



Operation Status of J-Parc Timing System and Future Plan



N. Kamikubota, N. Kikuzawa, F. Tamura, N. Yamamoto
J-Parc, KEK and JAEA, Tokai-mura, Ibaraki, Japan

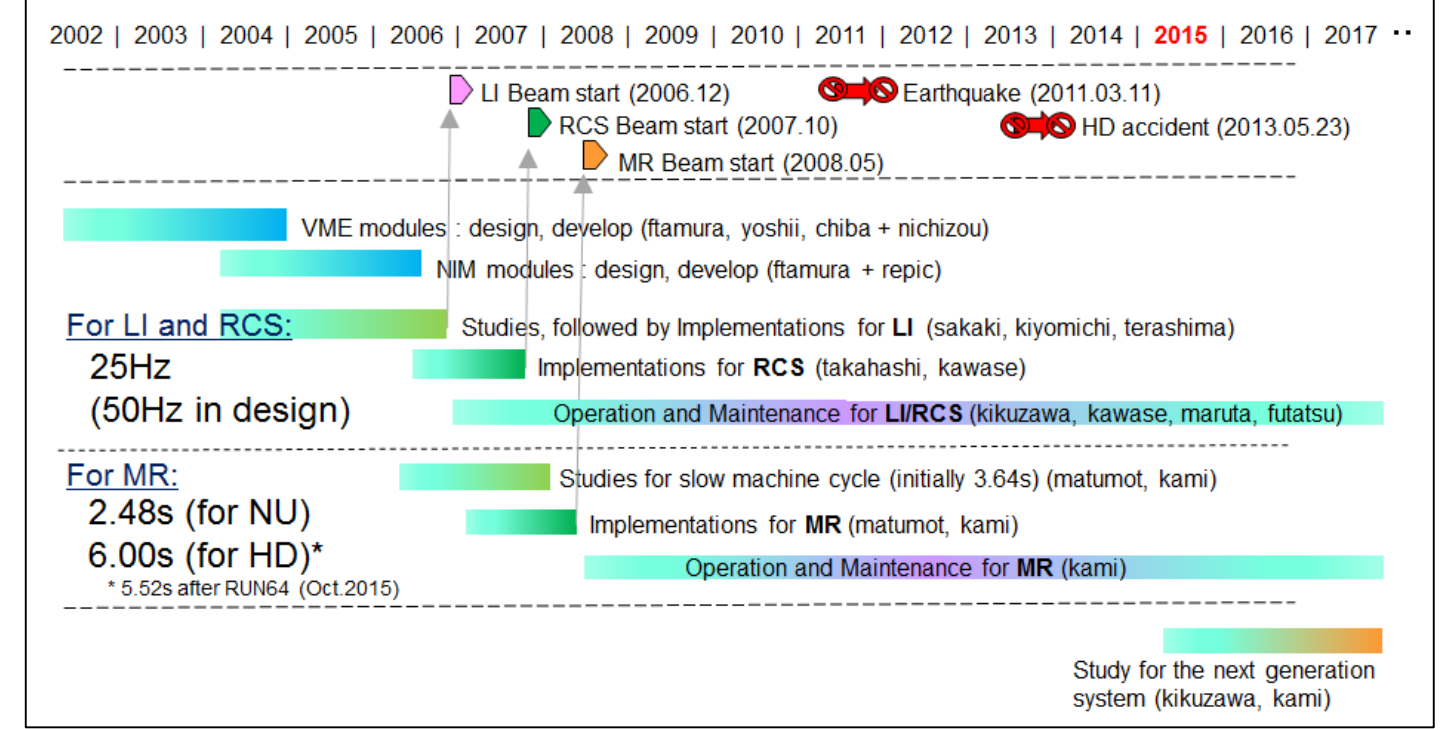
Summary

- J-Parc Timing hardware was developed roughly 10 years before, in collaboration with domestic companies
- Timing software was developed in house
- Rapid-cycle and slow-cycle co-exist
- Since 2006, the timing system has been used successfully in accelerator operation, with good enough reliability
- We start discussion on possible migration and extension for the next decade

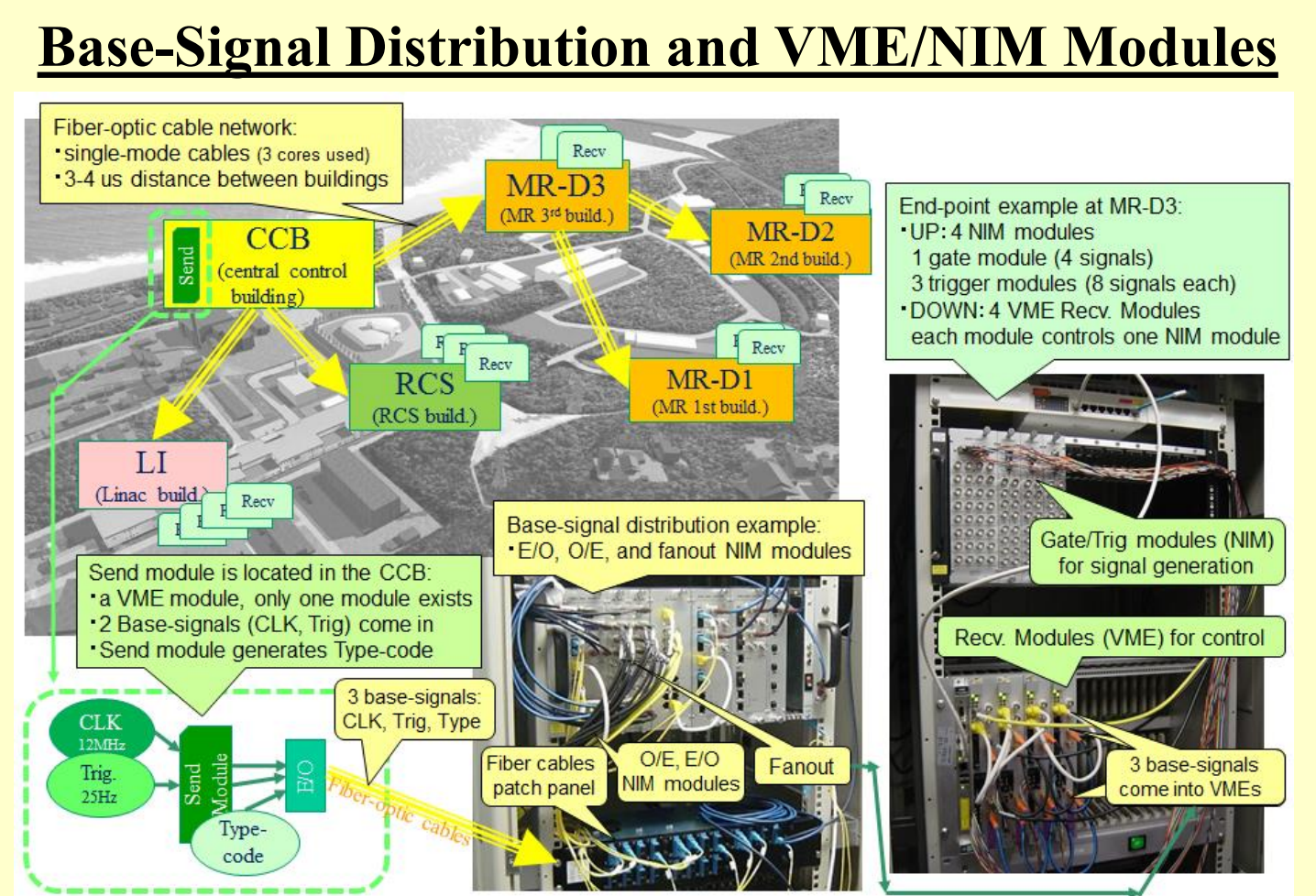
Facts in short

- J-Parc is an accelerator complex located in Ibaraki, Japan
 - Rapid cycle: LI(400MeV Linac) and RCS(3GeV) - 25Hz
 - Slow cycle: MR(30GeV Main Ring) - 2.48s or 6.00s (5.52s after Oct.2015)
- Hardware
 - Home-design VME modules for control, NIM modules for signal generation
 - Base signals (clock, trigger, type-code) are distributed over the facility buildings, using the fiber-optic cable network
- Software
 - EPICS and its tools are used in general
 - Java and python are preferred for table(waveform)-data handlings
- Scale of the system
 - One send-module
 - LI/RCS/MR - 118/43/45 VME receiver-modules, ~540/220/300 endpoints

J-Parc timing: History Overview



Timing System Details



Send module ; type-sequence and type-code

A send module:

- has a type-memory, which consists of 64 type-sequences
- uses one selected type-sequence at a moment
- sends the type-code in the selected type-sequence one byte-one at the 25Hz trigger rate

One type-sequence:

- can contain 256 type-codes at maximum
- corresponds to one machine-cycle; 62(150) type-codes for 2.48s(6.00s)
- has 4 subsections; M1(MSB+ spare 7bit), M2(8bit for LI), M3(8bit for RCS), and M4(8bit for MR)
- MSB is used to notify the end of the type-sequence

Example of type-sequence:

- The "563" sequence is for MLF-25Hz-MR-2.48s operation
- 62 type-codes; consists of 56 for MLF, 4 for MR, 2 empty
- LI/RCS uses the M2(M3) subsection
- "10" every 25Hz as a standard shot to MLF
- "20" to "29", "56" are shots to MR injection
- "24" to "25", "56", means empty - "no beam"
- "the 26", "30" corresponds to a MLF shot with residual magnetic-field corrections caused by the MLF-MR switching magnet
- MR uses the M4 subsection
- every 4 shots (160ms), the code is incremental "41", "42", "43", "44", ...

Example of type-code:

The 20th type-code in the type-seq "563" is 00-66-66-46
in which 66 for LI, 66 for RCS, 46 for MR.

A Java application GUI for a send-module control

During MR injection (red area), according to received type-codes

Receiver module ; LUT and delay-word

A receiver module:

- must select one of four subsections; ex) M2 for LI, M4 for MR
- has a Look-up table (LUT), which contains 256x8bit delay-words
- contains 24bit delay value and control bits
- has a MSB(31st), which is used to disable output
- has a special control-bit(30th), to continue delay counting without reset
- The 24bit delay count runs using 96MHz clock after receiving the 25Hz trigger, where 96MHz clock is generated from 12MHz master (CLK) by PLL
- is reset when next 25Hz trigger arrives, however ...
- can generate >40ms delay using the special control-bit above

A delay-word:

LI/RCS behave differently

Spec of a receiver module:

- minimum time resolution is 10.41ns (96MHz)
- maximum delay is ~170ms (24bit)

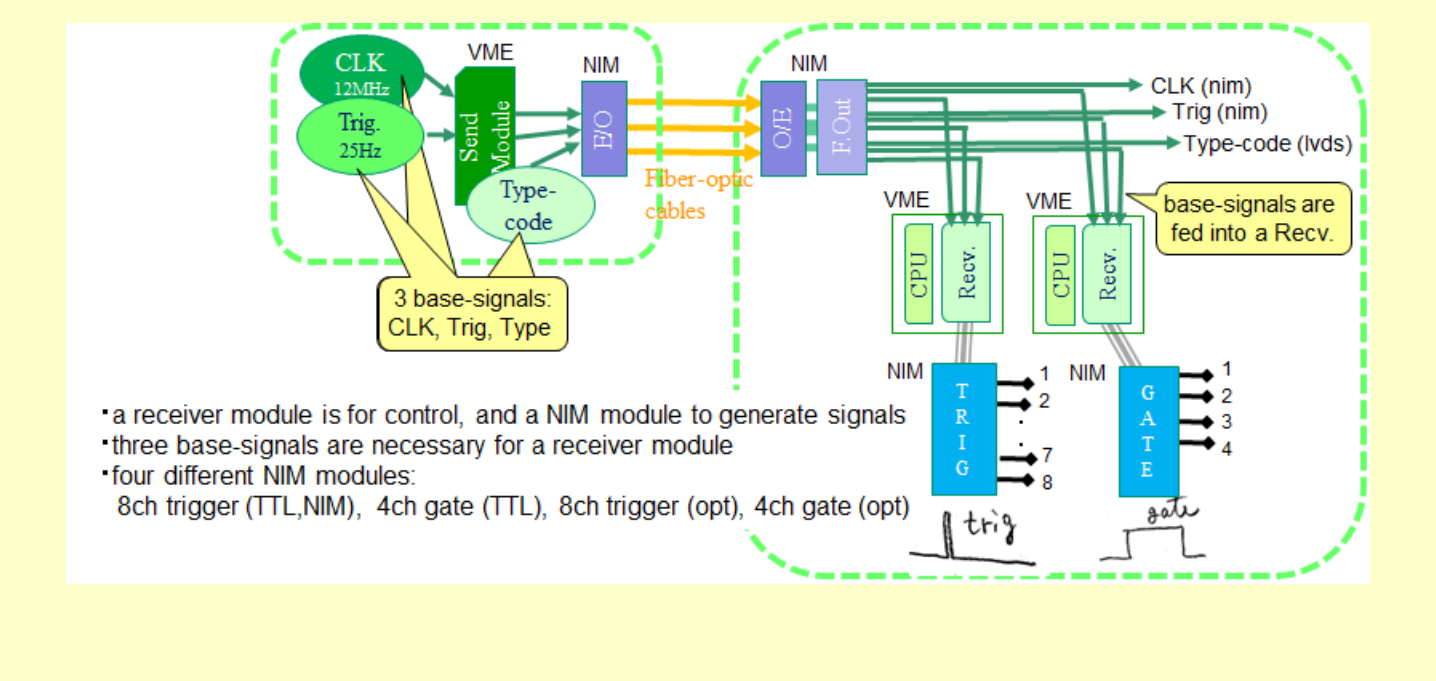
Example of LUT in MR:

- The receiver module 1 set to use M4
- Most of the elements in LUT here indicates "disabled", i.e. no signal
- The delay word "96000" here means generate a delayed pulse at 6ns, when the received type(M4) is 6
- delay will be 96000 x 10.41ns
- the special control-bit(30th) is set, but not shown

Part of LUT

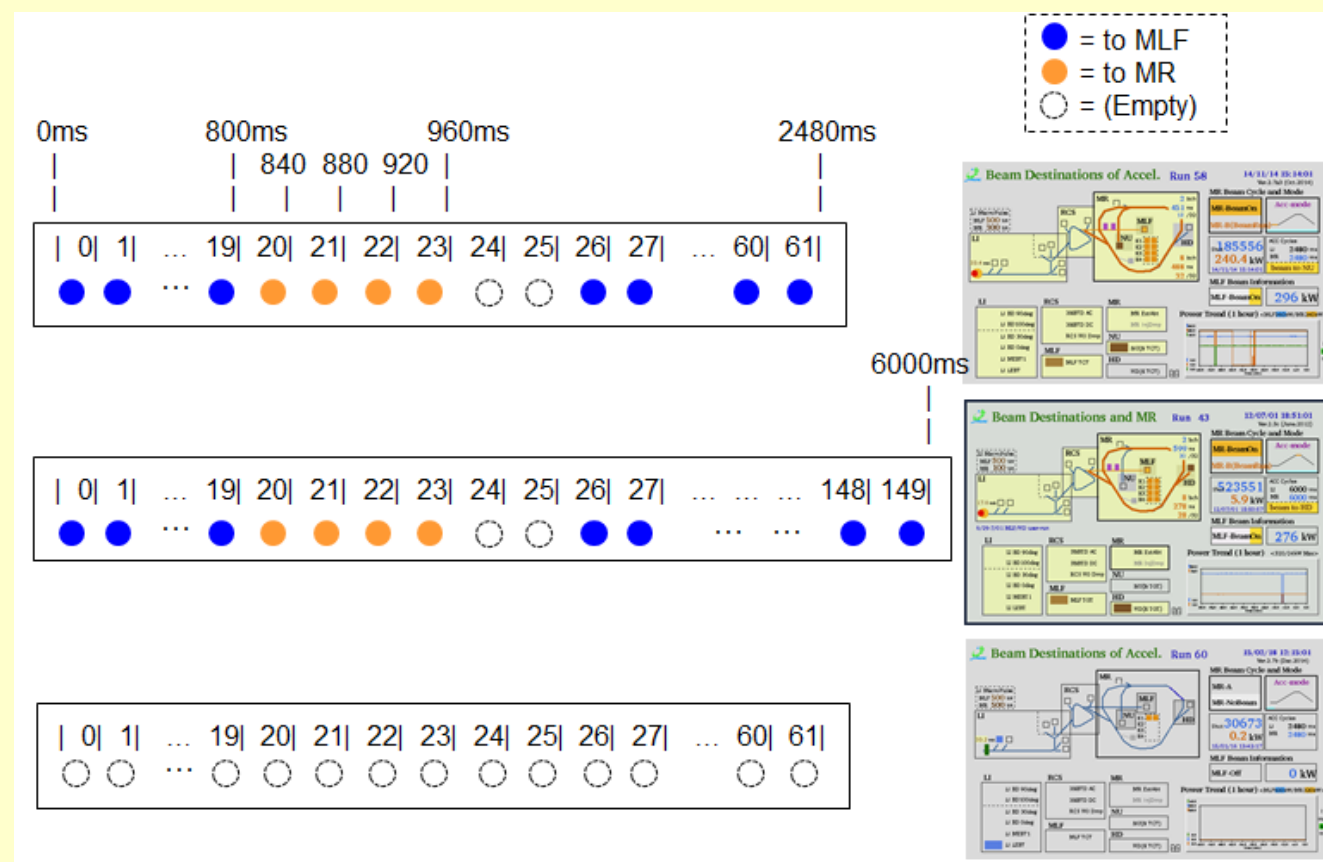
code	ch1	ch2	ch3	ch4	ch5	ch6	ch7	ch8
9600	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0
9601	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0
9602	0-122 96	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9603	0-122 0	0-122 96	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9604	0-122 0	0-122 0	0-122 96	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9605	0-122 0	0-122 0	0-122 0	0-122 96	0-122 0	0-122 0	0-122 0	0-122 96
9606	0-122 15	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9607	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9608	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9609	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9610	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9611	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9612	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9613	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96
9614	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 0	0-122 96

Receiver module, NIM module, and base-signals

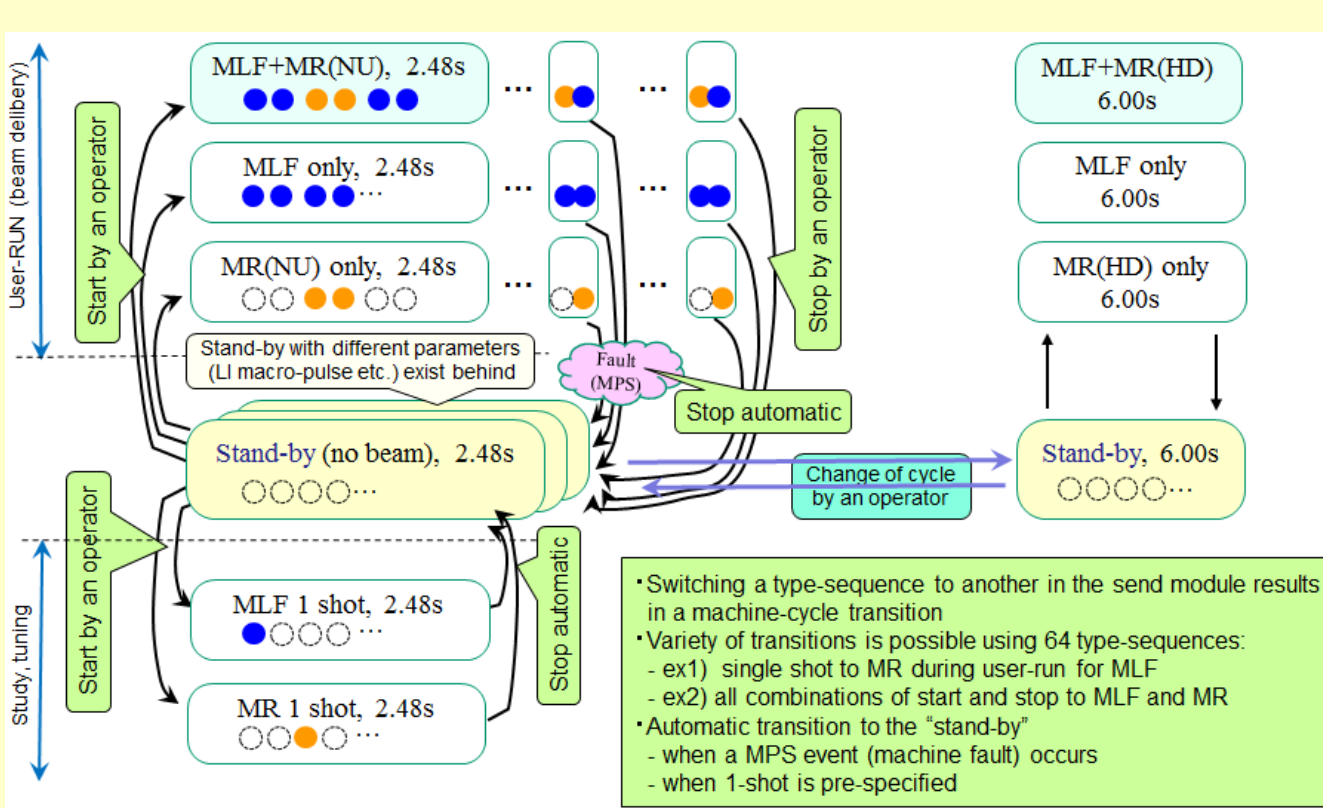


Operation

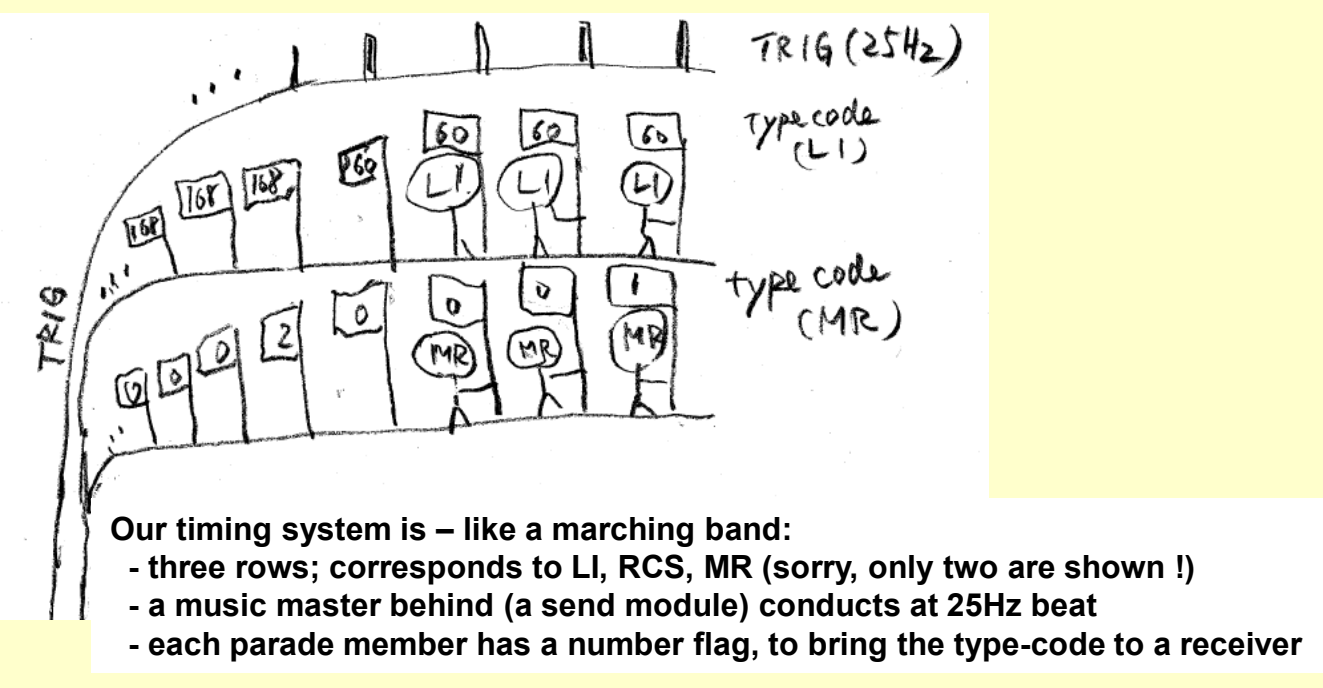
Beam slots in single machine-cycle



Transitions of machine-cycles



Timing Marching Band



Misc. Information

Synchronization timing

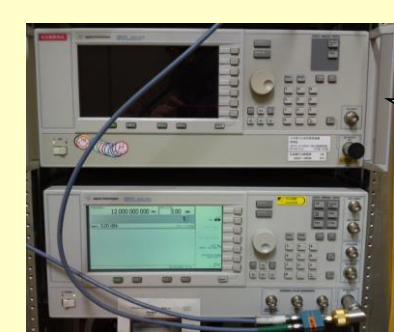
- Extraction kicker of RCS must be synchronized with the circulating beams. This trigger is generated by the RCS RF.
- MR injection devices are triggered by the same signal with appropriate delays.
- This delay is generated by a dedicated VME board, with resolution of 2ns.

Daily modulation

- The length of the fiber-optic cables between buildings is about 1 km. One-way path-through time is 3-4 us.
- Daily modulation due to environmental changes was observed: roughly ~1 ns.
- This modulation is considered small enough and permissible for our timing.

Master oscillator

- The master oscillator is a commercial product, a high-stability function generator.
- It generates the master clock: 12,000,000,000 MHz.
- We always keep a stand-by together, since the master oscillator is indispensable.



Future

Evaluation of present system

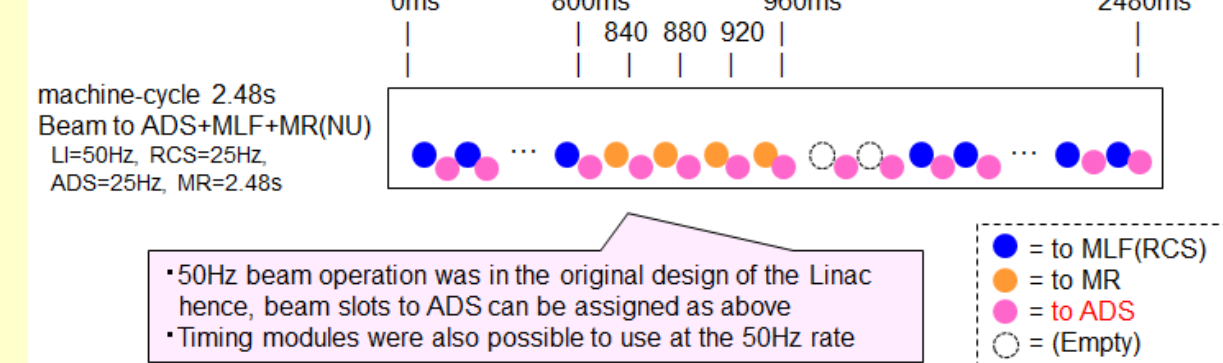
- Since 2006, VME modules (~200 modules in total) have worked very well without faults, except a few pieces
- Problems and considerations
 - Base signals, especially type-codes as a LVDS form, suffer external noise influences from pulsed power-supplies.
 - Life of optic devices : optic devices used in E/O and O/E modules, made in 2006-2010, are already discontinued
 - ADS, a new facility in J-Parc, will be constructed. Additional 25Hz beams will be needed around 2018-2019.
 - No good proposal for small component: when only one delay is requested for a new device, set of a VME system and NIM modules is necessary, results in too much space.

Ideas for the future

- Following ideas have been discussed
- Studies will be made in the near future

- Introduce SFP and FPGA
 - SFP is a safe optic device for future long availability
 - merge/divide 3 base-signals into from a fiber cable using FPGA technology
- Introduce MRF products
 - MRF provides various timing modules for accelerators
 - They have been used especially in EPICS community
 - Small-factor platform would solve space problem
 - Good link to a front-end module (E/R) would make good effects against external noise
 - Develop a protocol converter from J-Parc to MRF
 - Extend the J-Parc timing system to use MRF products

50Hz time slot for ADS



References:

- J-Parc Timing System
- J-Parc Timing System, F. Tamura et al., ICALEPCS 2003, Gyeongju, Korea, pp247-249
- Overview of Timing System for J-Parc MR, N. Kamikubota et al., PASJ meeting, Higashi-hiroshima, Japan, 2008, p.286-288 (in Japanese)
- The Status of the Timing System for J-Parc Linac / RCS, H. Takahashi et al., PASJ meeting, Higashi-hiroshima, Japan, 2008, p.262-264 (in Japanese)
- DESIGN STUDY OF J-Parc TIMING SYSTEM FOR NUCLEAR TRANSFORMATION EXPERIMENTAL FACILITY, Y. Itoh et al., PASJ meeting, Osaka, Japan, 2012, pp.738-740 (in Japanese)
- J-Parc control in general
- J-Parc CONTROL TOWARD FUTURE RELIABLE OPERATION, ICALEPCS 2011, N. Kamikubota et al., Grenoble, France, pp.378-381