

## List of Authors

0 Preface	Yoshishige YAMAZAKI
1 Overview	Yoshishige YAMAZAKI
2 Beam Dynamics Design	
2.1 Linac	
2.1.1 Fundamental design	Takao KATO and Yoshishige YAMAZAKI
2.1.2 Ion Source, LEBT, RFQ	Akira UENO, Yasuhiro KONDO, Kiyoshi IKEGAMI, and Hidetomo OGURI
2.1.3 MEBT1, DTL, SDTL	Takao KATO, Shinian FU, and Sheng WANG
2.1.4 MEBT2, ACS	
2.1.4.1 ACS	Masanori IKEGAMI and Takao KATO
2.1.4.2 MEBT2	Masanori IKEGAMI, Takao KATO, and Kazuo HASEGAWA
2.1.4.3 Simulation from the DTL to the ACS	Masanori IEKGAMI and Takao KATO
2.1.5 BT to 3-GeV Ring	Takao KATO, Kazami YAMAMOTO, Masanori MATSUOKA, Tomihiro OHKAWA, Kazuo HASEGAWA, Masanori IKEGAMI, Yoshito SHIMOSAKI, and Yoshiro IRIE
2.1.6 Superconducting Linac and MEBT-3	Kazuo HASEGAWA, Nobuo OUCHI, and Ken MUKUGI
2.2 3GeV Rapid-Cycling Synchrotron (RCS)	
2.2.1 Introduction	Fumiaki NODA and Kenta SHIGAKI
2.2.2 Beam Optics Design	Fumiaki NODA and Kenta SHIGAKI
2.2.2.5 Fringe field effects and Dynamic aperture	Alexander MOLODOJENTSEV
2.2.3 Injection, Beam Collimation and Extraction	
2.2.3.1 Injection	Fumiaki NODA and Izumi SAKAI
2.2.3.2 Beam Collimation	Kazami YAMAMOTO, Yoshiro IRIE, and Fumiaki NODA
2.2.3.3 Extraction	Kenta SHIGAKI and Fumiaki NODA
2.2.4 RF Acceleration	Masanobu YAMAMOTO, Eizi EZURA, Yoshinori HASHIMOTO, Chihiro OHMORI, Alexander SCHNASE, Akira TAKAGI, Fumihiko TAMURA, Tomonori UESUGI, and Masahito YOSHII
2.2.5 Emittance Blow-up and Halo-formation	Ken TAKAYAMA, Toshikazu ADACHI, Susumu IGARASHI, Shinji MACHIDA, Fumiaki NODA, Kenta SHIGAKI, Yoshito SHIMOSAKI, Masashi SHIRAKATA, and Norio TANI
2.2.6 Beam Transport to Neutron and Muon Production Targets	Hiroshi FUJIMORI, Masahide HARADA, Tetsuya KAI, Naokatsu KANEKO,

	Yoshimi KASUGAI, Chikara KONNO, Shin-ichiro MEIGO, Suguru MUTO, and Shinichi SAKAMOTO
2.2.7 Beam Transport to 50-GeV MR	Yoshihiro ISHI, Takeichiro YOKOI, Atsutoshi MUTO, Shin-ichiro MEIGO, Shinji MACHIDA, Yoshiharu MORI, and Masahito TOMIZAWA
2.3 50-GeV Main Ring	
2.3.1 Introduction	Yoshiharu MORI
2.3.2 Beam Optics Design	Shinji MACHIDA, Alexander MOLODOJENTSEV, Yoshihiro ISHI, Shinji SHIBUYA, and Yoshiharu MORI
2.3.3 Injection, Beam Collimation	Yoshihiro ISHI, Takeichiro YOKOI, Shinji MACHIDA, Yoshiharu MORI, Yoshihisa SHIRAKABE, and Masahito TOMIZAWA
2.3.4 Fast Extraction	Masahito TOMIZAWA, Yoshihiro ISHI, Shinji MACHIDA, and Yoshimasa YUASA
2.3.5 Slow Extraction	Masahito TOMIZAWA, Yoshitsugu ARAKAKI, Shinji MACHIDA, and Noboru TOKUDA
2.3.6 RF Acceleration	Tomonori UESUGI, Yoshinori HASHIMOTO, Chihiro OHMORI, Masanobu YAMAMOTO, Akira TAKAGI, Yoshiharu MORI, Alexander SCHNASE, Masahito YOSHII, Eizi EZURA, and Fumihiko TAMURA
2.3.7 Emittance Growth, Beam Instability	Shinji MACHIDA and Alexander MOLODOJENTSEV
2.3.8 Electron Proton Two Stream Instability	
2.3.8.1 Electron cloud build-up and e-p instability	Takeshi TOYAMA, Kazuhito OHMI, and Chihiro OHMORI
2.3.8.2 Secondary Electron Emission from Metals and Graphites	Shigeki KATO and Michiru NISHIWAKI
3 Component Design, R&D Strategy & Results, Construction Status	
3.1 Linac	
3.1.1 Ion Source	Hidetomo OGURI, Yuya NAMEKAWA, Takashi SHIMOOKA, Yoshikazu OKUMURA, Kazuo HASEGAWA, Akira UENO, Kiyoshi IKEGAMI, Yasuhiro KONDO, and Norihiko KAMIKUBOTA
3.1.2 Accelerating Structure and Beam Transport	
3.1.2.1 LEBT	Akira UENO, Yasuhiro KONDO, and Kiyoshi IKEGAMI
3.1.2.2 RFQ	Yasuhiro KONDO, Akira UENO, Kazuo HASEGAWA, Jun-ichi SAWADA, Kiyoshi IKEGAMI, Chikashi KUBOTA, Eiichi KADOKURA, Shuichi NOGUCHI,

3.1.2.3	MEBT1	Masashi OKADA, Shigeaki ARAI, Masato KAWAMURA, and Seiya YAMAGUCHI Takao KATO, Kazuo YOSHINO, Sheng WANG, Zenei IGARASHI, Masanori IKEGAMI, Jun-ichi KISHIRO, Chikashi KUBOTA, Fujio NAITO, Eiichi TAKASAKI, Seiya YAMAGUCHI, Yoshishige YAMAZAKI, Kazuo HASEGAWA, and Takashi ITO
3.1.2.4	DTL, SDDL	Fujio NAITO, Kazuo YOSHINO, Takao KATO, Zenei IGARASHI, Jun-ichi KISHIRO, Chikashi KUBOTA, Eiichi TAKASAKI, Masanori IKEGAMI, Yuji FUKUI, Masato KAWAMURA, Seiya YAMAGUCHI, Yoshio SAITO, Yoshishige YAMAZAKI, Shin-ichi KOBAYASHI, Kentaro SEKIKAWA, Msahito SHIBUSAWA, Kazuo HASEGAWA, and Takashi ITO
3.1.2.5	ACS	Noriyosu HAYASHIZAKI, Valentine V. PARAMONOV, Yoshishige YAMAZAKI, Takao KATO, Masanori IKEGAMI, Kazuo HASEGAWA, Hiroyuki AO, Satish C. JOSHI, and Leonid V. KRAVCHUK
3.1.2.6	Superconducting Linac	Shuichi NOGUCHI, Nobuo OHUCHI, Masanori MATSUOKA, Osamu TAKEDA, Nobuo AKAOKA, Ken MUKUGI, Toshihiro OHTANI, Hiroyuki ASANO, Kenji SAITO, Eiji KAKO, Toshio SHISHIDO, Kiyosumi TSUCHIYA, Norihito OHUCHI, Hiroyuki AO, and Kazuo HASEGAWA
3.1.2.7	BT to RCS	Masanori MATSUOKA, Kazuo HASEGAWA, Kazami YAMAMOTO, Yoshito SHIMOSAKI, Yoshiro IRIE, and Ken TAKAYAMA
3.1.2.8	Alignment	Masanori IKEGAMI, Yasuo HIGASHI, Fujio NAITO, and Takao KATO
3.1.3	RF Power Source	
3.1.3.1	Overview	Shozo ANAMI
3.1.3.2	324-MHz Klystron	Shigeki FUKUDA, Shozo ANAMI, Etsuji CHISHIRO, Chikashi KUBOTA, and Seiya YAMAGUCHI
3.1.3.3	972-MHz Klystron	Shigeki FUKUDA, Shozo ANAMI, Etsuji CHISHIRO, Chikashi KUBOTA, and Seiya YAMAGUCHI
3.1.3.4	Klystron Power Supply	Masaaki ONO, Shozo ANAMI, Etsuji CHISHIRO, Masato KAWAMURA, and Chikashi KUBOTA
3.1.3.5	Waveguides	Seiya YAMAGUCHI, Shozo ANAMI, Etsuji CHISHIRO, and Kazuaki SUGANUMA

- 3.1.3.6 RF Drive and Control System Tetsuya KOBAYASHI, Shinichiro MICHIZONO, Seiya YAMAGUCHI, and Shozo ANAMI
- 3.1.3.7 Chopper Driving System Seiya YAMAGUCHI, Shozo ANAMI, and Takao KATO
- 3.1.4 Vacuum System Yoshio SAITO, Chikashi KUBOTA, and Noriyosu HAYASHIZAKI
- 3.1.5 Beam Instrumentation Fumio HIROKI, Zenei IGARASHI, Jun-ichi KISHIRO, and Tetsuo TOMISAWA
- 3.2 RCS
- 3.2.1 Magnets and Power Supplies
- 3.2.1.1 Design of RCS Magnets Norio TANI
- 3.2.1.2 Resonant Network System Fengqing ZHANG, Yasuhiro WATANABE, Shoichiro KOSEKI, Toshikazu ADACHI
- 3.2.1.3 Eddy Current Effect Norio TANI
- 3.2.2 Injection, Beam Collimation, Extraction
- 3.2.2.1 Research and Development of Long-Lived Thick Carbon Stripper Foils Isao SUGAI, Yasuhiro TAKEDA, Michihiro OYAIZU, Hirokane KAWAKAMI, Yoshiro IRIE, Yoshio ARAKIDA, Izumi SAKAI, Isao YAMANE, Michikazu KINSHO, and Katsuya KURAMOCHI
- 3.2.2.2 Kickers Tadamichi KAWAKUBO, Shigeru MURASUGI, Eiji NAKAMURA, Kenta SHIGAKI, Taihei SHIMADA, Tomohiro TAKAYANAGI, and Shichiro TAZAWA
- 3.2.2.3 Septum Magnets Taihsei SHIMADA
- 3.2.2.4 Bump Magnets Izumi SAKAI, Tomohiro TAKAYANAGI, and Taihei SHIMADA
- 3.2.2.5 Collimator Hardware Design Kazami YAMAMOTO, Michikazu KINSHO, and Yoshiro IRIE
- 3.2.2.6 H<sub>0</sub> Beam Dump System Michikazu KINSHO, Katsuya KURAMOCHI, and Kazami YAMAMOTO
- 3.2.3 Vacuum System Yoshio SAITO, Michikazu KINSHO, Daiji NISHIZAWA, Tomio KUBO, Takeshi TOYAMA, and Hiroshi TSUTSUI
- 3.2.4 Beam Instrumentation Dai ARAKAWA, Naoki HAYASHI, Jun-ichi KISHIRO, Norio TANI, Takeshi TOYAMA, Ryoji TOYOKAWA, and Yuichi YAMAMOTO
- 3.2.5 Beam Transport Components to Neutron and Muon Production Targets Hiroshi FUJIMORI, Masahide HARADA, Tetsuya KAI, Naokatsu KANEKO, Yoshimi KASUGAI, Chikara KONNO, Shin-ichiro MEIGO, Suguru MUTO, and Shinichi SAKAMOTO
- 3.2.6 Beam Transport Components to 50-GeV Synchrotron Masahito TOMIZAWA, Yoshiharu MORI,

	Atsutoshi MUTO, Masayuki MUTO, Ario NAKAMURA, Yoshio SAITO, Masashi SHIRAKATA, Takeshi TOYAMA, Masahiko UOTA, and Takeichiro YOKOI
3.3 50GeV MR	
3.3.1 Magnets and Power Supplies	Masayuki MUTO, Kazuaki NIKI, Eiichi YANAOKA, Kazumi EGAWA, Hikaru SATO, and Tsuyoshi SUENO
3.3.2 Injection, Extraction, Beam Collimation, Beam Abort, Beam Dump	
3.3.2.1 Kicker	Yoshihisa SHIRAKABE, Izumi SAKAI, Akira TAKAGI, Masayuki MUTO, Masahito TOMIZAWA, Yoshiharu MORI, and Yoshihiro ISHI
3.3.2.2 Septum	Izumi SAKAI, Noboru TOKUDA, Yoshitsugu ARAKAKI, and Masahito TOMIZAWA
3.3.2.3 Beam halo scraper	Takeichiro YOKOI, Yasuo SATO, and Masahito TOMIZAWA
3.3.2.4 Beam Abort and Dump	Masahito TOMIZAWA, Yoshinori HASHIMOTO, and Takeichiro YOKOI
3.3.3 Vacuum System	Masahiko UOTA, Yoshio SAITO, Yoshimasa YUASA, Yoshihisa SHIRAKABE, Masahito TOMIZAWA, Masayuki SATOH, Yoshihide MORIMOTO, Shinichiro MICHIZONO, and Ken-ichi KANAZAWA
3.3.4 Beam Instrumentation	Takeshi TOYAMA, Dai ARAKAWA, Yoshinori HASHIMOTO, Junichi KISHIRO, and Ario NAKAMURA
3.4 RF Acceleration System	Tomonori UESUGI, Yoshinori HASHIMOTO, Chihiro OHMORI, Masanobu YAMAMOTO, Akira TAKAGI, Yoshiharu MORI, Alexander SCHNASE, Masahito YOSHII, Eizi EZURA, and Fumihiko TAMURA
3.5 Synchronization	Tomonori UESUGI, Yoshinori HASHIMOTO, Chihiro OHMORI, Masanobu YAMAMOTO, Akira TAKAGI, Yoshiharu MORI, Alexander SCHNASE, Masahito YOSHII, Eizi EZURA, and Fumihiko TAMURA
4 Tunnel Design, Component Layout, Maintenance Scenario	
4.1 Linac	Hiroshi YOSHIKAWA, Naoki NAKAMURA, Fumihiko MASUKAWA, Kazuhiro SUGANUMA, Seiya YAMAGUCHI, Takashi Horiguchi, Masao NAKATANI, Hiroyuki YAMADA, and Toshiyuki KITAMI
4.2 RCS	Hiromitsu SUZUKI, Kazami YAMAMOTO, Naoki HAYASHI, Kenta SHIGAKI, Jun-ichi KISHIRO, Michikazu KINSHO, Taihei SHIMADA, Fengqing ZHANG,

	Yasuhiro WATANABE, Norio TANI, Kenichiro KANAZAWA, Fumihiko TAMURA, Masanobu YAMAMOTO, Yoshiro IRIE, Daiji NISHIZAWA, and Fumiaki NODA Masahito TOMIZAWA, Yoshiharu MORI, Masayuki MUTO, Yoshihisa SHIRAKABE, and Yoshimasa YUASA
4.3 MR	
5 Control System	
5.1 Introduction	Junsei CHIBA
5.2 EPICS	
5.2.1 Basic architecture of the control system	Noboru YAMAMOTO
5.2.2 What is EPICS	Noboru YAMAMOTO
5.2.3 Usable Modules for Device control	Junsei CHIBA
5.3 Network	Kazuro FURUKAWA
5.4 Higher Level Applications and Operator Interface	Kazuro FURUKAWA
5.5 Database	Norihiko KAMIKUBOTA
5.6 Personnel Protection System	Yasunori TAKEUCHI
6 Timing System	Masahito YOSHII, Fumihiko TAMURA, Hitoshi KOBAYASHI, Akira TAKAGI, Eiichi KADOKURA, and Junsei CHIBA
7 Building, Cooling Water, Electricity, Air-Conditioning	
7.1 Linac	Hiroshi YOSHIKAWA, Naoki NAKAMURA, Keisuke IZUMI, Shinji KAWAMOTO, Michio ONOZAKI, Hiroyuki YAMADA, and Yasufusa NIIKAWA
7.2 RCS	Hiromitsu SUZUKI, Yoshio TANABE, Kazami YAMAMOTO, Michikazu KINSHO, Naoki HAYASHI, Kenta SHIGAKI, Taihei SHIMADA, Fengqing ZHANG, Yasuhiro WATANABE, Norio TANI, Kenichiro KANAZAWA, Fumihiko TAMURA, Masanobu YAMAMOTO, Yoshiro IRIE, Daiji NISHIZAWA, Fumiaki NODA, Michio ONOZAKI, Keisuke IZUMI, Shinji KAWAMOTO, Masahito YOSHII, and Chihiro OHMORI
7.3 MR	Masahito TOMIZAWA, Masaharu NUMAJIRI, Yoshiharu MORI, and Masayuki MUTO
8 Radiation Safety	
8.1 Introduction	Nobuo SASAMOTO and Takenori SUZUKI
8.2 Shielding Design for the Linac	Fumihiko MASUKAWA and Yoshihiro NAKANE
8.3 3-GeV synchrotron	Yoshihiro NAKANE, Noriaki NAKAO, Kazami YAMAMOTO, and Fumihiko MASUKAWA

- 8.4 50-GeV Synchrotron Masaharu NUMAJIRI, Masahito TOMIZAWA,  
and Takenori SUZUKI
- 8.5 Proton Beam Line between 3-GeV RCS and Materials and Life Science Facility  
Chikara KONNO
- 8.6 Annual Production of Radioactive Gas and Liquid and the Annual Total Exhaust  
Nobuo SASAMOTO, Takenori SUZUKI,  
and Hiroshi NAKASHIMA
- 8.7 Effective Dose due to an Abnormal Incident  
Nobuo SASAMOTO and Takenori SUZUKI
- 9 Schedule and Commissioning Strategy Hitoshi KOBAYASHI

**Editorial Board:**

Yoshishige YAMAZAKI, Editor in Chief;  
Kazuo HASEGAWA, Masanori IKEGAMI,  
Yosiro IRIE, Takao KATO, Hitoshi KOBAYASHI,  
Shinji MACHIDA, Yoshiharu MORI,  
Fumiaki NODA, Hiromitsu SUZUKI,  
Masahito TOMIZAWA, and Hiroshi YOSHIKAWA

**Editorial Staff:**

Noriko KANAZAWA