

BEAM COMMISSIONING SOFTWARE AND DATABASE FOR J-PARC LINAC

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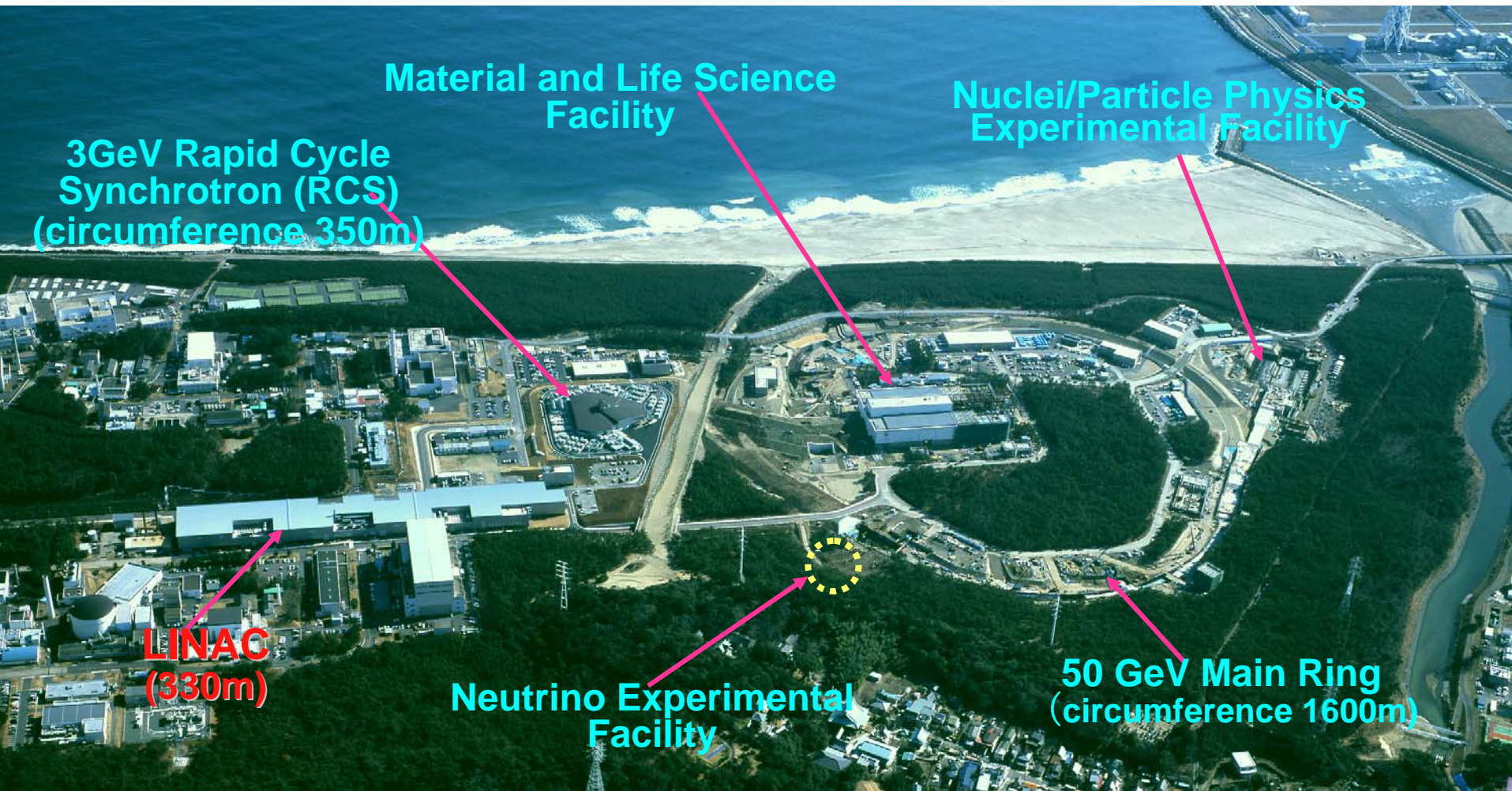
H. Ikeda, VIC

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

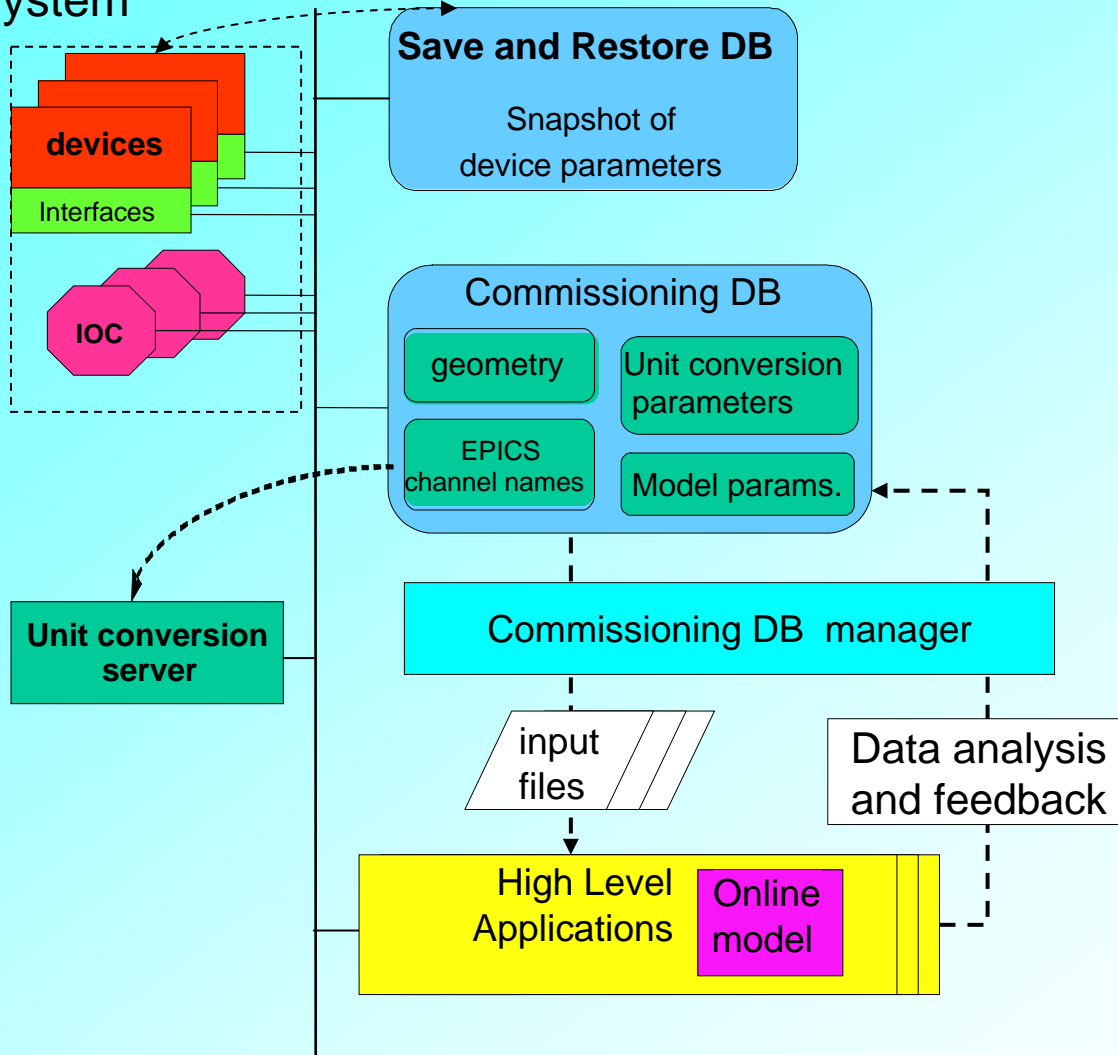
RCS commissioning started in Oct 2007

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

Control 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

The screenshot displays the 'LI Lattice' window with a table of lattice parameters. A red circle highlights a portion of the table, and arrows point from this area to the bullet points on the right. Below the table are several panels: 'lattice tag panel', 'alignment tag panel', 'beam tag panel', 'beam parameters', and a 'control panel' with buttons for database operations.

facility	area	element	element_type	s [mm]	eff. length [m]	G [T/m] (QM)	BL [Tm]/B [T] (...)	RF amp [MV]	RF phase [deg]	tag	match
LI	MEBT1	STMV08	DCV	6,441			0.0			matchuncor0...	
LI	MEBT1	FCT08	FCT	6,545.25						matchuncor0...	
LI	MEBT1	SCT08	BCM	6,545.25						matchuncor0...	
LI	DTL1	DTQ01	RG	6,636	40.9916	-35.386379				matchuncor0...	
LI	DTL1	BLMP01	BLM	6,673.233						matchuncor0...	
LI	DTL1	BLMS01	BLM	6,673.233						matchuncor0...	
LI	DTL1	RG01	RG	6,673.233				0.139996	-30.0	matchuncor0...	
LI	DTL1	DTQ02	RG	6,710.466	40.9916	69.865049				matchuncor0...	
LI	DTL1	BLMP02	BLM	6,748.418						matchuncor0...	
LI	DTL1	BLMS02	BLM	6,748.418						matchuncor0...	
LI	DTL1	RG02	RG	6,748.418				0.14326	-30.0	matchuncor0...	
LI	DTL1	DTQ03	RG	6,786.37	40.9916	-68.30927				matchuncor0...	matchsim
LI	DTL1	BLMP03	BLM	6,825.053						matchuncor0...	
LI	DTL1	BLMS03	BLM	6,825.053						matchuncor0...	
LI	DTL1	RG03	RG	6,825.053				0.146531	-30.0	matchuncor0...	
LI	DTL1	DTQ04	RG	6,863.736	40.9916	67.58505				matchuncor0...	matchsim
LI	DTL1	RG04	RG	6,903.17				0.149796	-30.0	matchuncor0...	
LI	DTL1	DTQ05	RG	6,942.604	40.9916	-67.52516				matchuncor0...	matchsim
LI	DTL1	RG05	RG	6,982.765				0.153053	-30.0	matchuncor0...	
LI	DTL1	DTQ06	RG	7,022.926	40.9916	67.23502				matchuncor0...	matchsim
LI	DTL1	RG06	RG	7,063.373				0.156304	-30.0	matchuncor0...	
LI	DTL1	DTQ07	RG	7,104.82	42.8232	-63.47634				matchuncor0...	
LI	DTL1	RG07	RG	7,146.445				0.159547	-30.0	matchuncor0...	
LI	DTL1	DTQ08	RG	7,188.071	42.8232	62.693851				matchuncor0...	
LI	DTL1	RG08	RG	7,230.502				0.16278	-30.0	matchuncor0...	
LI	DTL1	DTQ09	RG	7,272.934	42.8232	-61.953649				matchuncor0...	
LI	DTL1	RG09	RG	7,316.094				0.166009	-30.0	matchuncor0...	
LI	DTL1	DTQ10	RG	7,359.254	42.8232	61.213448				matchuncor0...	

lattice tag panel

tag	timestamp	comment
base0000	2006-11-20	initial base lattice for LINA...
match061201	2006-12-01	after matching by Ikegami...
match20MeV061201	2006-12-01	20MeV, 5mA, matching (u...
match37MeV061201	2006-12-01	37MeV, 5mA, matching (u...

tag: matchuncor070626
timestamp: 2007/08/20 0:00:00
comment: Uncorrected QM field based on match070820, for matching study on 26 Jul

alignment tag panel

tag	timestamp	comment
align0000	2006-12-01	base all...

tag: align0000
timestamp: 2006/12/01 0:00:00

beam tag panel

tag	timestamp	comment
match0...	2006-...	LINAC c...
match5...	2007-...	LINAC c...
matchR...	2007-...	RFQ ge...

tag: matchuncor070626
timestamp: 2007/09/10 17:24:50
comment: RFQ geom cor (actually T miss params

beam parameters

alpha_x	-1.3453	alpha_y	2.01561	alpha_z	-0.066842
beta_x	0.14848	beta_y	0.19599	beta_z	0.632114024396
emit_x	13.625	emit_y	13.71	emit_z	627.9982734889
x	0.0	y	0.0	z	0.0
x'	0.0	y'	0.0	z'	0.0
W (keV)	2.966	q	-1	I	5.0
spacecharge	1				

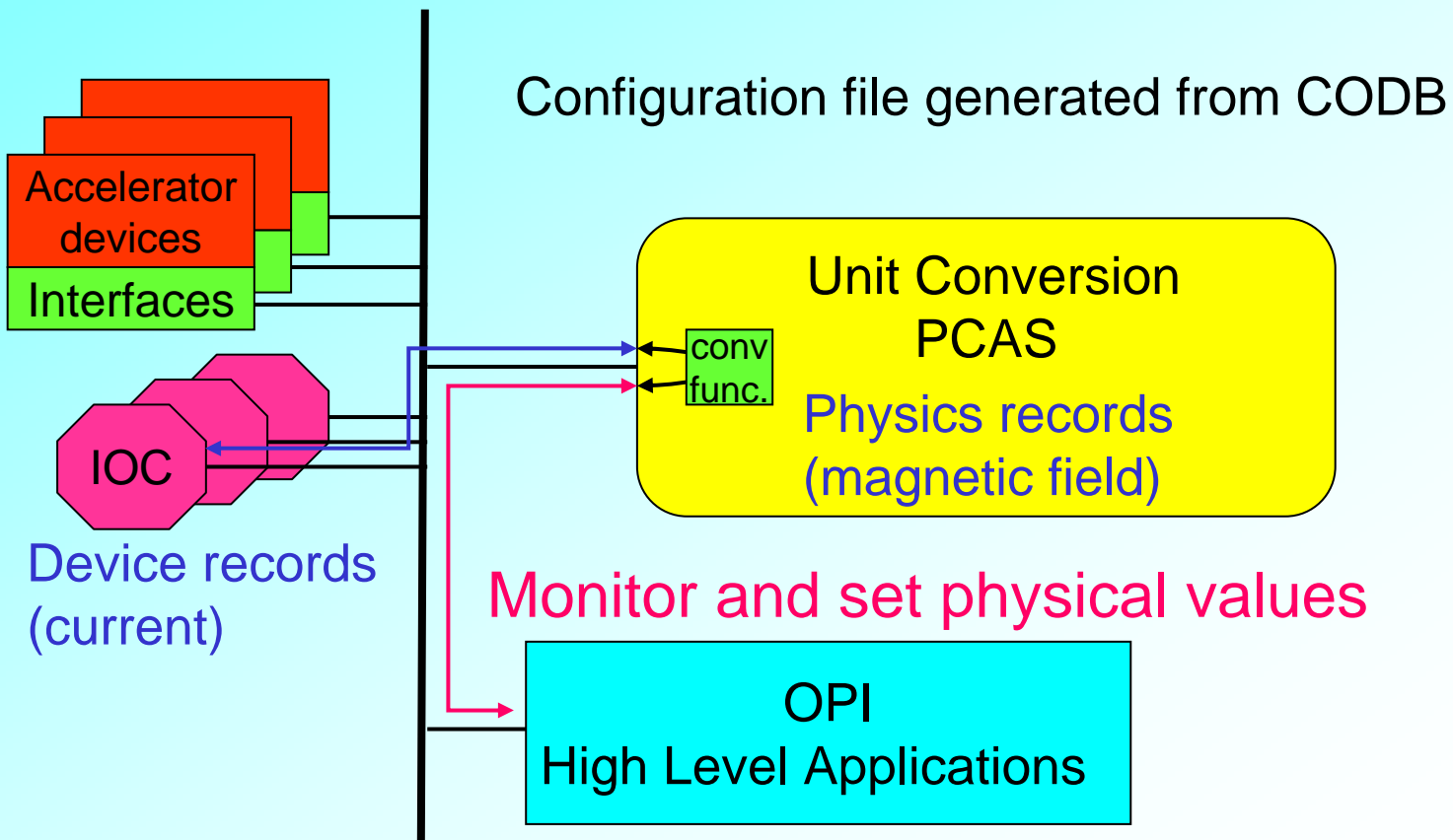
control panel

- load DB
- generate T3D
- save to Lattice DB
- save to Beam DB
- update data from XAL file
- delete Lattice DB

- GUI for Commissioning DB
 - Geometry
 - Device parameters (e.g. magnetic field)
- Generation of XAL input files
- Save a data set with a tag and comments
 - Different beam settings
 - Corrected device 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 : 3rd order polynomial (inverse function solved analytically)



High level application frameworks

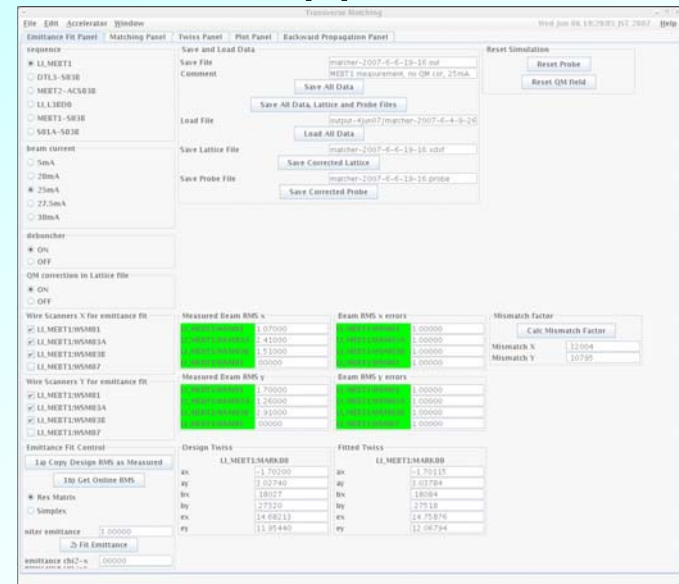
- JCE (Java Commissioning Environment)
 - Framework based on a SAD script language
 - Parser and core codes in Java
 - Quick development of applications
 - Beam diagnostics displays
 - Magnetic field set panel
 - Transverse matching
- XAL
 - Framework in Java developed at SNS
 - Developed for J-PARC
 - 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->{KBFFComponentFrame[
  Add-> {KBFFGroup[Text->"Wire Scanners X for emittance fit
  Add-> {KBFFCheckBox[Width->xwid,Variable:>awsx[1],T
  Add-> {KBFFCheckBox[Width->xwid,Variable:>awsx[2],T
  Add-> {KBFFCheckBox[Width->xwid,Variable:>awsx[3],T
  Add-> {KBFFCheckBox[Width->xwid,Variable:>awsx[4],T
  ....
```



JCE application



The screenshot shows the JCE application interface with several panels:

- Emittance Fit Panel:** Contains sections for "Wire Scanners X for emittance fit" and "Wire Scanners Y for emittance fit". Each section has a list of checkboxes for different components (e.g., LL.MERT1.WSMB1, LL.MERT1.WSMB2, etc.).
- Measured Beam RMS:** A table showing measured values for X and Y directions.
- Beam RMS x errors:** A table showing error values for X and Y directions.
- Mismatch Factor:** A section with input fields for "Calc Mismatch Factor", "Mismatch X", and "Mismatch Y".
- Design Twiss and Fitted Twiss:** Tables showing Twiss parameters for different components.

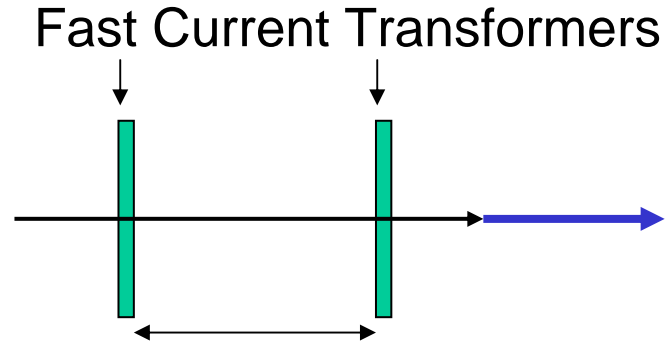
Applications for J-PARC LINAC Commissioning

RF tuning application (XAL)



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

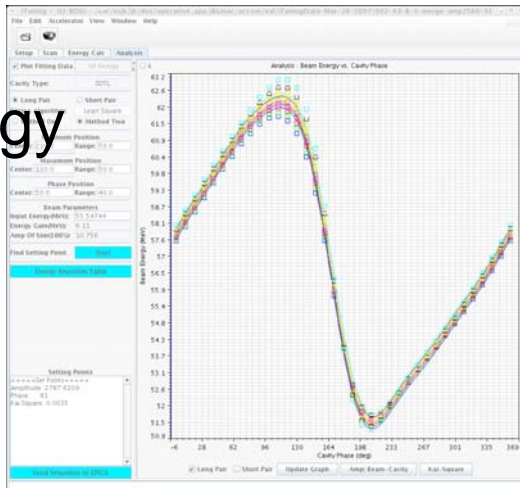
H- Beam



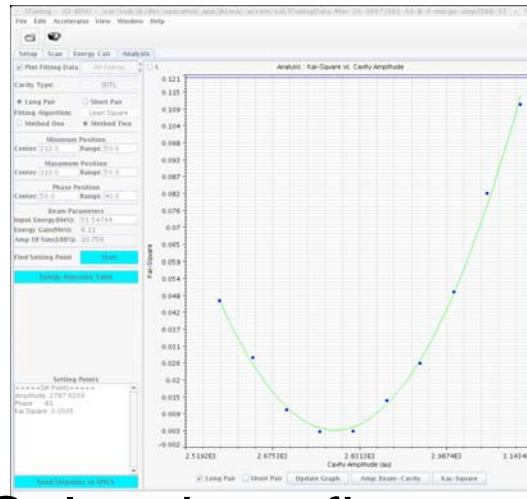
Scan RF amplitude and phase

time of flight → Energy

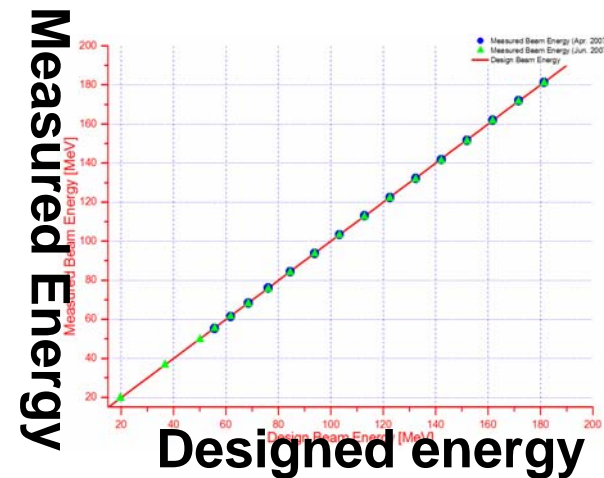
Energy



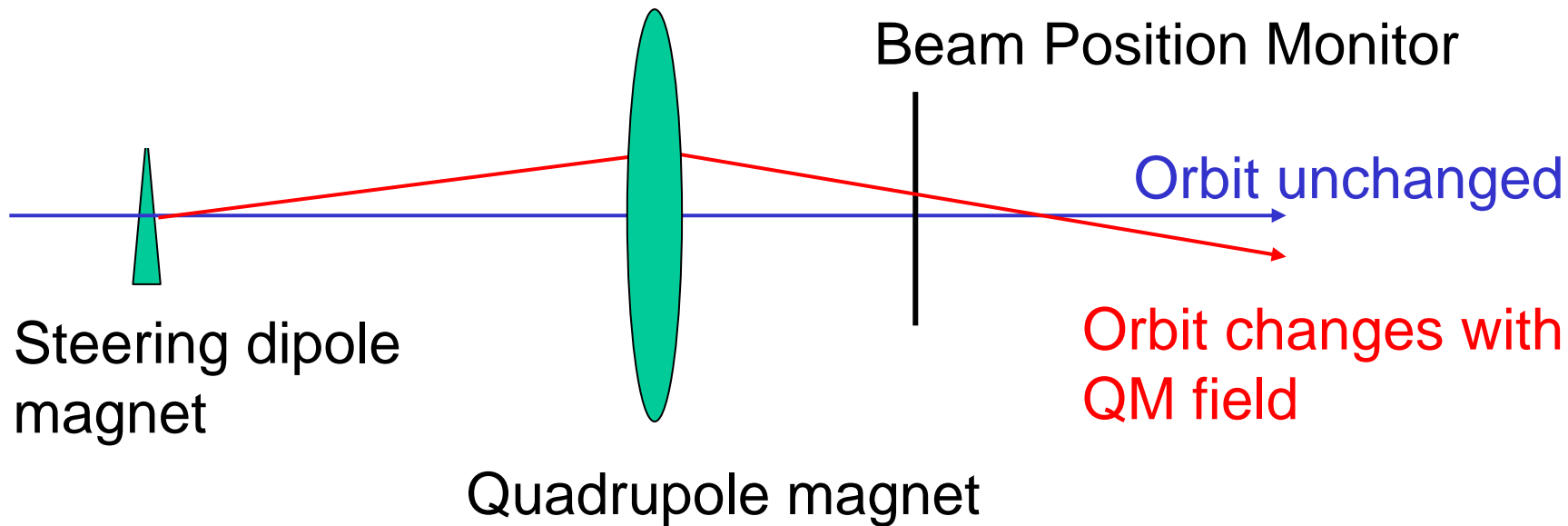
RF phase



Select best-fit
amplitude with model



Beam Based Alignment

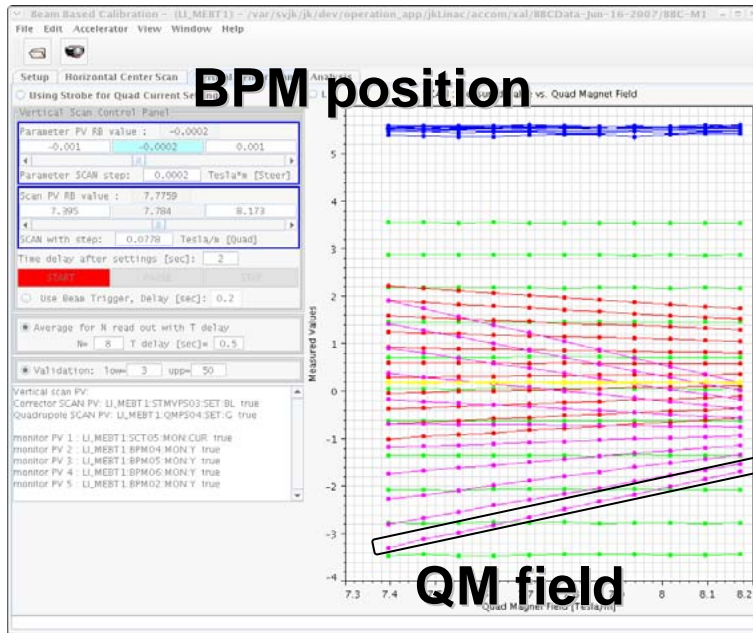


- Tune steering magnet so that the orbit passes through the center of a quadrupole magnet

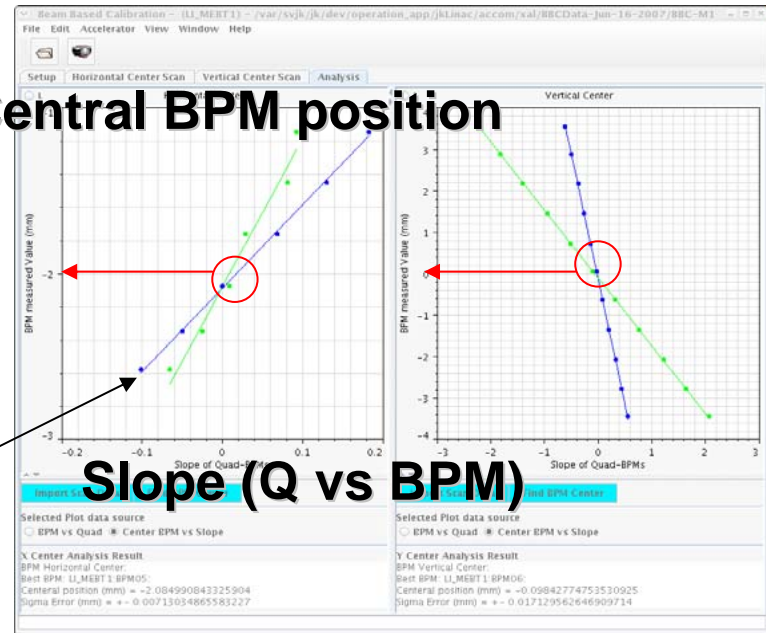
Beam Based Alignment application (XAL)

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

MEBT1 BPM05

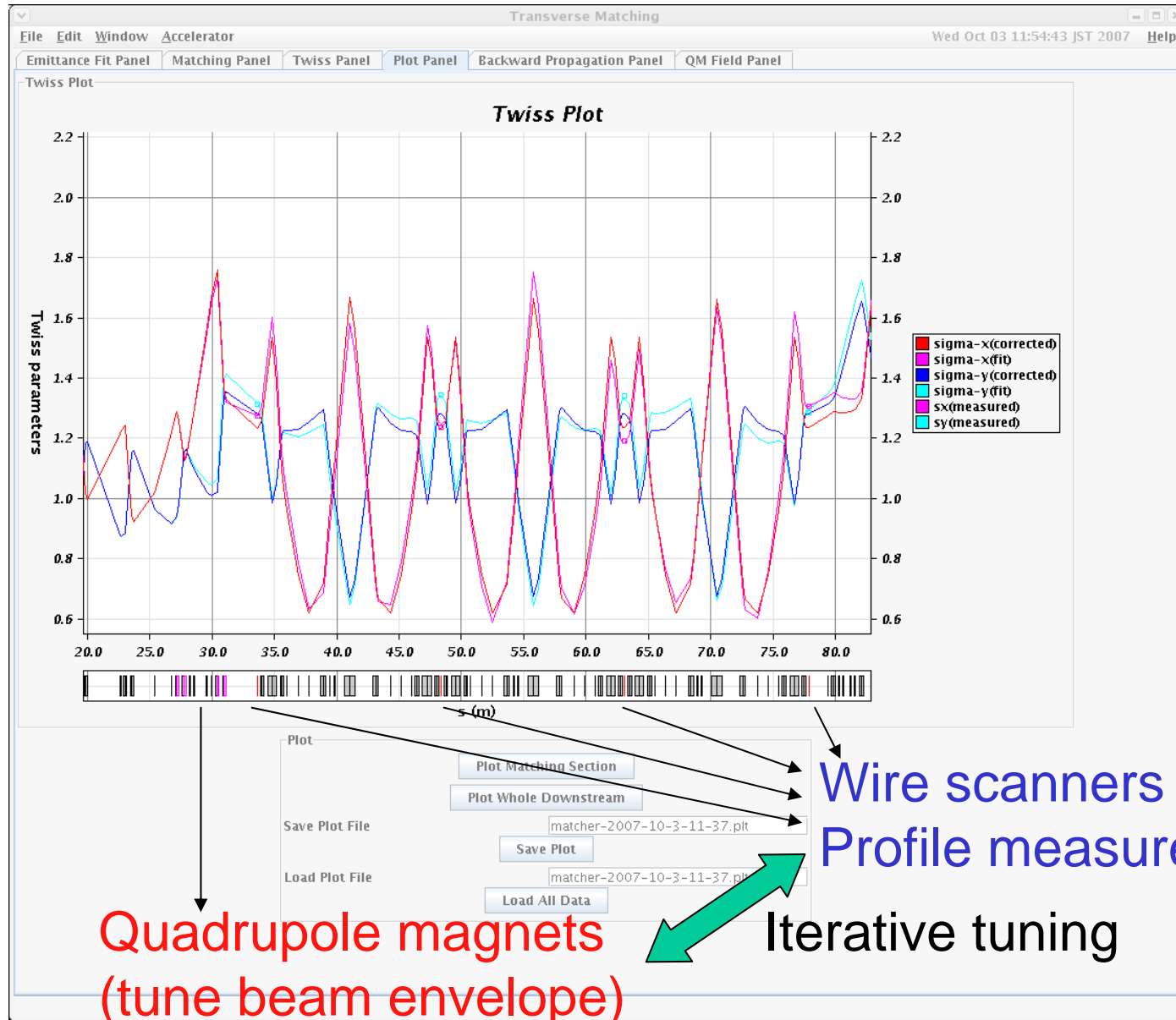


BPM positions vs QM field at each steering field



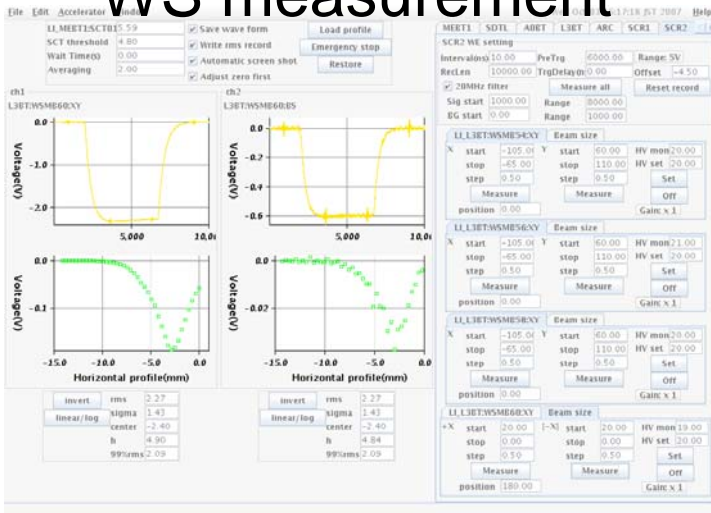
Central BPM positions vs steering slope (from left plot)

Transverse matching

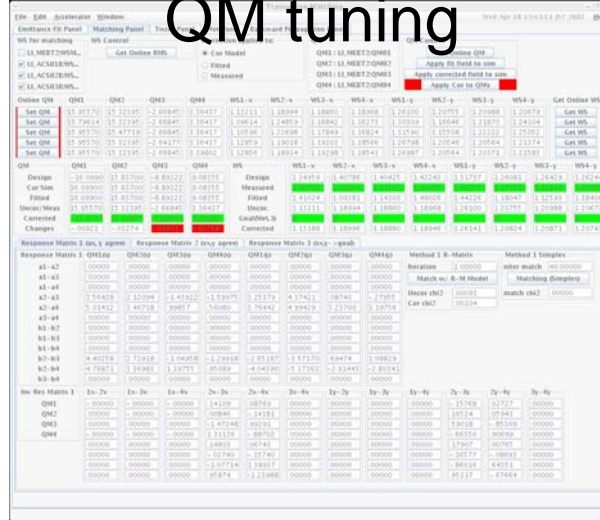


Transverse matching application (JCE)

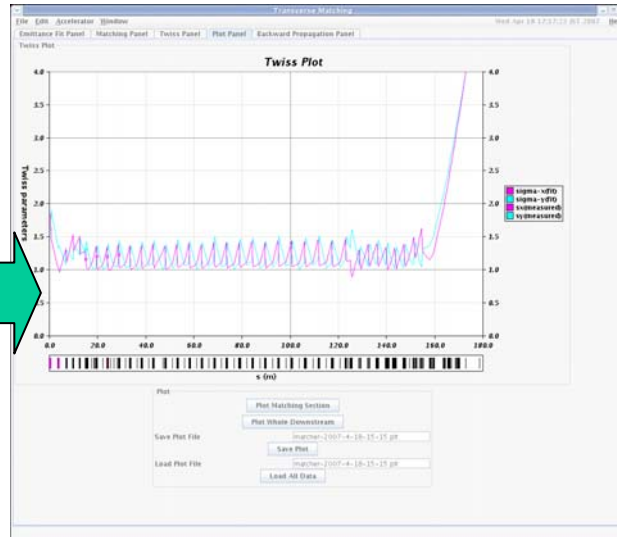
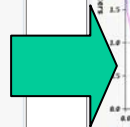
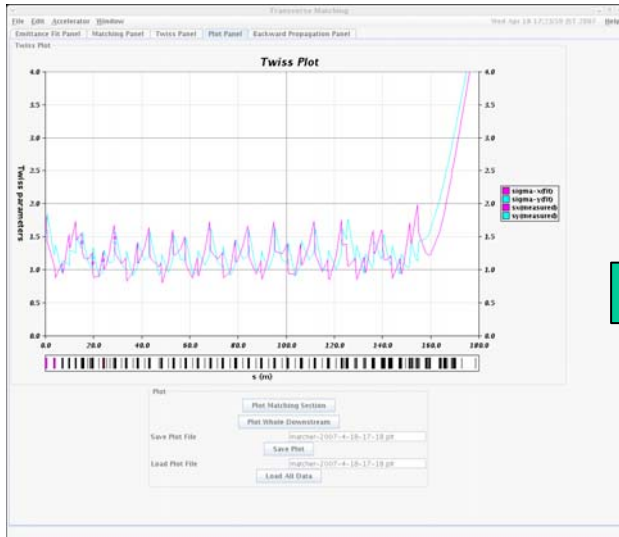
WS measurement



QM tuning



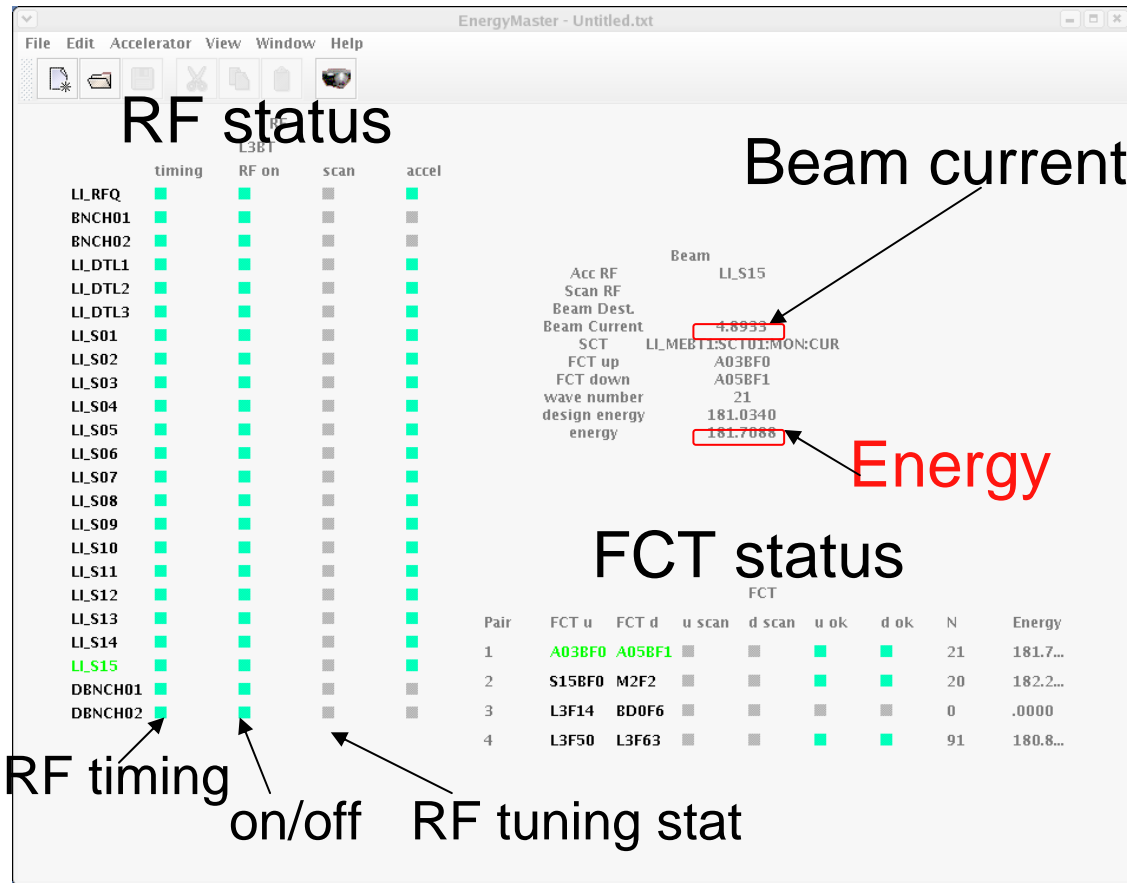
- Measurement of beam profiles with wire scanners
- Optimize QM field for periodic beam envelope with Newton-Raphson method
- Mismatch factor of less than 5% achieved



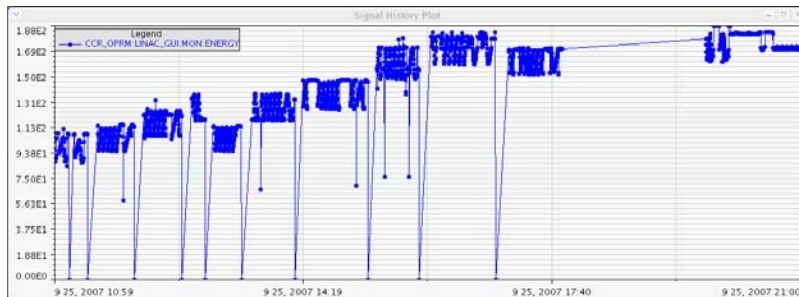
Before correction

After correction

Energy analysis application (XAL)



- Integrate all information for energy calculations
- Choose a proper FCT pair and calculate energy



Energy evolution during RF tuning

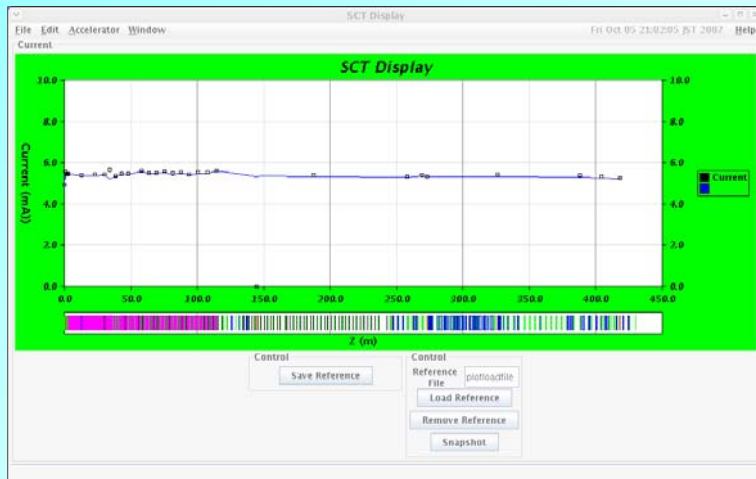
JCE applications

- Magnet field setter
- Beam Loss monitor display

Control	MEBT1	DTL1	DTL2	DTL3	SOTL	MEBT2	ABET	L3BT	DUMP	L3BT Bend
MONOC										
MONOCUR										
U.L3BT-QMDS05	4.99222	U.L3BT-QMDS05	4.99222	U.L3BT-QMDS05	30.11136					
U.L3BT-QMDS07	4.99222	U.L3BT-QMDS07	4.99222	U.L3BT-QMDS07	30.24759					
U.L3BT-QMDS09	4.99222	U.L3BT-QMDS09	4.99222	U.L3BT-QMDS09	30.14799					
U.L3BT-QMDS11	4.99222	U.L3BT-QMDS11	4.99222	U.L3BT-QMDS11	30.16620					
U.L3BT-QMDS13	4.99222	U.L3BT-QMDS13	5.00128	U.L3BT-QMDS13	30.18462					
U.L3BT-QMDS15	2.49541	U.L3BT-QMDS15	2.44661	U.L3BT-QMDS15	36.92208					
U.L3BT-QMFS20	3.34032	U.L3BT-QMFS20	3.34321	U.L3BT-QMFS20	34.87766					
U.L3BT-QMFS21	2.28296	U.L3BT-QMFS21	2.28484	U.L3BT-QMFS21	33.79121					
U.L3BT-QMFS22	1.69451	U.L3BT-QMFS22	1.69559	U.L3BT-QMFS22	25.23810					
U.L3BT-QMFS23	1.65449	U.L3BT-QMFS23	1.65621	U.L3BT-QMFS23	24.65201					
U.L3BT-QMFS32	1.65449	U.L3BT-QMFS32	1.64760	U.L3BT-QMFS32	24.92281					
U.L3BT-QMFS33	1.94511	U.L3BT-QMFS33	1.69559	U.L3BT-QMFS33	25.23810					
U.L3BT-QMFS34	2.28296	U.L3BT-QMFS34	2.28360	U.L3BT-QMFS34	33.77289					
U.L3BT-QMFS35	2.34032	U.L3BT-QMFS35	2.34232	U.L3BT-QMFS35	34.86154					
U.L3BT-QMFS36	2.49541	U.L3BT-QMFS36	2.49785	U.L3BT-QMFS36	35.94129					
U.L3BT-QMPS51	1.11250	U.L3BT-QMPS51	1.11282	U.L3BT-QMPS51	21.93846					
U.L3BT-QMPS52	1.11250	U.L3BT-QMPS52	1.11181	U.L3BT-QMPS52	21.92161					
U.L3BT-QMPS01	3.97574	U.L3BT-QMPS01	3.97682	U.L3BT-QMPS01	23.75311					
U.L3BT-QMPS02	4.03998	U.L3BT-QMPS02	4.03660	U.L3BT-QMPS02	24.52383					
U.L3BT-QMPS03	5.14848	U.L3BT-QMPS03	5.15201	U.L3BT-QMPS03	31.30037					
U.L3BT-QMPS04	4.77966	U.L3BT-QMPS04	4.77820	U.L3BT-QMPS04	29.02930					
U.L3BT-QMPS15	1.39434	U.L3BT-QMPS15	1.39448	U.L3BT-QMPS15	20.62271					
U.L3BT-QMPS16	2.35254	U.L3BT-QMPS16	2.37822	U.L3BT-QMPS16	24.04762					
U.L3BT-QMPS17	4.97903	U.L3BT-QMPS17	4.98028	U.L3BT-QMPS17	30.75641					
U.L3BT-QMPS18	4.24568	U.L3BT-QMPS18	4.24159	U.L3BT-QMPS18	25.76922					
U.L3BT-QMPS46	0.43622	U.L3BT-QMPS46	0.43344	U.L3BT-QMPS46	6.41026					
U.L3BT-QMPS47	1.82137	U.L3BT-QMPS47	1.82044	U.L3BT-QMPS47	26.92308					
U.L3BT-QMPS48	1.28430	U.L3BT-QMPS48	1.28143	U.L3BT-QMPS48	29.20403					
U.L3BT-QMPS49	1.53549	U.L3BT-QMPS49	1.53489	U.L3BT-QMPS49	22.72894					
U.L3BT-QMPS30	1.11250	U.L3BT-QMPS30	1.11518	U.L3BT-QMPS30	19.45955					

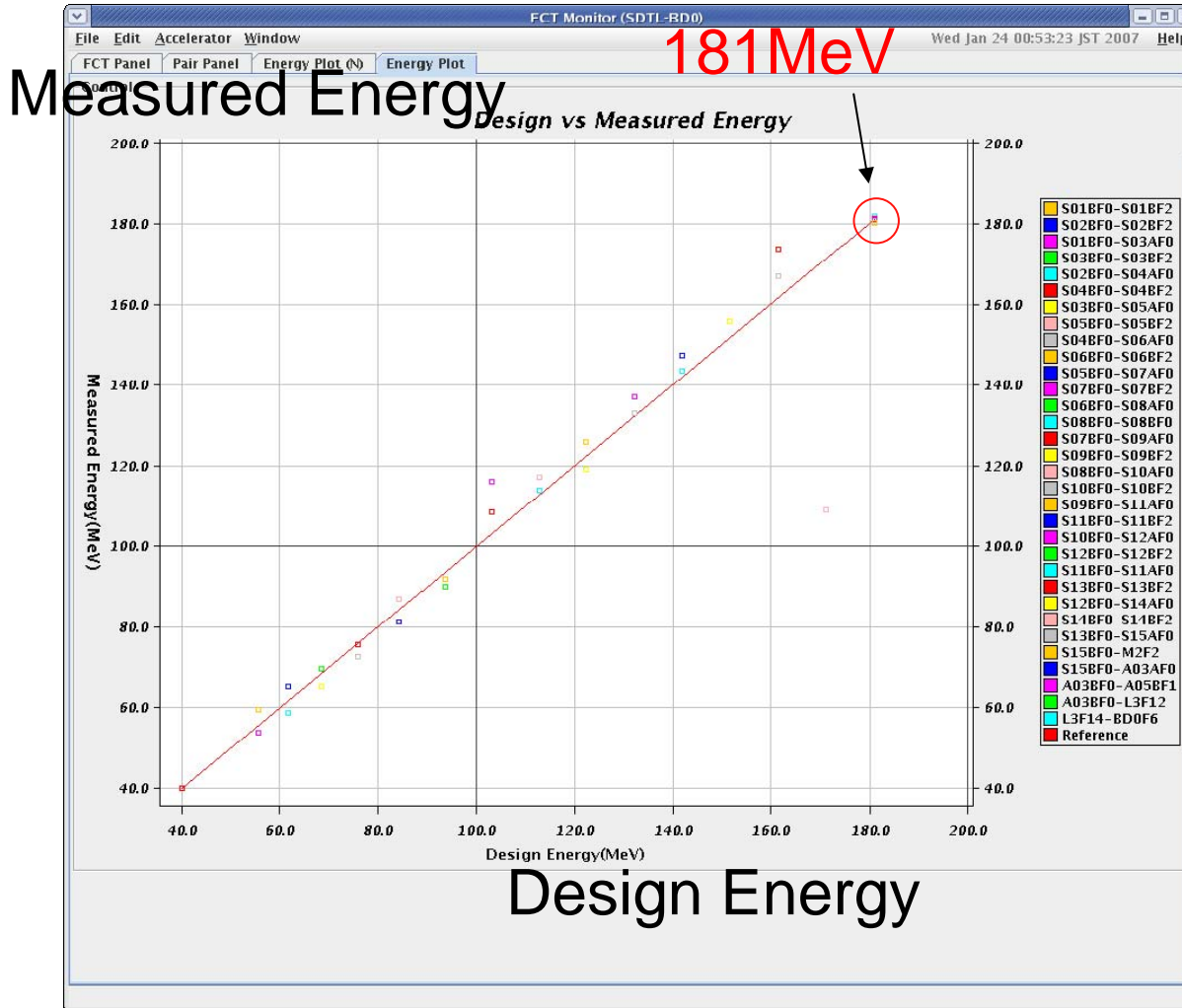


- Current monitor display
- Beam position monitor display



First acceleration to 181 MeV

24 Jan 2007



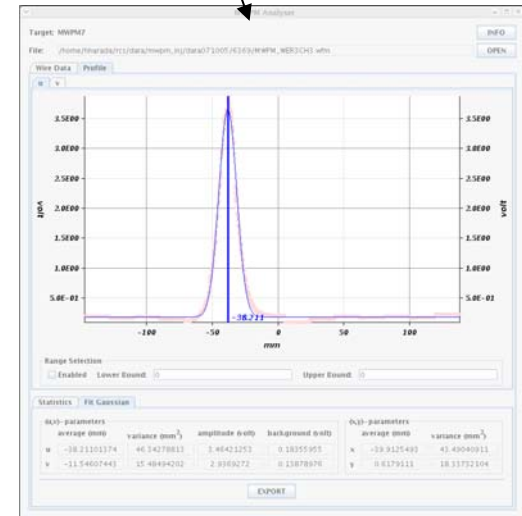
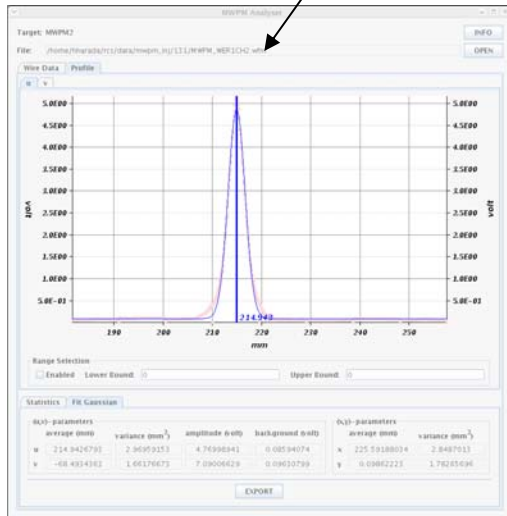
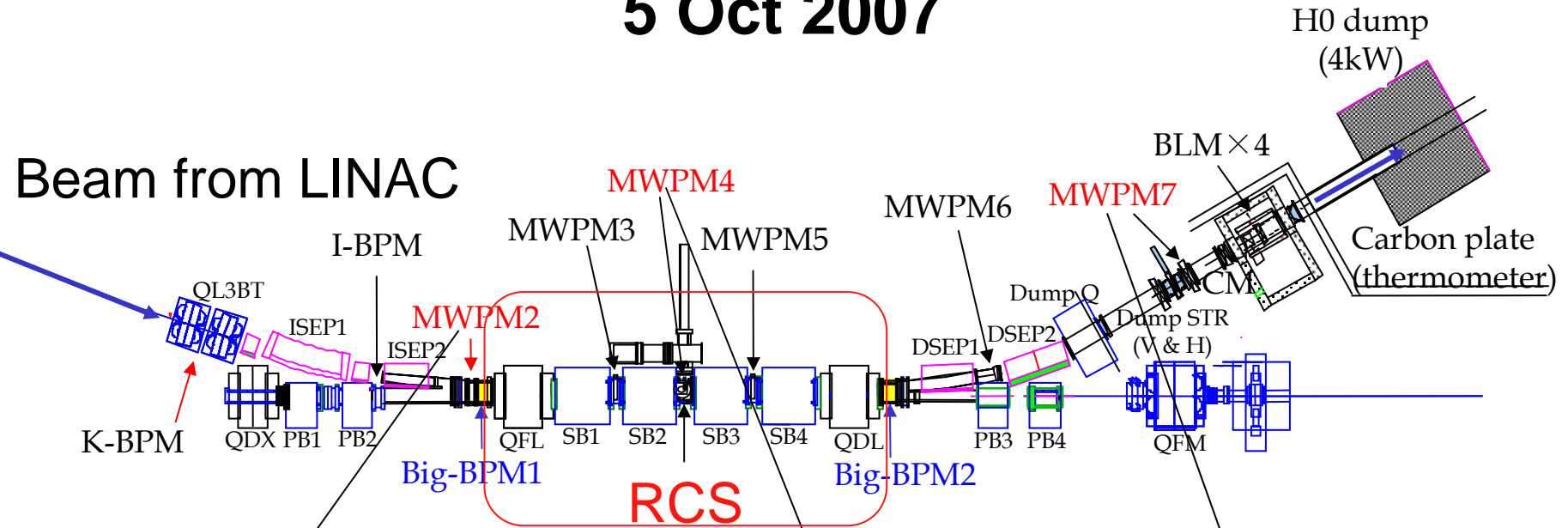
First acceleration to 181 MeV

24 Jan 2007



First Injection to RCS (H0 dump)

5 Oct 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!



2007 10 16