

### BEAM COMMISSIONING SOFTWARE AND DATABASE FOR J-PARC LINAC

#### Hiroyuki Sako

#### G. Shen, H. Sakaki, H. Takahashi, H. Yoshikawa, JAEA H. Ikeda, VIC C. K. Allen, ORNL

#### Outline

- Overview of commissioning software system
- Database
- High-Level Application frameworks
- Beam commissioning applications
- Conclusions



#### J-PARC Accelerator Complex



LINAC commissioning since Sep 2006

RCS commissioning started in Oct 2007



# Design concepts of commissioning software system

- Large number of device channels at J-PARC LINAC
  - ~20k with beam monitors, magnets and RFs must be fully controlled
- Various settings of devices
  - Various beam destinations (4 dump lines, 1 transport line to RCS)
  - Energy 3~181 MeV (during RF tuning)
- Central data source
  - Use of RDB
- Online model and device control
  - Should be closely connected
- Easy development and maintenance of applications
  - Java



### **Commissioning Software System**



- Device Control
  - EPICS CA

• JCA/CAJ

- Database
  - Commissioning DB
  - Save & Restore DB
- Unit Conversion Server
  - Physics records
- High Level Applications
  - JCE/XAL
- Generation of input files for HLA
  - Data analysis in commissioning and feedback for device parameters



### Commissioning DB (CODB)

- Central data source for commissioning software and infrastructure
  - Geometry of beam-line devices
  - EPICS names
  - Device and beam modeling parameters
  - Unit conversion function parameters
  - Generation of input files for high level applications
- PostgreSQL
  - "The world's most advanced open source DB"
  - Being improved rapidly (both performance and functionalities)



### **Commissioning DB Manager**

												×		
lattice parameters						LI Lattice								CI II for Commissioning
				sort area	sort elem	ent sort t	/pe sort s					_	•	GUI IOI COMMISSIONING
facility LI	MEBT 1	element STMV08	element_type	s [mm] 6,441	eff. length [m.	G [T/m] (QM)	BL[Tm]/B[T](	RF amp[MV]	RF phase[deg	] tag matchuncor0	match			
LI	MEBT 1	FCT08	FCT	6,545.25						matchuncor0				<b>DR</b>
	MEBT 1	SCT08	BCM	6,545.25	40.0016	25.206220				matchuncor0				
	DTL1	BLMP01	BLM	6.673.233	40.9916	-55.500579				matchuncor0				
LI	DTL1	BLMS01	BLM	6,673.233						matchuncor0				Coomotry
	DTL1	RG01	RG	6,673.233	40.0016	CO. 005 0.40	0.	139996	-30.0	matchuncor0				
U	DTL1	BLMP02	BLM	6,748,418	40.9910	09.003049				matchuncor0				
LI	DTL1	BLMS02	BLM	6,748.418						natchuncoro				
	DTL1	RG02	RG	6,748.418	40.0016	68.30037	0.	14326	-30.0	natchuncor0	we at all give			– Device parameters
	DTL1	BLMP03	BLM	6.825.053	40.9916	-68.30927				matchuncor0	matensim			
LI	DTL1	BLMS03	BLM	6,825.053						matchuncor0				
LI	DTL1	RG03	RG	6,825.053	10.0016	67.50505	0.	146531	-30.0	natchuncor0				
	DTL1	RG04	RG	6,863.736	40.9916	67.58505	0	149796	-30.0	matchuncor0	matchsim			
LI	DTL1	DTQ05	QH	6,942.604	40.9916	-67.52516	•••	210700	20.0	matchuncor0	matchsim			
LI	DTL1	RG05	RG	6,982.765			0.	153053	-30.0	matchuncor0				
	DTL1	DTQ06 RC06	RG	7,022.926	40.9916	67.23502	0	156204	-30.0	matchuncor0	matchsim			
LI	DTL1	DTQ07	QH	7,104.82	42.8232	-63.47634	· · · · ·	100001	20.0	matchuncor0				
LI	DTL1	RG07	RG	7,146.445			0.	159547	-30.0	matchuncor0				
	DTL1	DTQ08	QV RC	7,188.071	42.8232	62.693851	0	16778	-20.0	matchuncor0				(Concration of XAL input
U	DTL1	DT009	OH	7,230.302	42.8232	-61.953649	0.	10270	-50.0	matchuncor0			7	Generation of AR Input
LI	DTL1	RG09	RG	7,316.094			0.	166009	-30.0	matchuncor0			/	
<u> </u>	DTL1	DTQ10	QV	359.254	42.8232	61.213448				matchuncor0		- /	/	filoc
_lattice tag	panel							_hr	an tag nanal			Ι		11162
	tag	times	tamp	comment		alignment ta	g panel	De	ann cay paner			1		
base0000		2006-11-20	in	itial base lattice f	or LINA 🔺	tag	timestamp comm	ent	match0	. 2006 LINA		/		
match061 match20M	201 eV061201	2006-12-01	2	ter matching by I OMeV_5mA_matr	kegami =	angriocoo	2000-1  base al		match5	2007 LINA	(C c 📃 🖉			
match37M	eV061201	2006-12-01	3	7MeV, 5mA, mate	hing (u				matchR	2007 RFQ	ge 🗸 🖌			
anatah Dida	UAC1301	2006 12 01		Matt Frank annala					tan mate	chuncor070626				
tag	matchuncor0	70626				tag align0000				- /			Sava a data cat with a	
timestamp 2007/08/20 0:00:00						timestamp 2007/09/10 17:24:50				~ /	- X		Jave a Uala Sel Will a	
comment	Uncorrected	QM field based or	for matching stu	dy on 26 Jur	timestamp 2006/12/01 0:00:00 comment RFQ geom cor (actually Tyliss params)				lly Tyriss params					
											I I			tag and commonte
	beam parameters													lay and comments
		alpha_x	-1.3453	alpha_y 2.0	01561	alpha_z =0.	066842	control p	anel		/			
		beta_x	0.14848	beta_y 0.1	19599	beta_z 0.6	32114024396		Ioad DB		/			<ul> <li>Ditterent beam settings</li> </ul>
		emit_x	13.625	emit_y 13	.71	emit_z 62	7.9982734889		generate I 3D	/	·			Billoroni souri oottingo
		x	0.0	у 0.0	)	z 0.0		54	ve to Dear DR	<u> </u>				Corrected device
		×	0.0	y' 0.0	)	z' 0.0		save to Beam DB update data from XAL file delete Lattice DB					- Corrected device	
		W (keV)	2.966	q -1								noromotoro in the		
		spacecharge	1											parameters in the
														commissioning

### **Unit Conversion Server**



- Provides physics records in connection to device records
  - Indispensable for efficient beam commissioning
- Portable Channel Access Server
- ~400 magnet power supplies
  - Conversion function : 3<sup>rd</sup> order polynomial (inverse function solved analytically)



# High level application frameworks

. . .

#### • JCE (Java Commissioning Environment)

- Framework based on a SAD script language
- Parser and core codes in Java
- Quick development of applications
  - Beam diagnostics displays
  - Magnetic field set panel
  - Transverse matching
- XAL
  - Framework in Java developed at SNS
  - Developed for J-PARC
    - Beam envelope simulator
    - RF tuning
    - Orbit correction
    - Beam based alignment
    - Energy analyzer
    - Save and Restore DB
- JCE/XAL common functionalities
  - XAL input files
  - XAL online model
  - XAL wrapper class for JCA/CAJ

#### JCE script

Add->{KBFComponentFrame[

Add-> {KBFGroup[Text->"Wire Scanners X for emittance fit Add-> {KBFCheckButton[Width->xwid,Variable:>awsx[1],Te Add-> {KBFCheckButton[Width->xwid,Variable:>awsx[2],Te Add-> {KBFCheckButton[Width->xwid,Variable:>awsx[3],Te Add-> {KBFCheckButton[Width->xwid,Variable:>awsx[4],Te

# JCE application

	THEFT	rpr Matching .			shine has the kinema set that	
Testas Panel Plat Par	and Earthward Pro-	sanation Panel				
Save and Load Data				Recet Simulat	lee .	
Save File		at (her - 2007-)	-6-10-10-bit		Revet Probe	
Comment		EIT1 measure	nest, no OM cor, 25mA		NEME CODE	
	Save All	Data		eset QM field		
104	ane All Data Lattin	and Profee fil				
Load File		ana - 60an 07/1				
and a set	Load All	Data				
Save Lattice File	matcher-2007-6-6-19-16 vdif					
	Save Corrected Lattice					
Save Probe File	imatcher-2007-E-E-13-16 probe					
	Save Currented Probe					
Measured Beam RMS v	· · · · · · · · · · · · · · · · · · ·	Eman RMS we		Mismatch Factor		
			11015			
LOCAL CONTRACTOR 1		CONCEPTION.	1.00000	Ci	ic Mismatch Factor	
Contraction of the	07000	1	1.00000 1.00000	Ca Mismatch X	R: Mismatch Factor	
I. MINISTRATING I I. MINISTRATING I I. MINISTRATING I	07000 41000 51000		1000 1.00000 1000 1.00000 1.00000	Ca Mismatch X Mismatch Y	Constant Factor	
	07000 41000 51000 0000		1 00000 1 00000 1 00000 1 00000 1 00000	Ca Mismatch X Mismatch Y	tc Mismatch Factor	
Academic and All and A	07000 41000 51000 0000	En am RNIS y e	E 00000 E 00000 E 00000 E 00000 E 00000 E 00000 E 00000	Ca Mismatch X Mismatch Y	At Mismatch Factor	
Contraction of the second seco	07030 41030 51030 0000 70030	Enam RMS y r	100000 100000 100000 100000 100000 100000 100000	Ca Mismatch X Mismatch Y	6: Mismatch Factor	
An entertain and entertain a comparison of the second and the seco	07000 41000 51000 0000 70000 26000	Enam RMS y c	1 00000 1 00000 1 00000 1 00000 1 00000 1 00000 1 00000 1 00000 1 00000 1 00000	Ca Mismatch X Mismatch Y	8c Mismatch Factor 122004 10795	
Contraction of the second seco	07000 41000 51000 0000 70000 26000 91000	<ul> <li>A constant of a c</li></ul>	1 00000 1 00000 1 00000 1 00000 1 00000 1 00000 1 00000 1 00000 1 00000 1 00000	Ca Mismatch X Mismatch Y	6c Mismatch Factor 122004 10795	
Contraction of the second seco	07000 41000 51000 0000 7 70000 26000 91000 0000	n and a long a sing a long a sing a long a sing a long a sing a s	1.00000         1.00000           1.00000         1.00000           1.00000         1.00000           1.00000         1.00000           1.00000         1.00000           1.00000         1.00000           1.00000         1.00000           1.00000         1.00000           1.00000         1.00000	Ca Mismatch X Mismatch Y	122004 10795	
Control Constants 1 Control Constants 1 Control Constants 1 Control Constants 1 Constitution Constants 1 Constants 1 Constant	07000 41000 51000 0000 7 7 70000 26000 91000 0000	Construction Const	Hark	Ca Mismatch X Mismatch Y	22004 10795	
Oracin Constant of Con- tracting Constant of Con- constant of Constant of Con- tracting Constant of Con- tracting Constant of Con- tracting Constant of Con- tracting Constant of Con- constant of Constant of Con- constant of Constant of Con- Design Twess U.METEM	07000 41000 51000 0000 70000 26000 26000 26000 26000 26000	Constitution Const	Example 2 00000	G Mismatch X Mismatch Y	C Mumatch Factor	
Design Twiss Design Twiss Design Twiss Design Twiss Design Twiss U.MIETEM RK	07000 41000 51000 0000 7 70000 91000 91000 91000 91000 91000	n John Charles La John Charles La John Charles La John Charles La John Charles La John Charles Charles Charles Fitthed Twolss Li, Jak	HINY 1 COODD 1 COOD	Ga Mismatch X Mismatch Y	10795	
Design Twess Original Control of	07000 41000 51000 0000 7 70000 91000 91000 0000 91000 0000 91000 0000 91000 0000 91000 0000 91000 0000 91000 0000 91000 0000 91000 90000 90000 90000 90000 90000 90000 90000 90000 90000 90000 90000 90000 90000 90000 90000 9000000	Fitted Twiss	HINK 1,000000 1,00000000 1,000000 1,000000 1,00000 1,00000 1,00000	Ca Mismatch X Mismatch Y	12 Minutch Factor	
Design Twess	07000 41000 51000 0000 26000 26000 26000 25000 00000 00000 00000 00000 00000 00000 0000	Fitted Twiss Example to the second to the se	Coccos	Ga Mismatch X Mismatch Y	k Minutch Factor	
Control of the second s	07090 41000 51000 0000 7 70000 26000 20000 26000 2000000	Fitted Twiss Fitted Twiss Fitte	Image: Control of the second of the	Ga Misenatch X Misenatch Y	Ic Minutch Factor	
An analysis of the second seco	07030 41006 51000 0000 F 7 70000 26030 91080 91080 0000 17 70200 00740 8027 7120 4.48213	Enam IMS y n Enam IMS y n Enam IMS y n Enam IMS y n Enam IMS y n Fitted Twiss Ly as ay ay ay ay by by ex	1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000           1 0000         1 0000	G Mismatch X Mismatch Y	k Munatch Factor	
Control of the second of the s	07090 41000 51000 0000 26000 26000 26000 26000 26000 0000 26000 2000 2000000	Enem RMS y n Enem RMS y n en	1000 10000 100000 100000 100000 100000 100000 100000 100000 100000 10	Ca Mismatch X Mismatch Y	k Hendth Factor	
Consign Texts of Consig	07030 41030 51830 0000 70000 2000000	Eram RMS y Eram RMS y Fitted Twiss Guidentee Fitted Twiss U, and W N N N N N N N N N N N N N N N N N N	0000 1.0000 1.00000 1.000000 1.000000 1.00000000 1.0000000000	Ca Misewatch X Misewatch Y	k Henuth Fator	
	Sever and Lead Data Sever and Lead Data Sever Int Lead Time Lead Time Sever Lattice File Sever Prober File Measured Ecom BMC	Tests Park Backend Pro Serve and Load Dyta Serve Tail Serve Tail Serve Tail Serve Tail Serve All Serve	Insist Poor I mot Poor I Exclosed Propagation Poor Server and Load Data Server Rill Control Data Comments Lead Tile Lead Tile Execution Control Data Server All Data Server Comments (2017 All Server Co	Texts Flored         Text Flored         Eachesid Propagation Plant           Sear and Local         Implicer 2007-6-6-10-35 mml           Sear Fill         Implicer 2007-6-6-10-35 mml           Sear Fill         Implicer 2007-6-6-10-35 mml           Sear Fill         Implicer 2007-6-6-10-35 mml           Sear All Disk         Implicer 2007-6-6-10-35 mml           Sear Corrected Littlice         Implicer 2007-6-6-10-35 mml           Sear Corrected Littlice         Implicer 2007-6-6-10-35 mml           Sear Corrected Littlice         Sear Corrected Plate           Sear Corrected Plate         Sear Corrected Plate	Notes Fueld         Backward Propagation Paint           See and Load Data         Imment - 2017 - 4 - 1 - 1 d million           See and Load Data         Imment - 2017 - 4 - 1 - 1 d million           See and Latine and Propagation Provide Paint         Imment - 2017 - 4 - 1 - 1 d million           Load Tife         Import - 2017 - 4 - 1 - 1 d million           See fill Data         Import - 2017 - 4 - 1 - 1 d million           See faile Paint         Import - 2017 - 4 - 1 - 1 d million           See faile Paint         See Constitute Latino           See faile Paint         See Constitute Latino	



### Applications for J-PARC LINAC Commissioning

RF tuning application (XAL)

• Tune amplitude and phase of RF to accelerate beam to a designed energy by measuring time of flight of beam.





RF phase







Quadrupole magnet

 Tune steering magnet so that the orbit passes through the center of a quadruple magnet

### Beam Based Alignment application (XAL)

- Change QM and steering field and measure beam positions with BPM
- Find center of QM

#### MEBT1 BPM05

J-PARC



BPM positions vs QM field at each steering field

Central BPM positions vs steering slope (from left plot)



### **Transverse** matching



## Transverse matching application (JCE)





Measurement of beam profiles with wire scanners

Optimize QM field for periodic beam envelope with Newton-Raphson method

 Mismatch factor of less than 5% achieved

#### Before correction

#### After correction

### Energy analysis application (XAL)





## Energy evolution during RF tuning



### **JCE** applications

#### • Magnet field setter

GIGOAL		MONEG		MONCUR		
LI LISTI GMDPS05	4 99122	LI LIET:OMDPS05	4.08922	LI LIETCOMDISES	30 31136	
	4.99322	LL L38T:0MDPS07	4 99525	LLL38T:0MDP507	30.34799	
LEBRT GMOPSON	4 99122	LL L3ET-OMDP509	4 09525	LL LIET:OMDPS09	10 14799	
LEBET:OMOPS11	4.99322	LL138T:0MDPS11	4.99827	LI.L38T:OMDP511	30.36630	
LISTIOMOPS13	4 99322	LL138T:QMDP513	5.00128	LLL38T:QMDP513	30 38462	
L1380 QMINE19	2.49541	LL18ET:QMFP519	2.49661	LI_LIET:QMFPS19	16.92308	
LLBRT OMPS20	2.34012	LLL3BT:0MFPS20	2.34321	LI_L3@T:QMFPS20	34.87766	
LEBRINGMIPS21	2.28296	LL138T:QMFPS21	2 28484	LL_L3ET:0MFPS21	33 79121	
1.1.301:QMIPS22	1.69451	LI, L38T:QMFI522	1.69559	LI, L38T: QMFPS22	25.23810	
LISET QMEPS23	1.65449	LL_L3BT:QMFP523	1.65621	LI_L3ET:QMFP523	24.65201	
LISTICATES32	1.65449	U_L38T-QMFPS32	1.64760	LI_LIET:QMFPS32	24,52381	
LUBRE QMERS37	1.69451	LL_L38T:QMFPS33	1.69559	LL, L3ET: QMFPS33	25 23810	
LEBET: OMPPSEI	2.28296	ULL38T:QMFPS34	2 28360	LL_L3ET:QMFPS34	33.77289	
LIETOMPESTS	2.14012	LL_L38T:QMFPS35	2.34212	LI_L3ET:QMFPS35	34.00154	
LL38T:QMPPS36	2.49541	LL_L3BT:QMFP536	2.49785	LL_L38T:QMEPS36	36 94139	
LITETOMPEST	1 3 1 2 5 0	LL_L38T:QMFP\$51	1.31282	LL_L30T:QMFPS51	21.93846	
LIBET QMPR52	131250	LL_L38T:QMFP552	131181	LL_L3ET:QMFPS52	21 92161	
LASTICIMPSOL	3,87574	LLL3BT:QMP501	3 87682	LI_L387:QMP501	23 55311	
L1001:QMIS02	4 03998	LLUBT:QMP502	4.03660	LL,L3ET:QMP502	24.52381	
1.138T:0/MP503	5.14848	LI, 1.38T: QMP503	5.15201	LI, L38T: QMP503	31.30037	
LEBUT:QMR64	4 77966	LL18ERQMP504	4 77820	LI_L3ET:QMP504	29.02930	
LINCOMP15	1.39494	LI_L387:QMP515	3.39448	LL13ET:QMP515	20.62271	
LABIT:QMP536	3.95354	LI_L3BT:QMP516	3.95822	LI_L3ET:QMPS16	24.04762	
LATERIQAREST?	4.97503	LL18FT:QMP517	4.98018	LI_LIET:QMP517	10 25641	
1.13111.0/09518	4.24568	LI_L3BT:QMPS18	4.24159	LI_L38T:QMPS18	25.76923	
L387:0MP546	0.43622	LL_L3BT:QMP546	0.43344	LL_L38T:QMP\$46	6,41026	
L3810MP547	1.62337	LI_L38T:QMPS47	1.82044	LL_L3ET:QMPS47	26.92308	
LL30T:0MP548	1.98430	LL_L3BT:QMP548	1.98143	LI_L38T:QMP548	29.30403	
LITER OMPSIO	1 53549	LL_L3BT:QMPS49	1 53685	LI_L3ET:QMP549	22 72894	
LITCHIESE	1.31250	LLL3BT:QMPS50	1.31518	LI_L3ET:QMP550	19.45055	

#### Beam Loss monitor display



#### Current monitor display



#### • Beam position monitor display





# First acceleration to 181 MeV 24 Jan 2007





#### First acceleration to 181 MeV 24 Jan 2007





Beam profiles measured by MWPMs



### **Conclusions and Outlook**

- Commissioning software system developed and successfully applied to J-PARC LINAC
  - Commissioning DB
  - Unit conversion server
  - JCE and XAL
- Improvements for more efficient operation
  - Maintenance scheme of Commissioning DB
  - Development of Save and Restore DB

### Thank you for your attention!

NAUTI \*NEELEY

