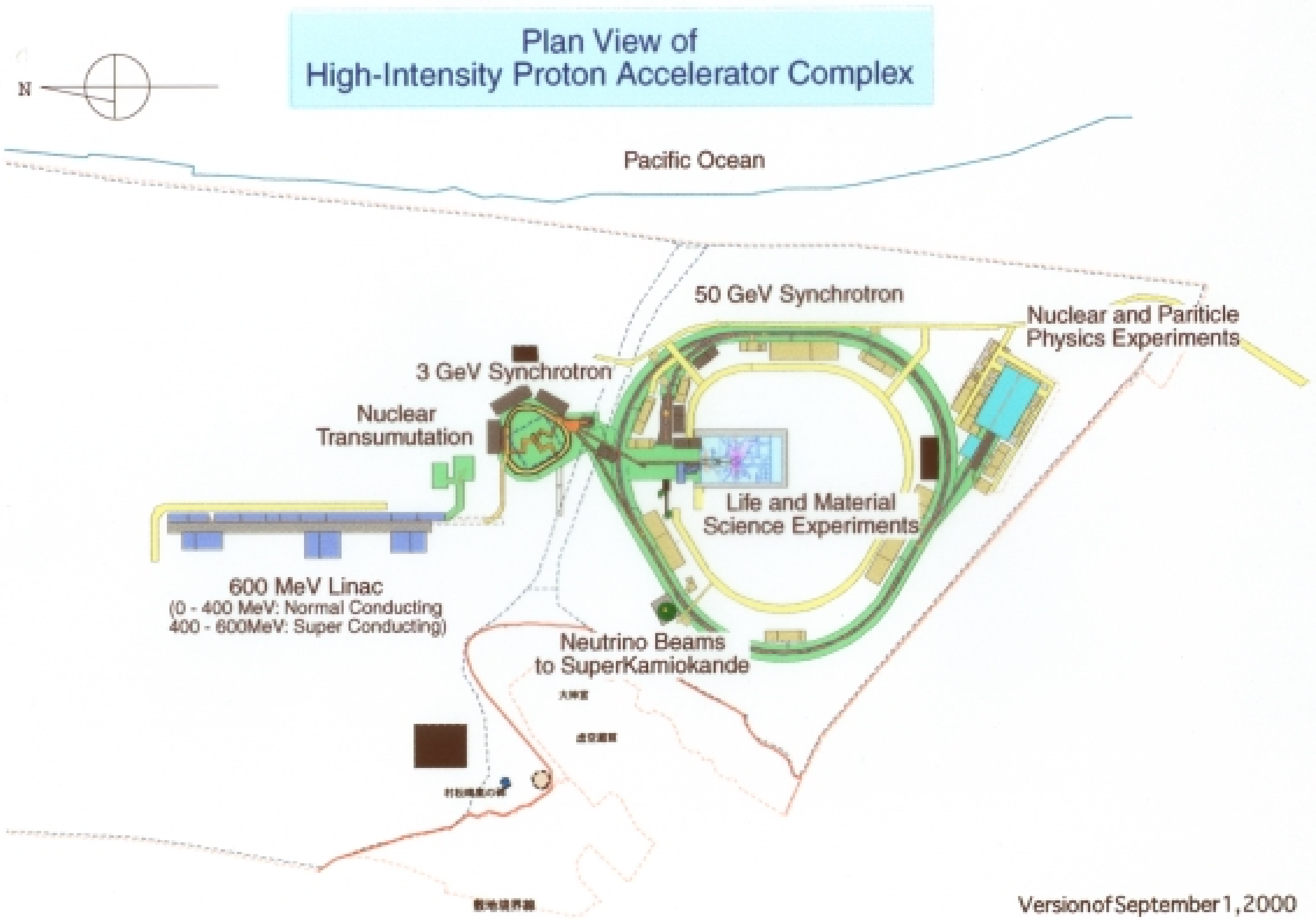
Y. Mori (KEK)

* Introduction

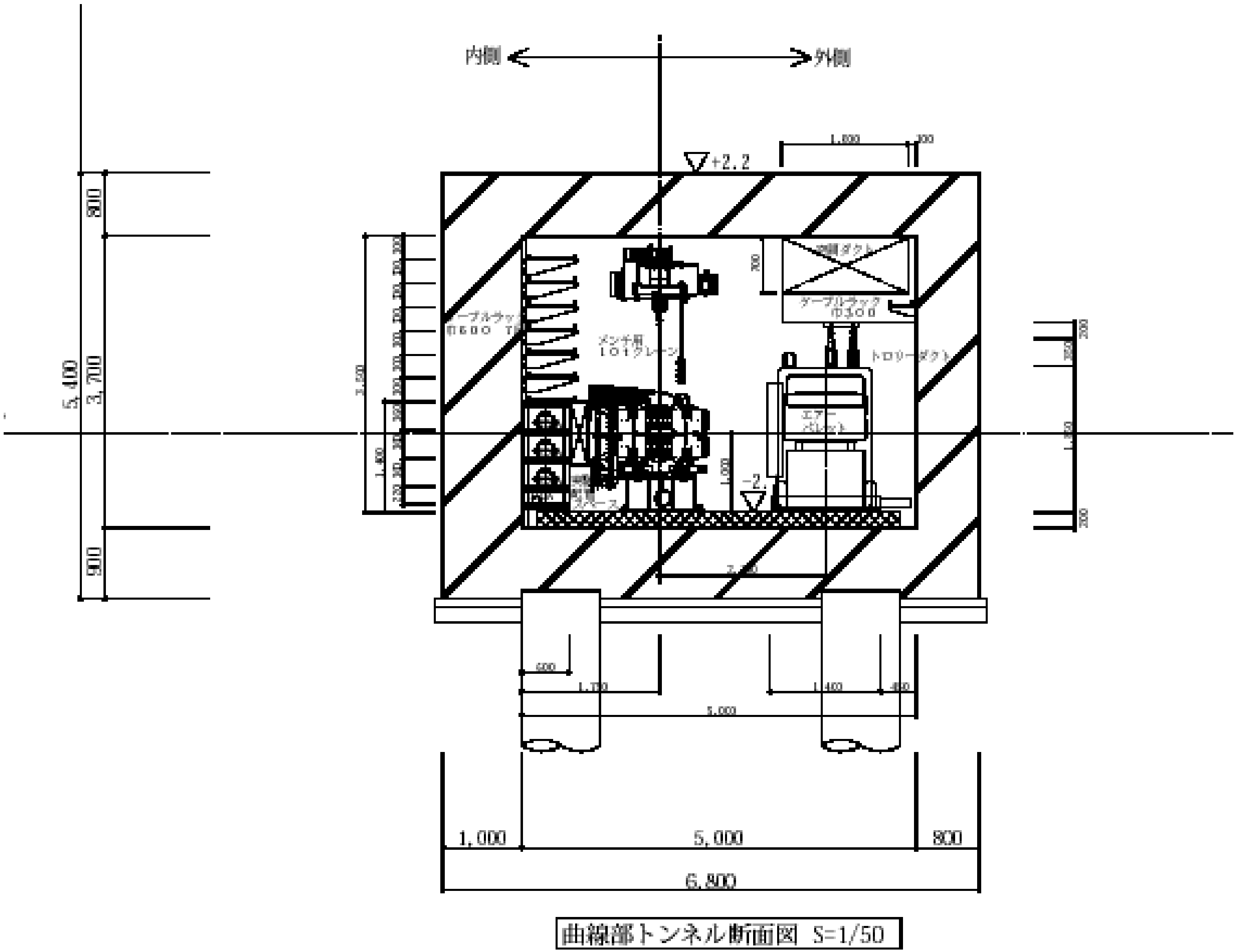
* Design

* Hardware R&D

Facility Layout



Tunnel : cross section



Specifications

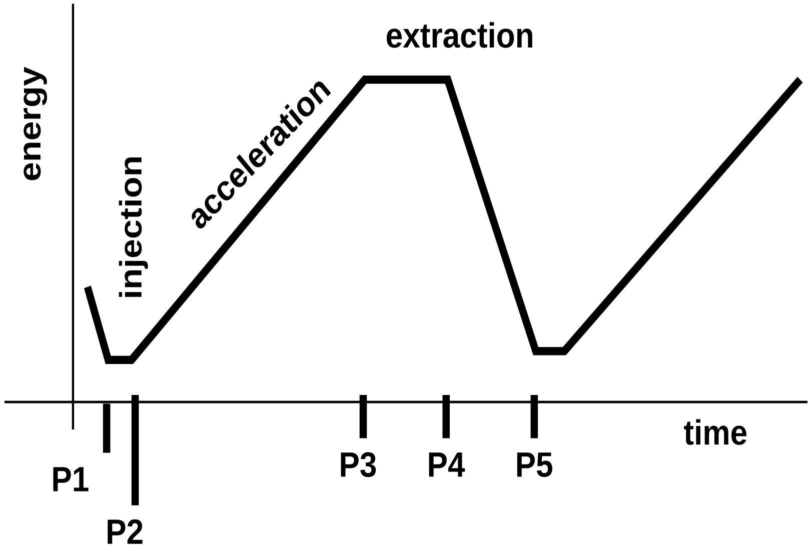
- 50GeV PS

# of protons	3.3 E14 ppp
repetition rate	0.3 Hz (~3.6 sec)
average beam current	15 microA (slow beam extr.)
beam power @50GeV	0.75 MW

- 3GeV PS

injection energy	400 MeV
# of protons	0.83 E14 ppp
repetition rate	25 Hz (40 msec)
average beam current	333 micro A
beam power @50GeV	1 MW

Acceleration Cycle



P1 - P2(injection)	0.14 s
P2 - P3(acceleration)	1.9 s
P3 - P4(extraction)	0.7 s
P4 - P5	0.9 s
total	3.64 s

slow extraction of 50GeV

duty factor	0.20
average current	15μA

High intensity proton accelerators

50GeV PS

* AGS (BNL)	30GeV	0.6-0.7x10E14 ppp
* Maing Injector (FNAL)	120GeV	0.2-0.3x10E14 ppp

3GeV PS

* ISIS (RAL)	800MeV	0.2MW
* PSR (LANL)	800MeV	0.6MW
* SNS	1.3GeV	1-2MW

Minimization of Beam Loss : key issue for reality

"radiation safety" & "maintenance"

beam loss-> * controlled : localized and shielded (ESS at extraction)

* uncontrolled : whole ring ~1W/m

allowed beam losses :

-Injection	135W	0.3%	uncont.
-collimator	450W	1%	cont.
-ring	0.5W/m	0.36%	uncont.
-slow beam ext.	7.5kW	1%	contr.
-fast beam ext.	1.125kW	0.15%	contr.
total	8.9kW	2.7%	slow beam ext.
	2.5kW	1.8%	fast beam ext.

Residual Radiation Activity

example -> 3GeV PS collimator

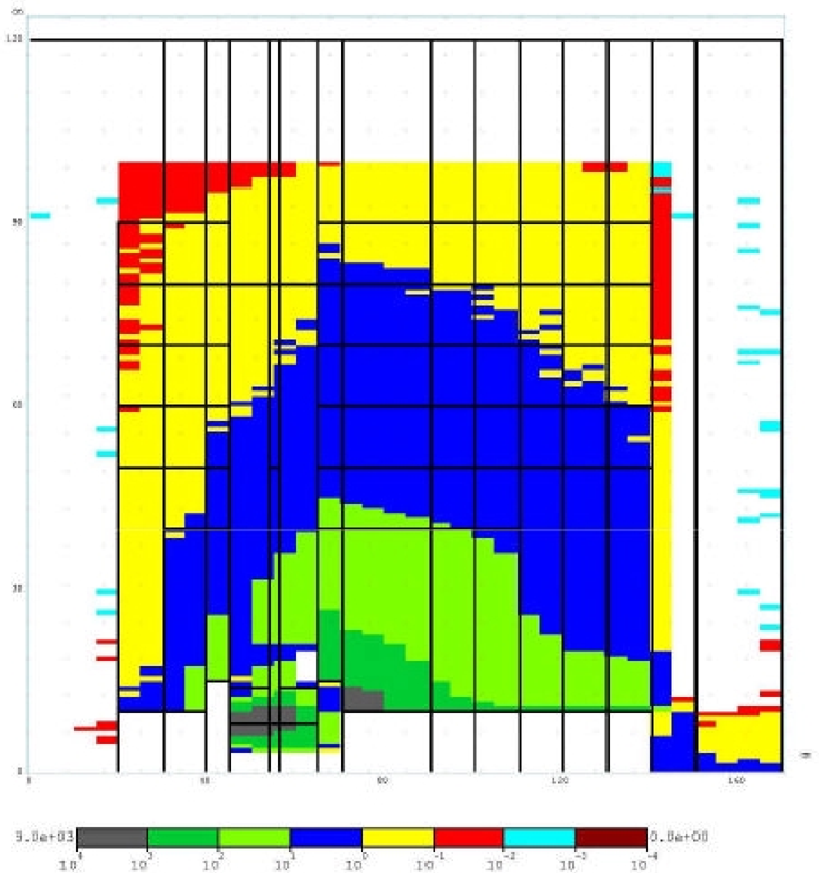
. Inner side @ Jaw

> 1Sv/h (beam loss 1.2kW)

. Outer shield surface

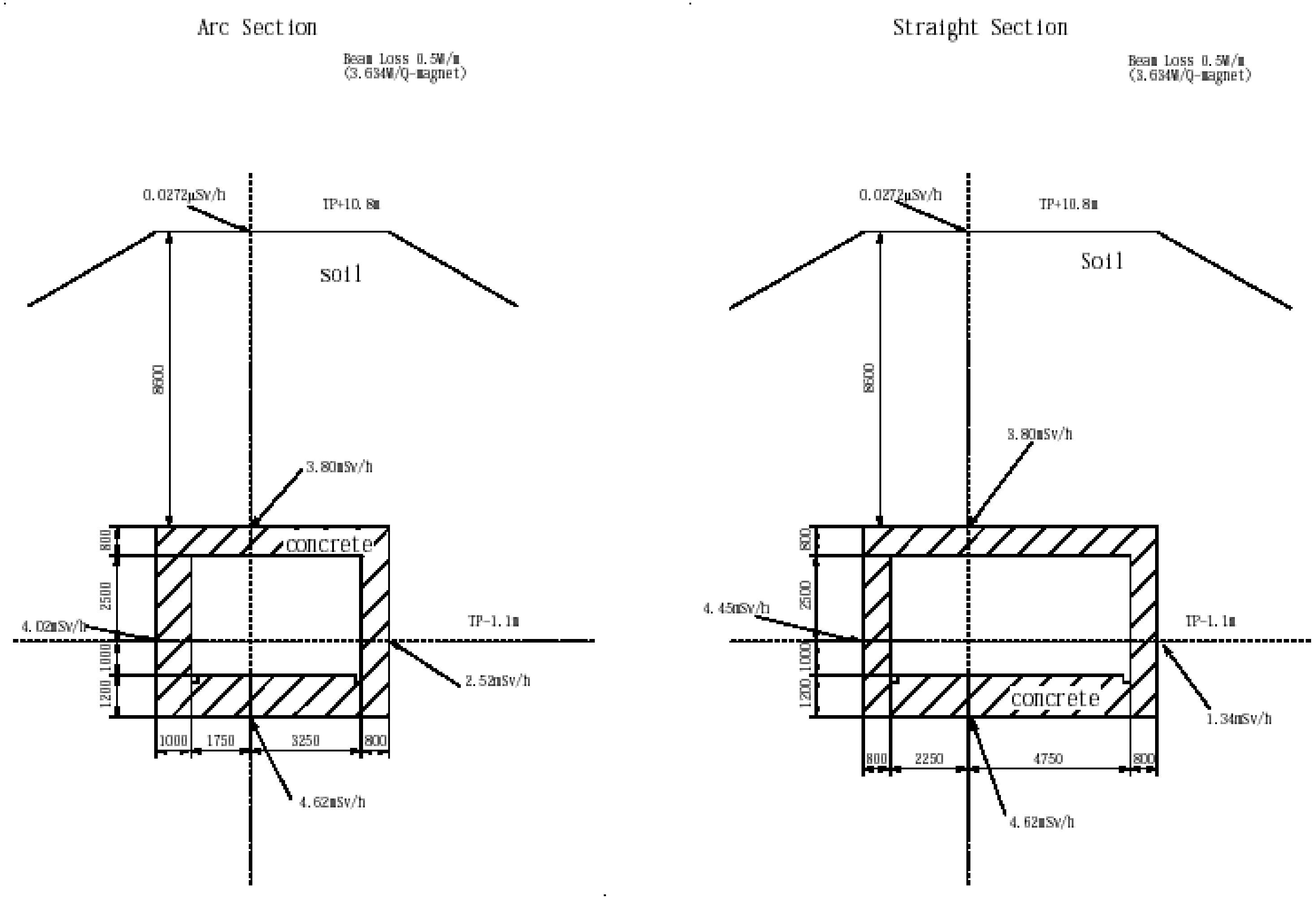
shield : 30cm iron & 40cm concrete

~7mSv/h



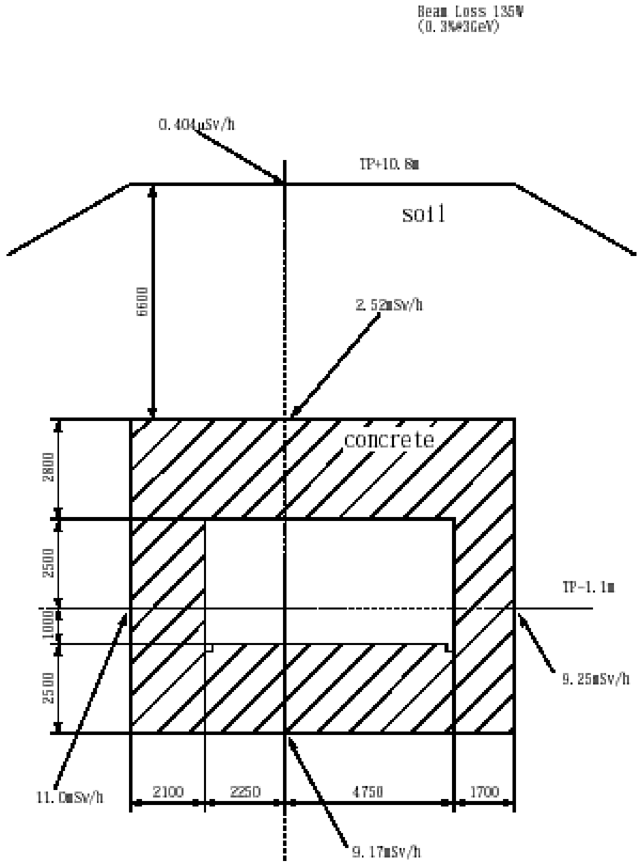
* after 1day cooling off following 30days operation

Radiation Shield (1)

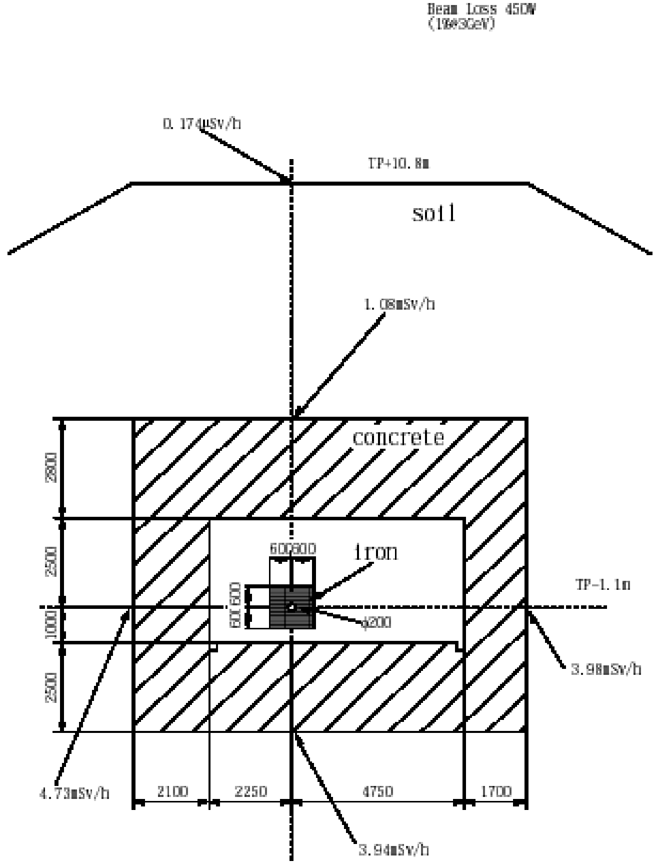


Radiation Shield (2)

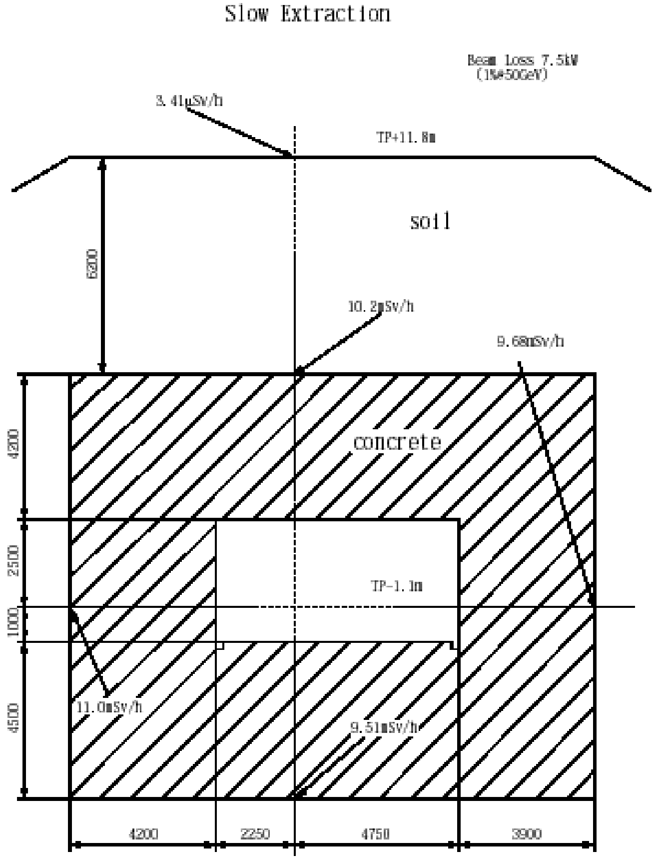
Injection

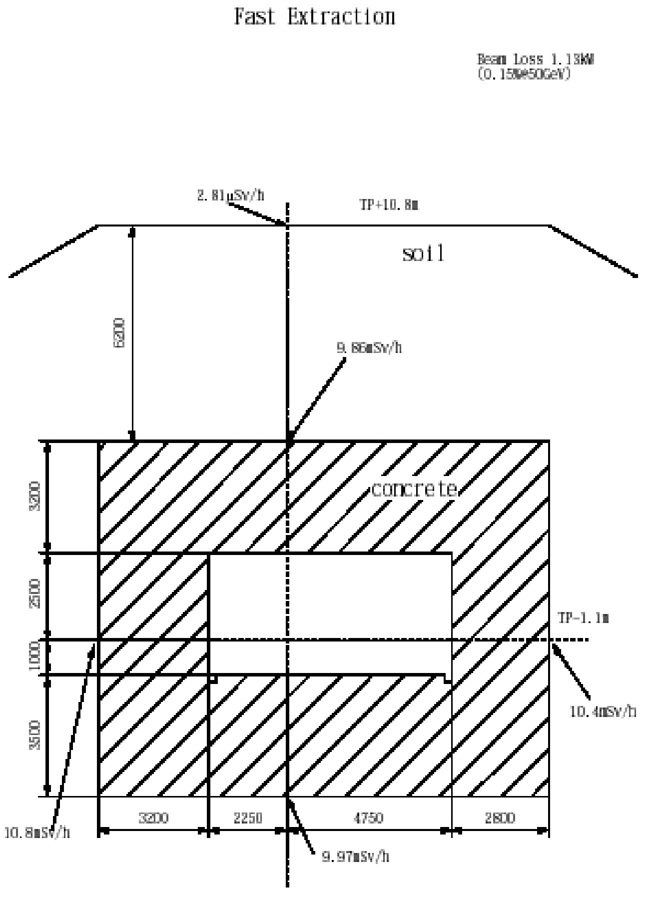


Ring Scraper

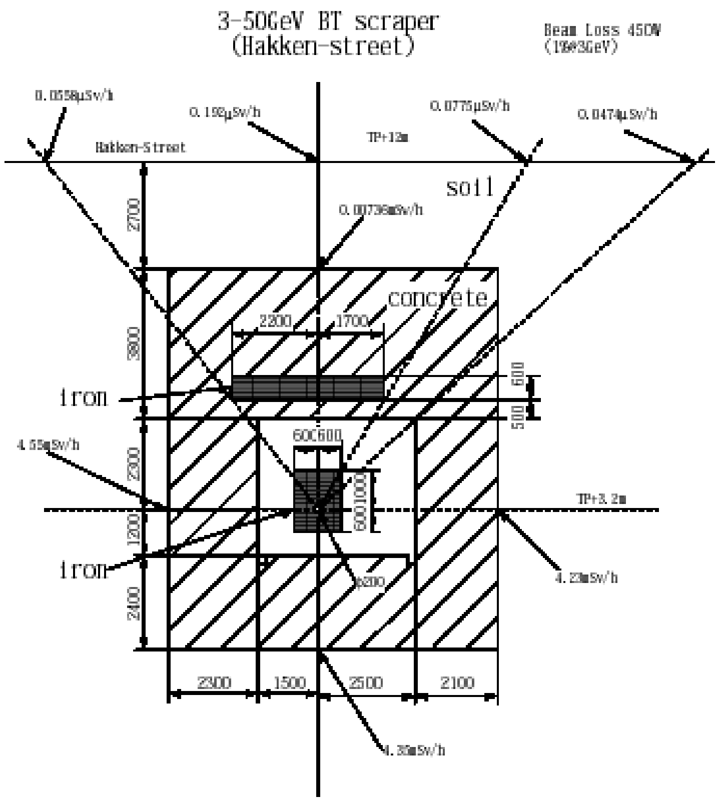


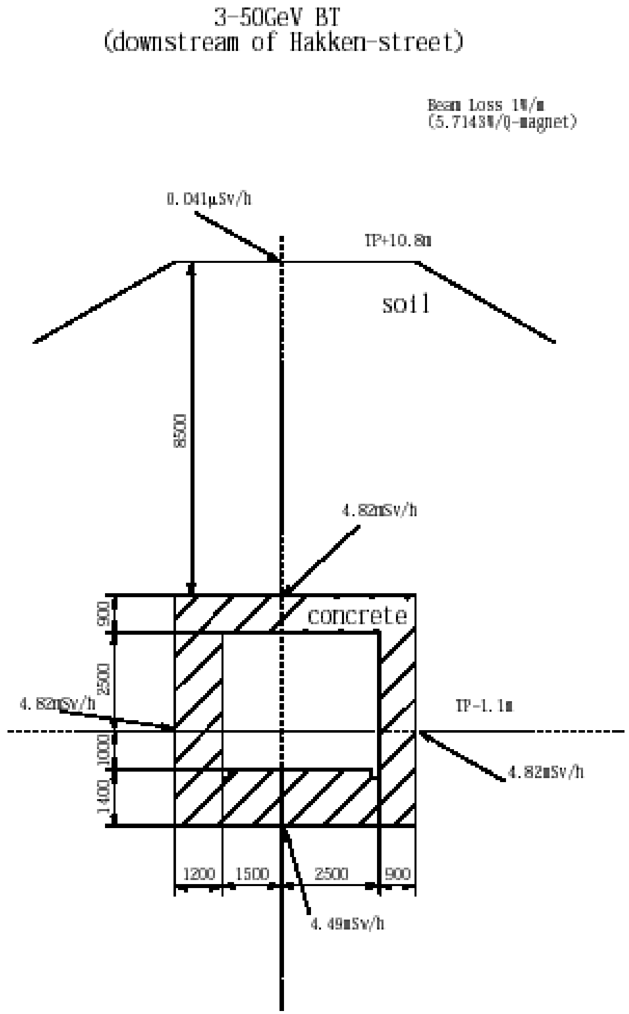
Radiation Shield (3)





Radiation Shield (4)





What causes beam loss?

Beam Dynamics View:

high intensity beam beahaviors

- Space Charge Effect

  Coherent, Incoherent, Non-linearity, Halo formation
- Instablities : e-p inst.
- others?

large acceptance

- fringe field effect

Space Charge Effect (tune shift :spread)

. 50GeV PS

- 0.14

*emittance	54 πmm.mrad
*beam intensity	3.33x10E14 ppp
*bunching factor	0.27
*form factor	1.7

. 3GeV PS

-0.15

*emittance	214 πmm.mrad
*beam intensity	8.33x10E13ppp
*bunching factor	0.42

Emittance & Acceptance for 50GeV PS

	emittance (πmm.mrad)	collimator acceptance	phsyical acceptance
3GeV PS			
injection	144	324	486
extraction	54(core)		
3GeV BT			
collimator	54	54	120
50GeV PS			
injection	54	54-81	81
extraction (30GeV)	10		
extraction (50GeV)	6.1		

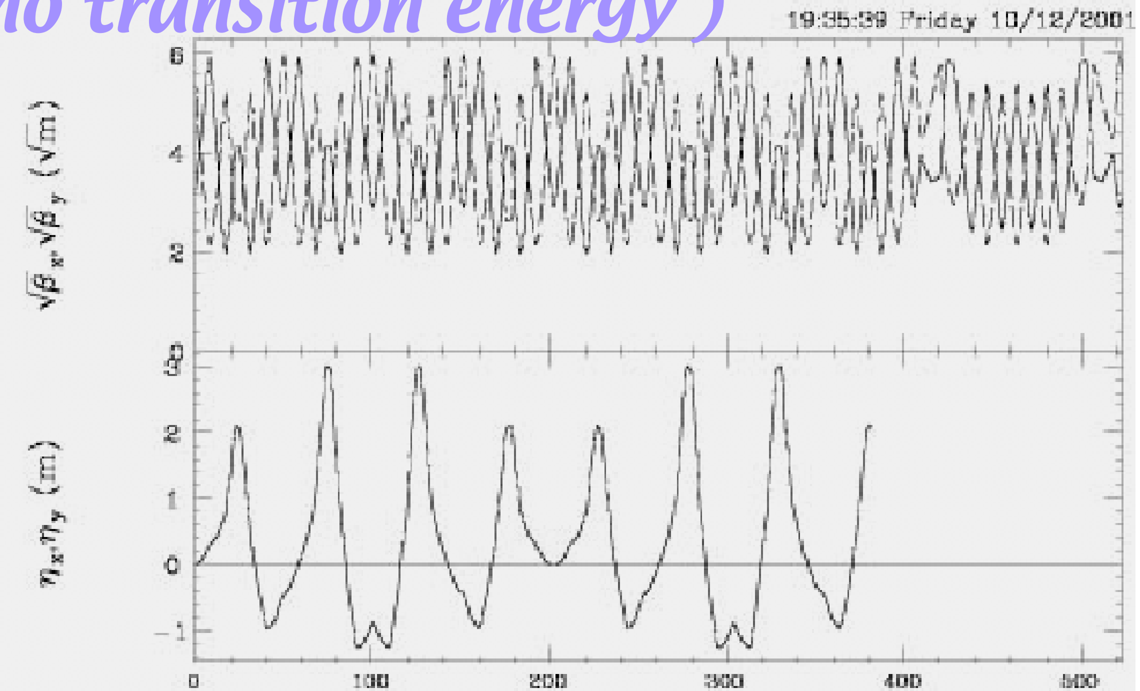
Lattice of 50GeV PS

* Negative dipspersion at bending magnets :

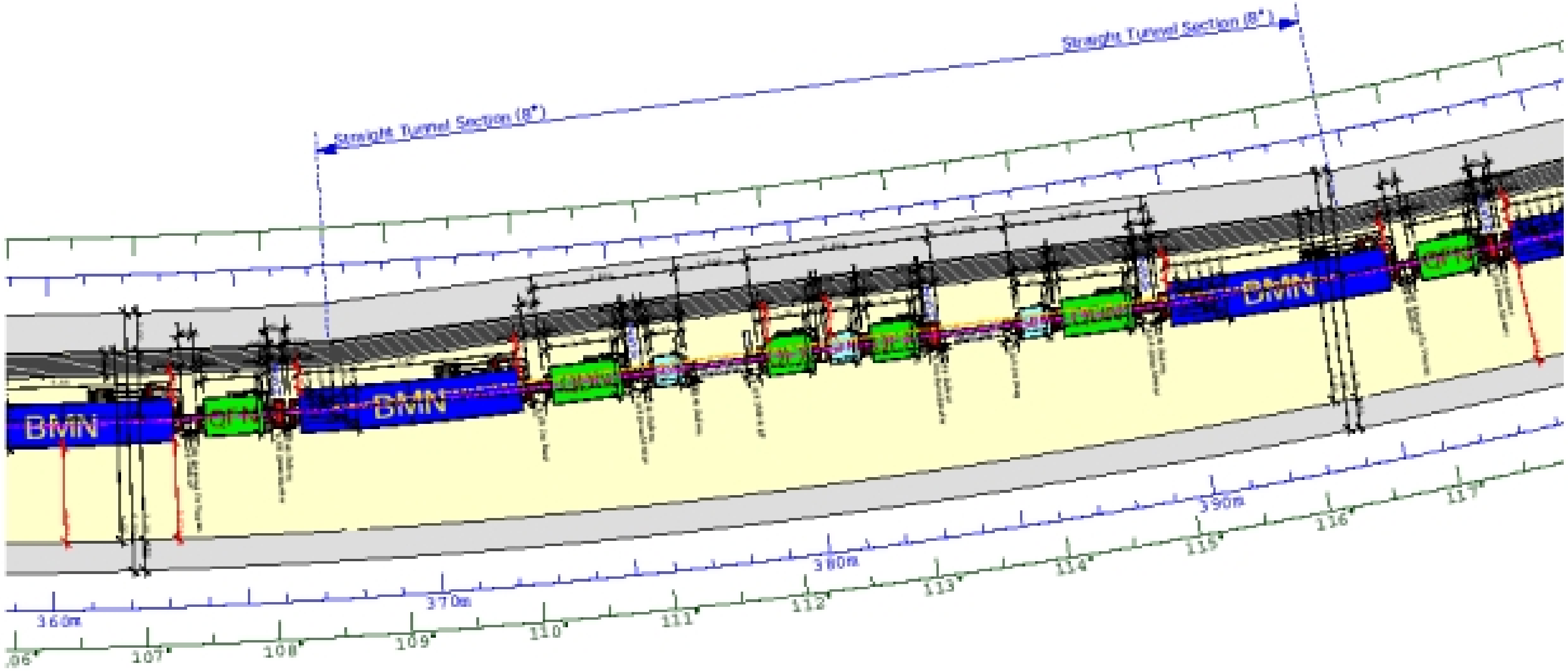
missing-bend structure

*Imaginary transition gamma :

g -> 32i (no transition energy)

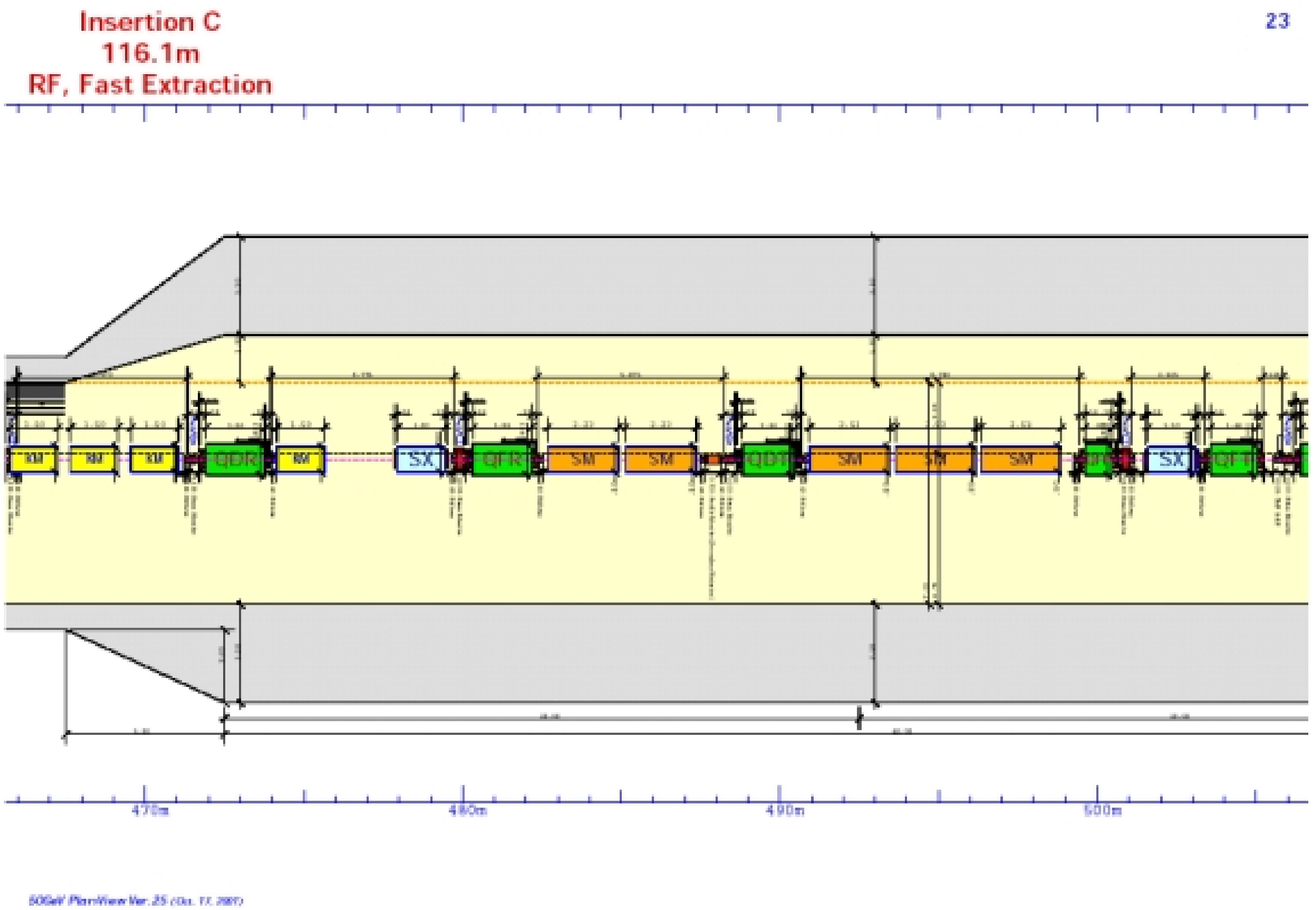


Layout of Magnets (Missing Bend. Mag. Section)



50GeV PlanView Ver.25 (Oct 17, 2001)

Layout of Magnets (Fast Extraction)



Hardware R&D

1) Magnets
   - 1.9 T - D magnet, large bore Q magnet

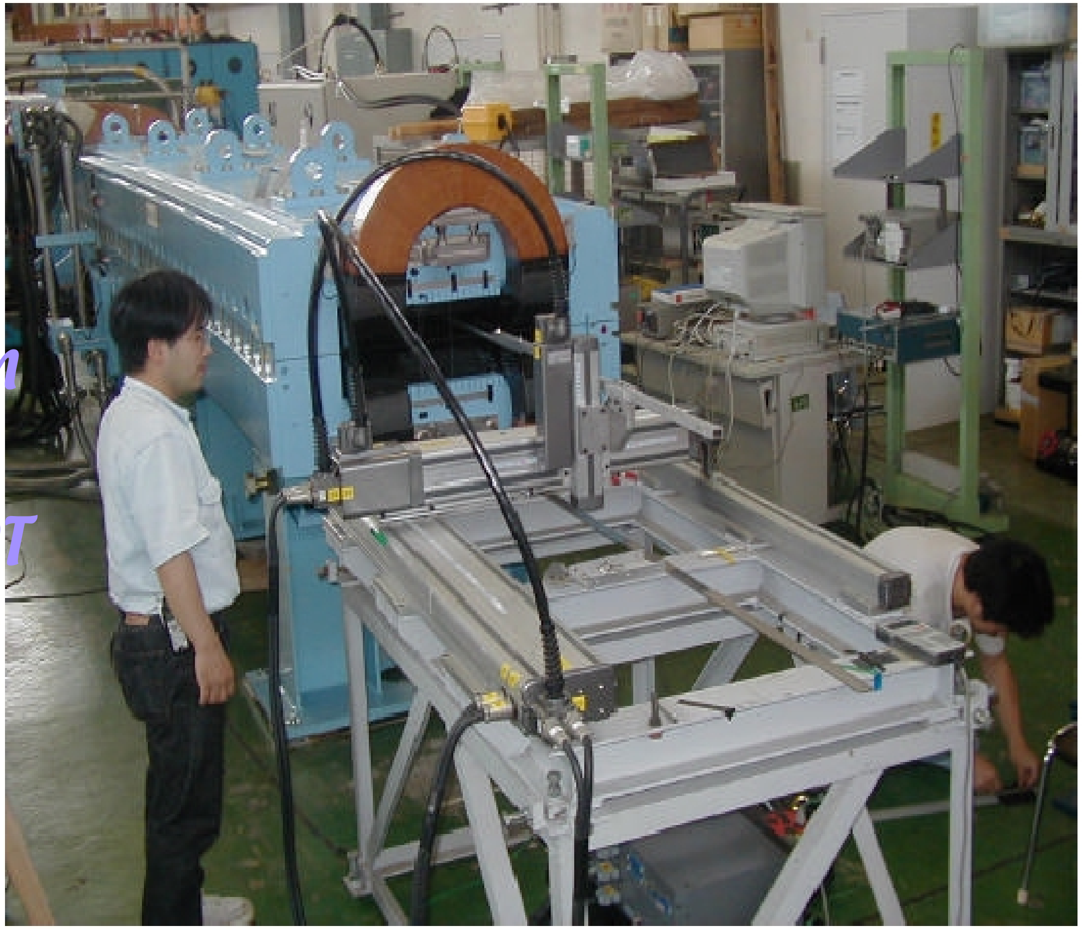
2) Magnet Power Supply
   - low ripple & 100% power factor with IGBT

3) RF System
   - High gradient RF cavity with Magnetic Alloy

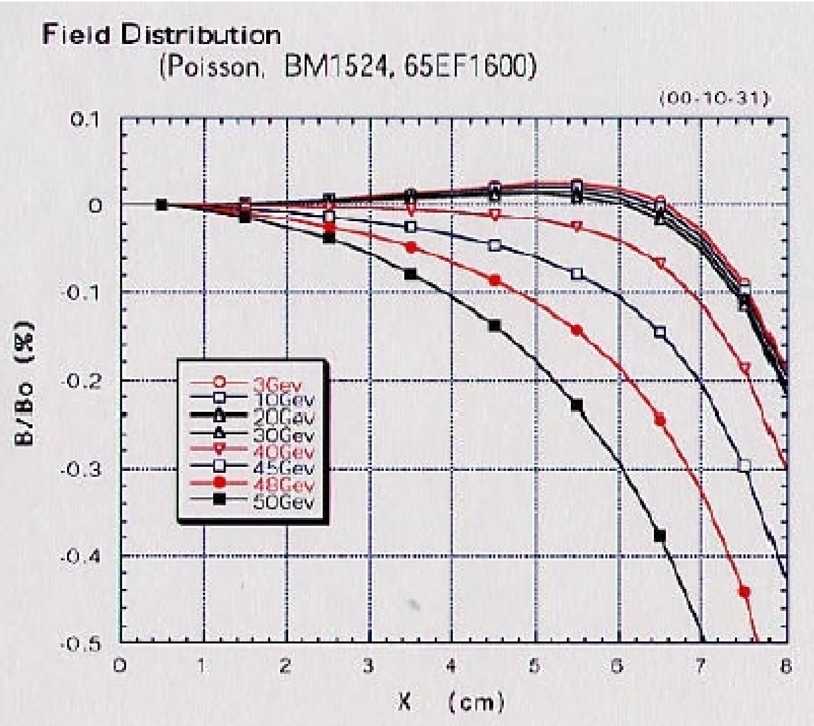
4) Electro-static Septum
   - Small beam loss at slow beam extraction

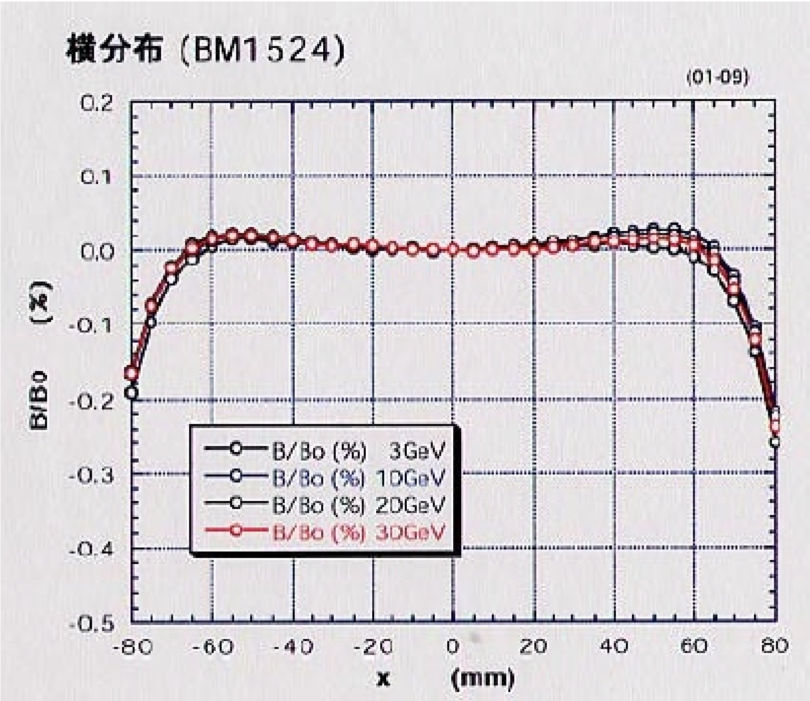
Dipole Magnet for 50GeV PS (R&D)

Gap Height	106mm
Useful Aperture	120mm
Field	0.143-1.9T
Length	5.85m



Field Measurement : Dipole Magnet (R&D)



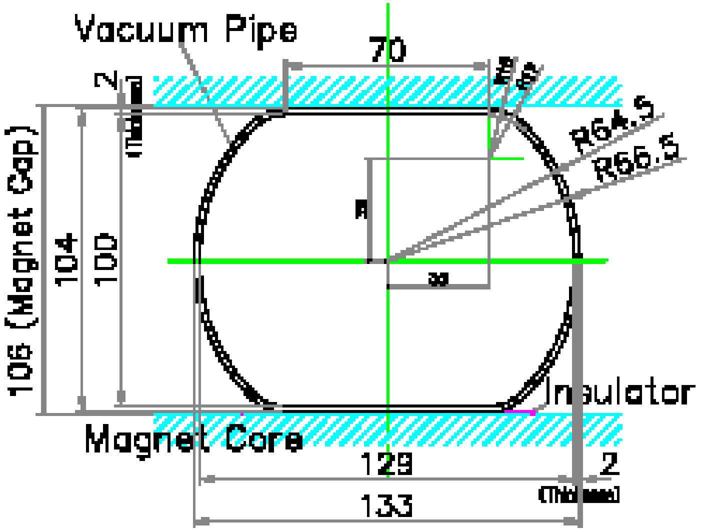


Good agreement with calculation

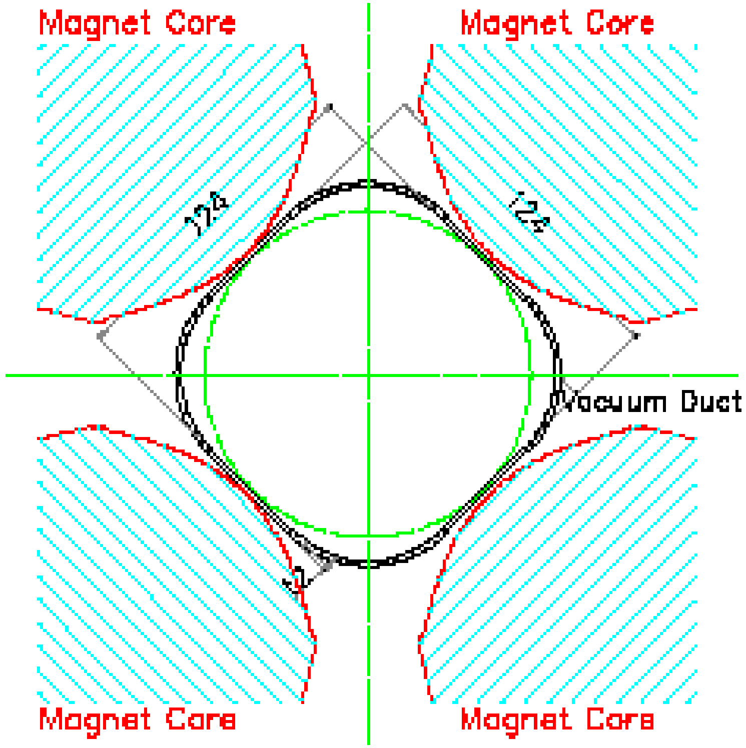
Quadrupole Magnet of 50GeV PS (R&D)

Bore Radius 63mm
Usefule Ap. 132mm
Max. Field 18T/m
Length(max.) 1.86m

Vacuum Duct



bending magnet



quadrupole magnet

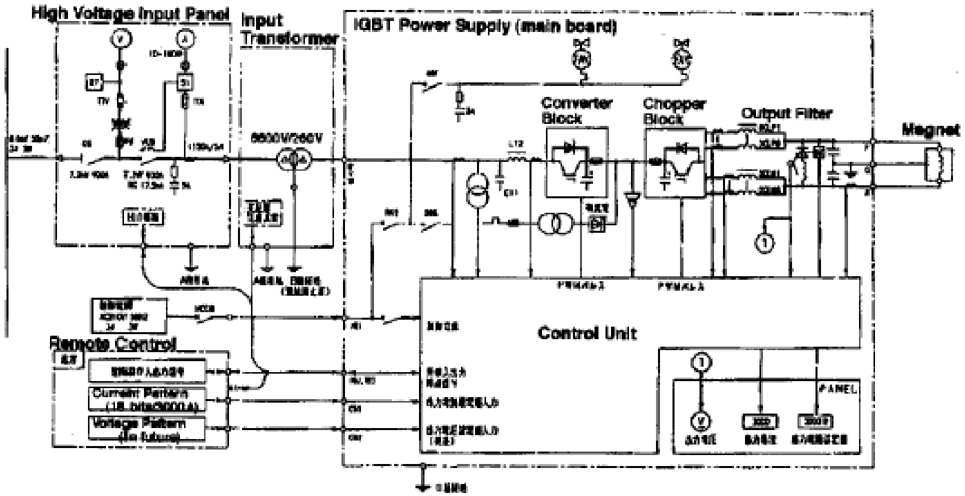
Magnet Power Supply

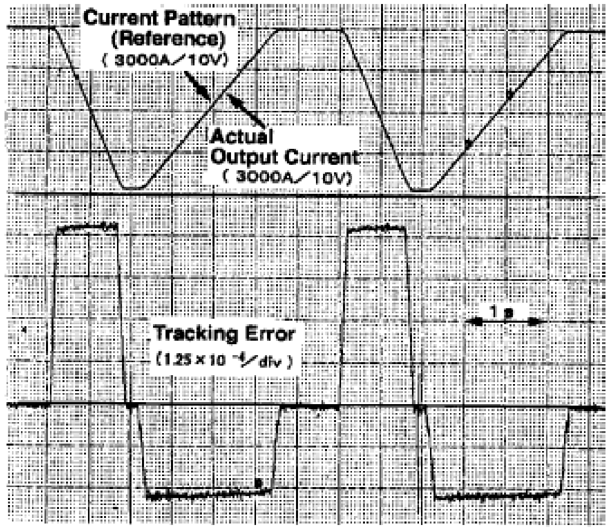
* development of new type high power switching devices (IGBT, IEGT)

accelerator	year	spec.	w.f.	conv.
INS-ES	1962	21.5Hz	sin.	MG
KEK-booster	1974	20Hz	sin.	SCR
KEK PS	1976	0.5Hz	trape.	SCR
SPring-8 syn.	1996	1Hz	trape.	SCR
Tsukuba U.	2000	0.4Hz	trape.	IGBT

Magnet Power Supply (R&D)

* conver-chopper type (high freq. switch. ~80kHz)
* no reactive power -> 100 % power factor
* ripple ~ 10^{-6}
* tracking error ~10^{-4}

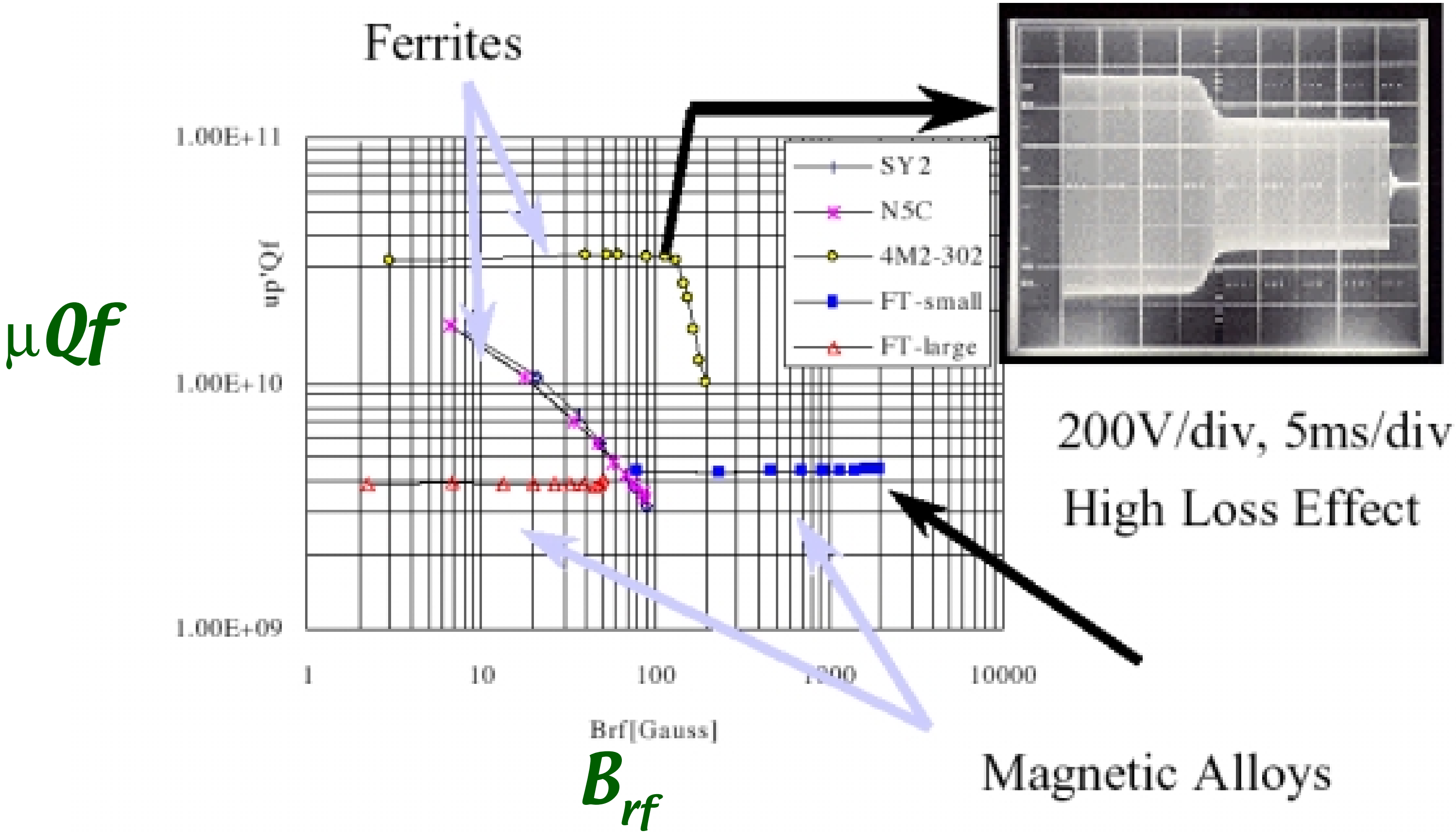




RF Cavity with Magnetic Alloy

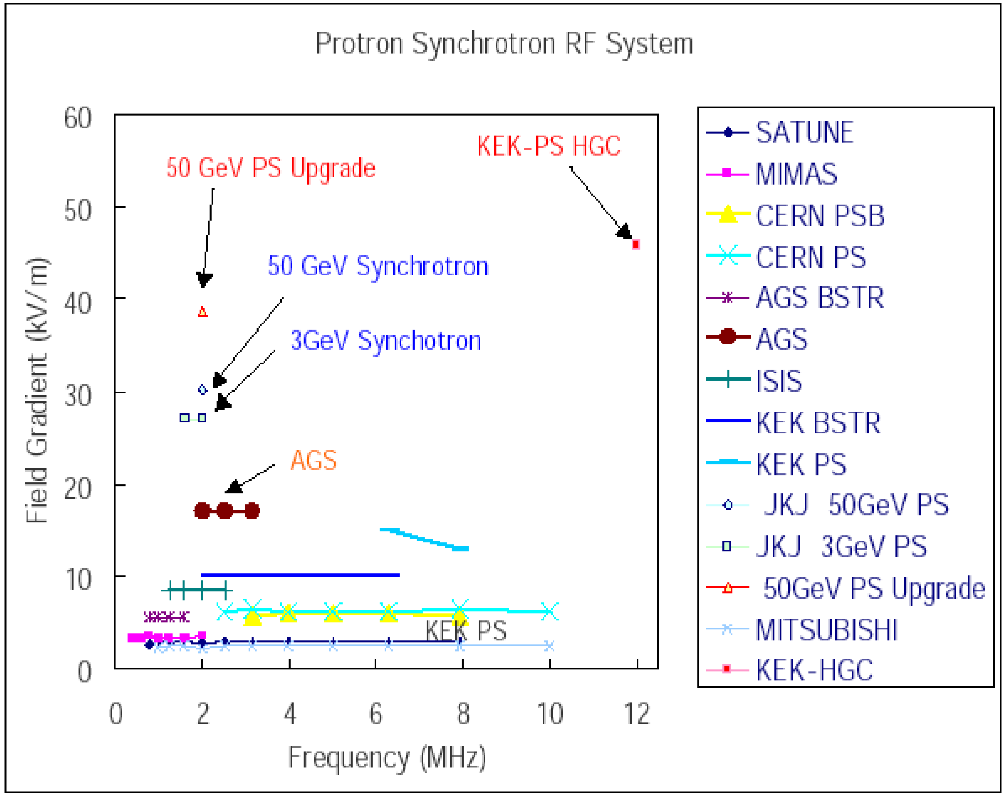
* RF behaviour at high field

μQf (shunt.imp.) vs. B_{rf}



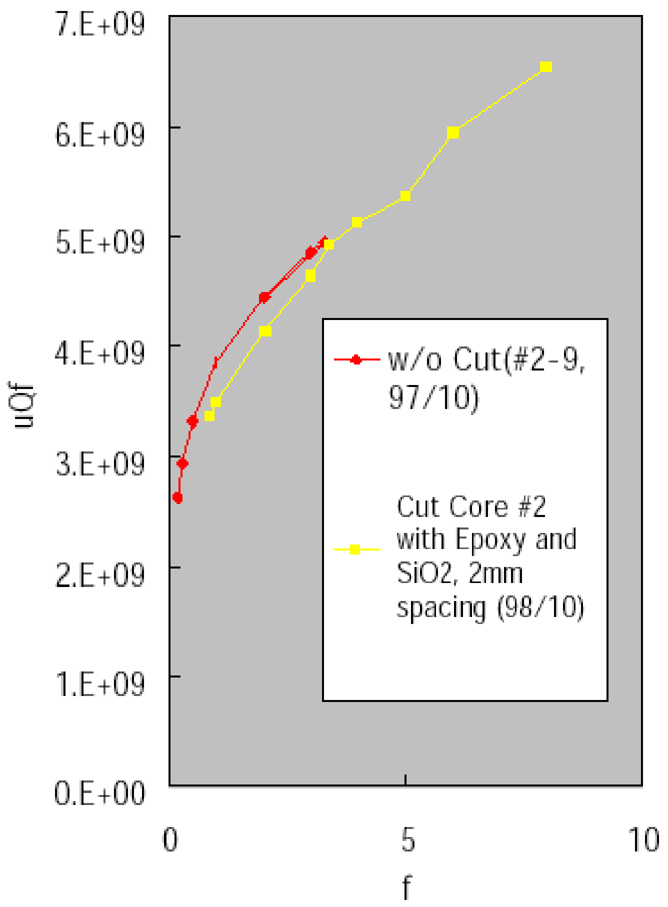
High Field Gradient RF Cavity with Magnetic Alloy (MA Cavity)

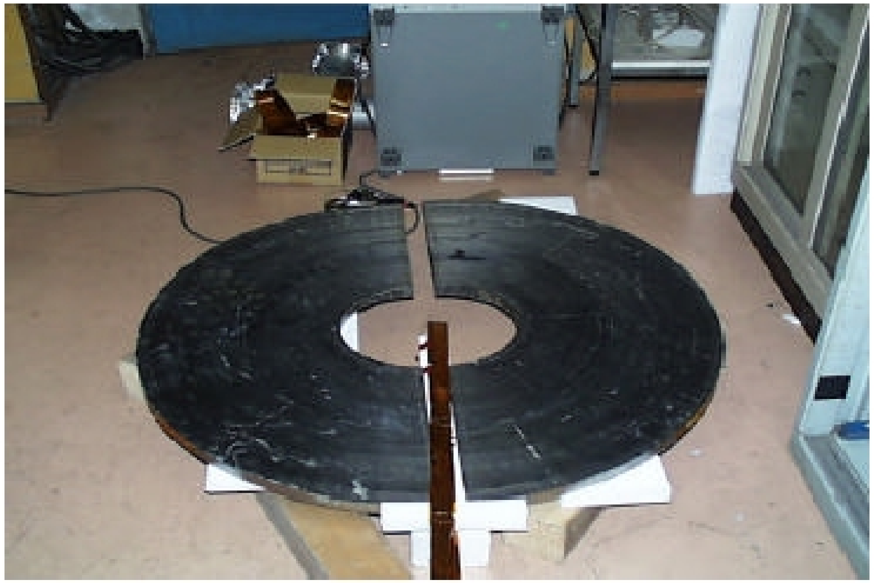
Field Gradient of RF Cavity



MA Cavity - Cut Core

** Increase of Q-value with cut core -> beam loading*





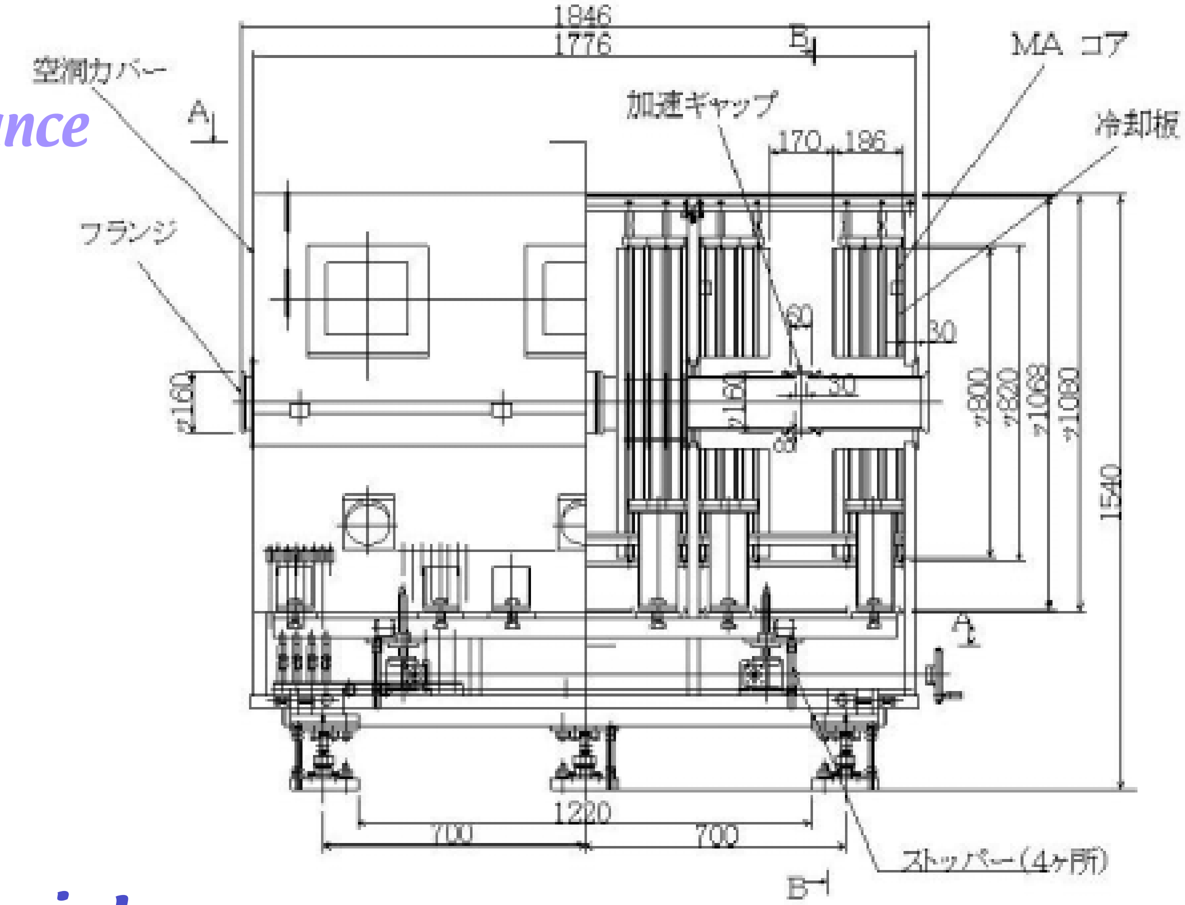
High Gradient MA Cavity (R&D)

* Cooling (indirect)

-copper cooling plate

-keeping high shunt impedance

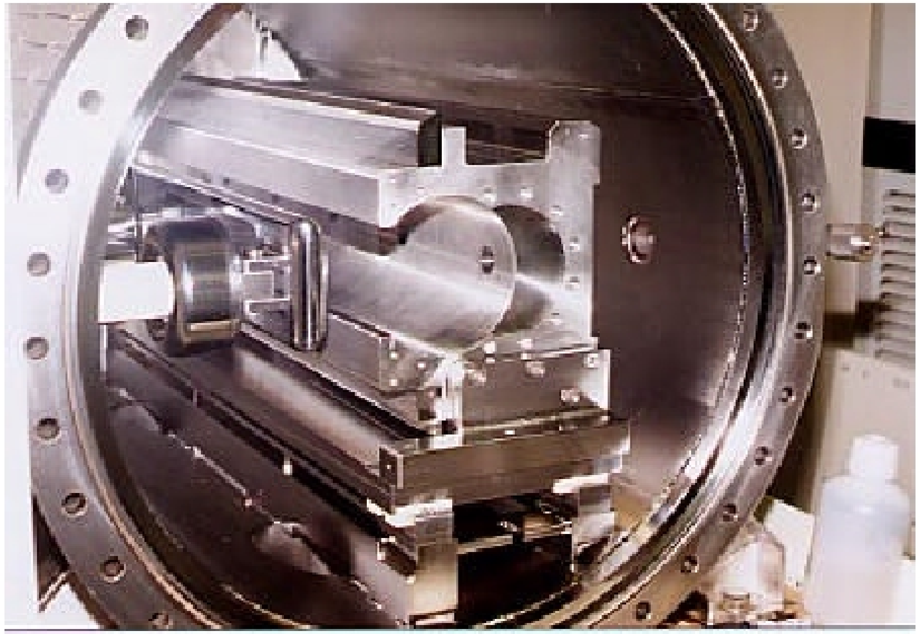
core cutting with water-jet



MA Caivty

Electro-static Septum (R&D)

* High Field -> 237kV (1.4 x design voltage)
* Need high quality ceramic feedthrough



Future

* Neutrino Factory (Japanese scenario) - FFAG based
* 50GeV PS as Proton Driver of 1-4 MW