

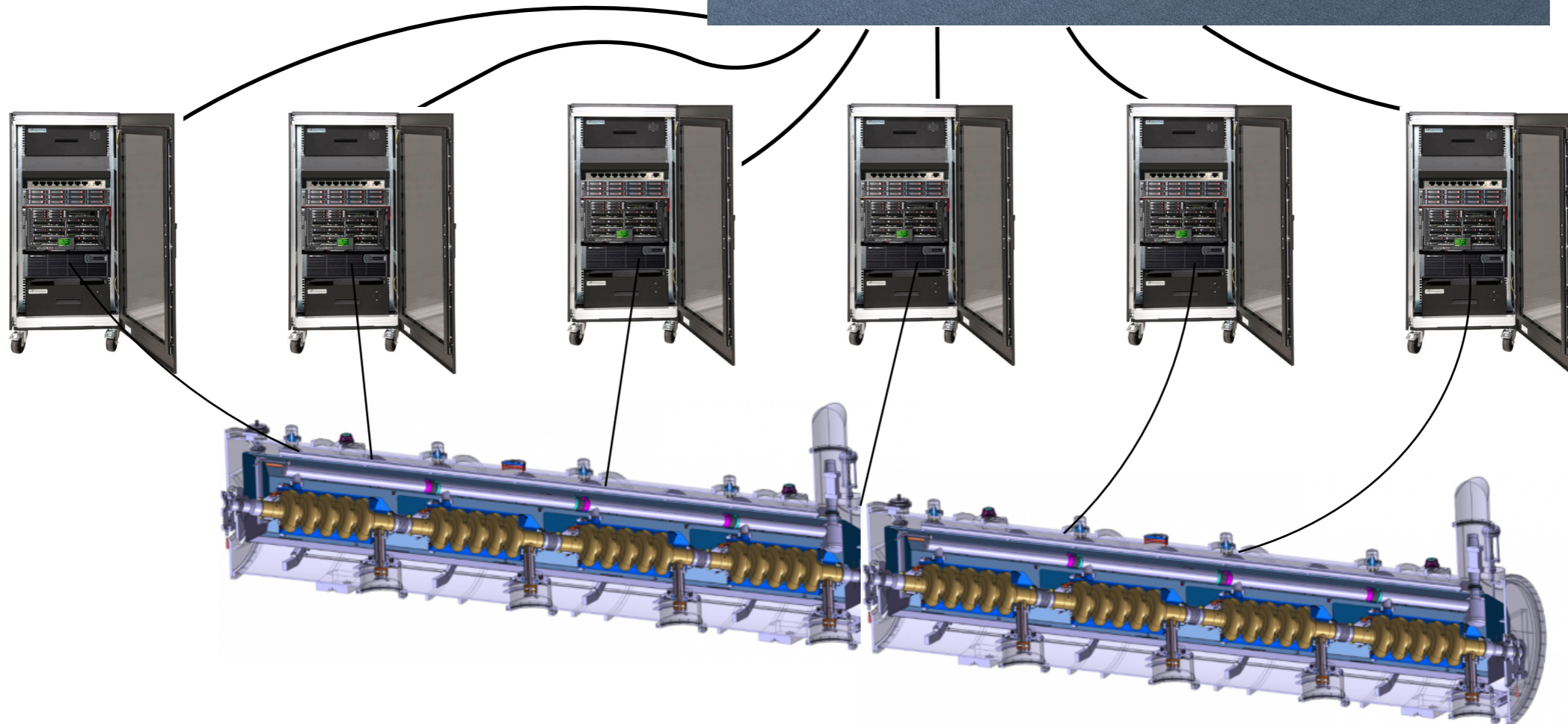
Thursday 6th of April 2017



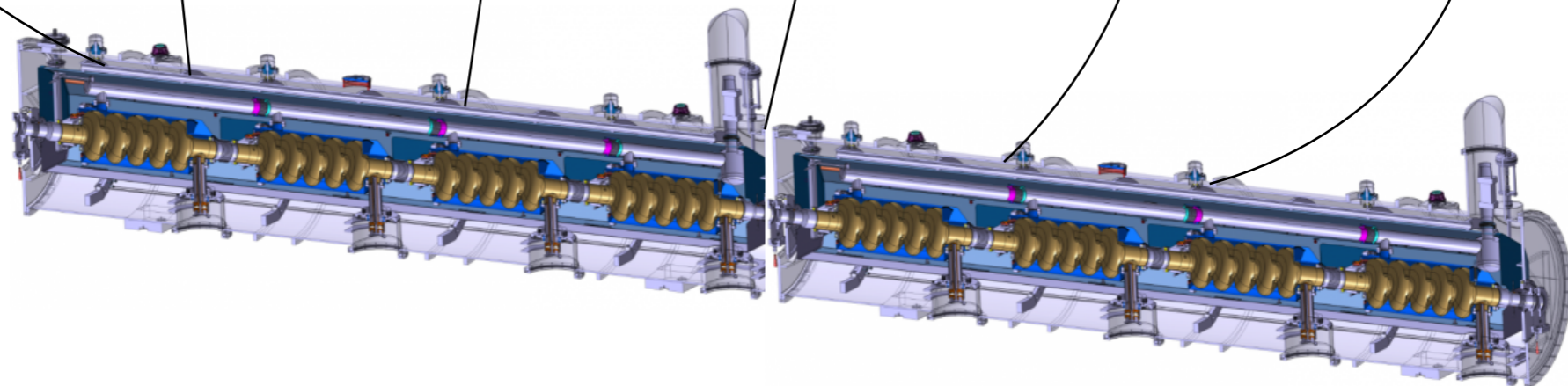
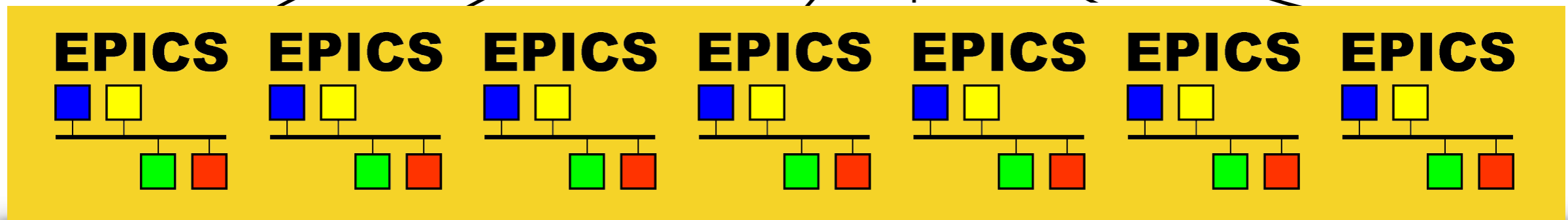
# EPICS 7 applications and services

Emanuele Laface

# The context

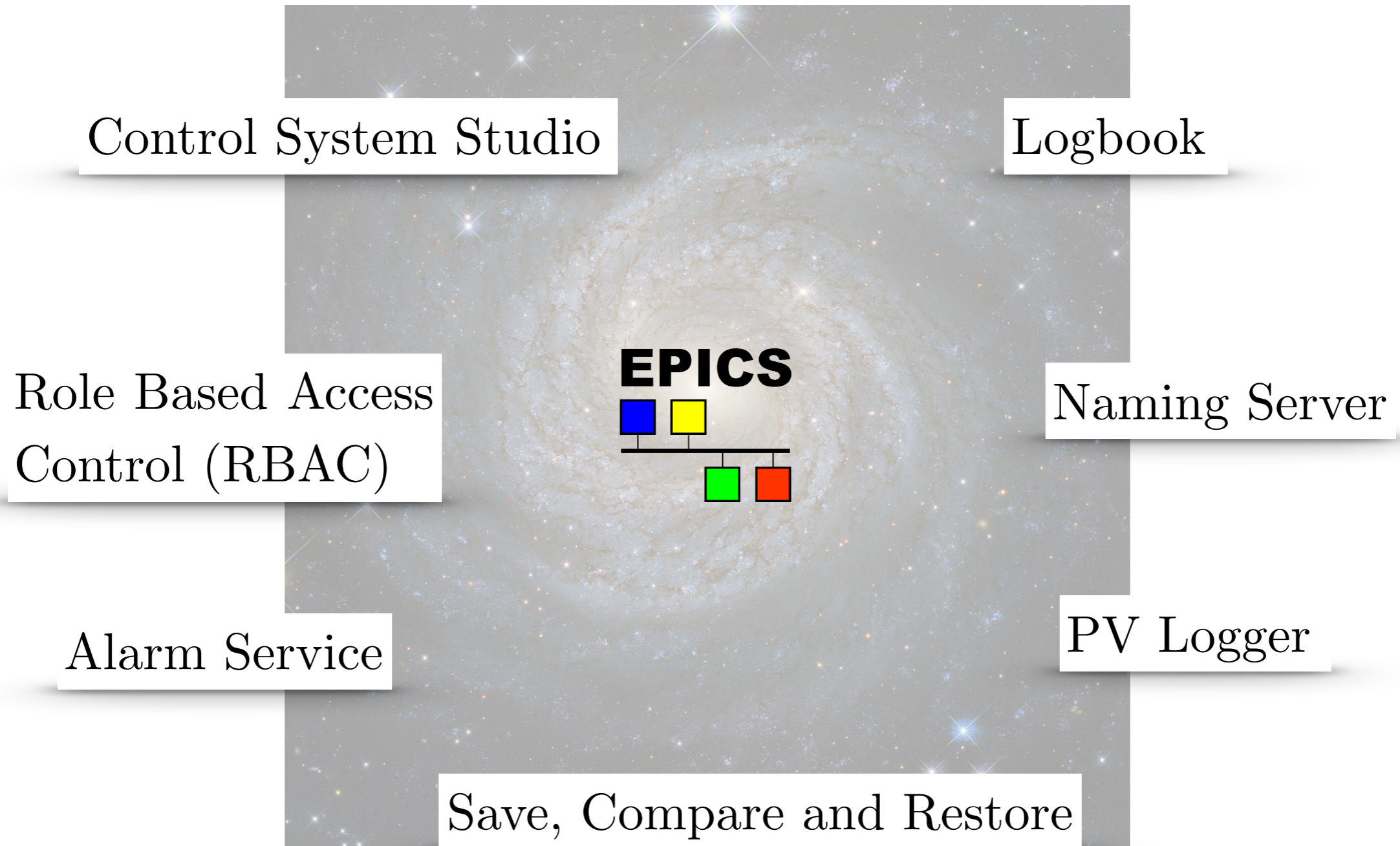


# The context



# The context

There is a galaxy of applications and services that will work with EPICS



# The context

In this presentation I will be focused on the applications required for the Beam Commissioning. The so called High-Level Applications.

# The plan

2018-02-05 ~ 2018-03-11

Beam commissioning up to LEBT

2018-09-17 ~ 2018-10-14

Beam commissioning up to MEBT

2019-01-28 ~ 2019-03-03

Beam commissioning up to DTL4

2019-06-10 ~ 2019-06-23

Beam commissioning up to tuning dump

2020-04-xx

Target ready (no beam yet??)

2021-03-xx

First neutron instrument ready (first beam to target??)

2023-08-xx

User program starts

2025-xx-xx

5 MW beam power??

# Expected by Beam Physics team

## Simple scan and check

### General

- Polarity
- Beam based alignment

### LEBT

- Iris vs current
- Chopper timing/voltage
- Gas pressure vs space charge compensation

### RFQ

- Power vs energy/transmission
- LEBT solenoids/steerers vs transmission

### MEBT

- Chopper timing/voltage
- Collimator positions

### A2T (including dogleg)

- Achromatic condition
- Phase advance between the raster system and shield wall

## Physics based tuning

### Standard

- Trajectory correction
- Phase scan
- Matching with 3(+)profiles
- Quad/buncher scan
- Matching with an emittance measurements

### Other linear model based

- Quad transfer function measurement
- Transfer matrix measurement
- Beam based alignment

### Special??

- Matching with an emittance measurement

# Expected by Beam Physics team

## Simple scan and check

### General

- Polarity
- Beam based alignment

### LEBT

- Iris vs current
- Chopper timing/voltage
- Gas pressure vs space charge compensation

### RFQ

- Power vs energy/transmission
- LEBT solenoids/steerers vs transmission

### MEBT

- Chopper timing/voltage
- Collimator positions

### A2T (including dogleg)

- Achromatic condition
- Phase advance between the raster system and shield wall

## Physics based tuning

### Standard

- Trajectory correction
- Phase scan
- Matching with 3(+)profiles
- Quad/buncher scan
- Matching with an emittance measurements

### Other linear model based

- Quad transfer function measurement
- Transfer matrix measurement
- Beam based alignment

### Special??

- Matching with an emittance measurement

Scanning

Model

Scanning and measurements

Measurements



# OpenXAL

Based on EPICS

Works at SNS

Is in Java (as CSS)

Linear solvers (SVD)

Virtual accelerator



Collaboration

Open Source

Includes an online model

Several applications already available

# OpenXAL

As framework for physics applications we agreed, to use OpenXAL.



Paper  
Document Number ESS-0017729  
Date Oct 2, 2014  
Revision 1.3 (1)  
State Preliminary

Evaluation of OpenXAL



## DOCUMENT REVISION HISTORY

Revision	Reason for revision	Date
1	New Document	
1.1	Comments from Y. Levinsen	25/11/14
1.2	Comments from M.Eshraqui, Y. Levinsen	14/10/14
1.3	Comments from E. Laface, L Fernandez	21/10/14

# Our OpenXAL

Since 2014 we worked hard to improve the existing version of OpenXAL in three directions

model

scripting

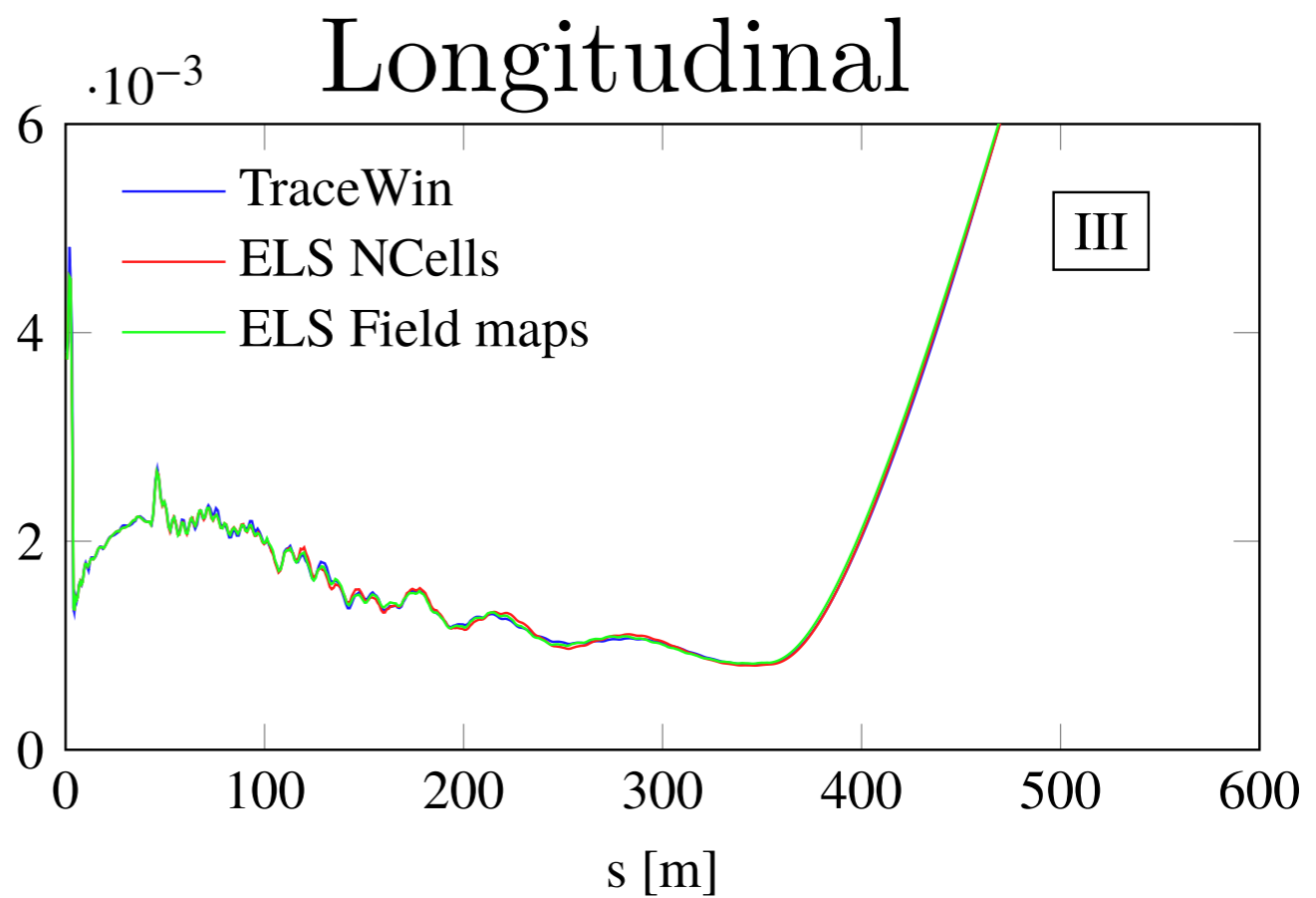
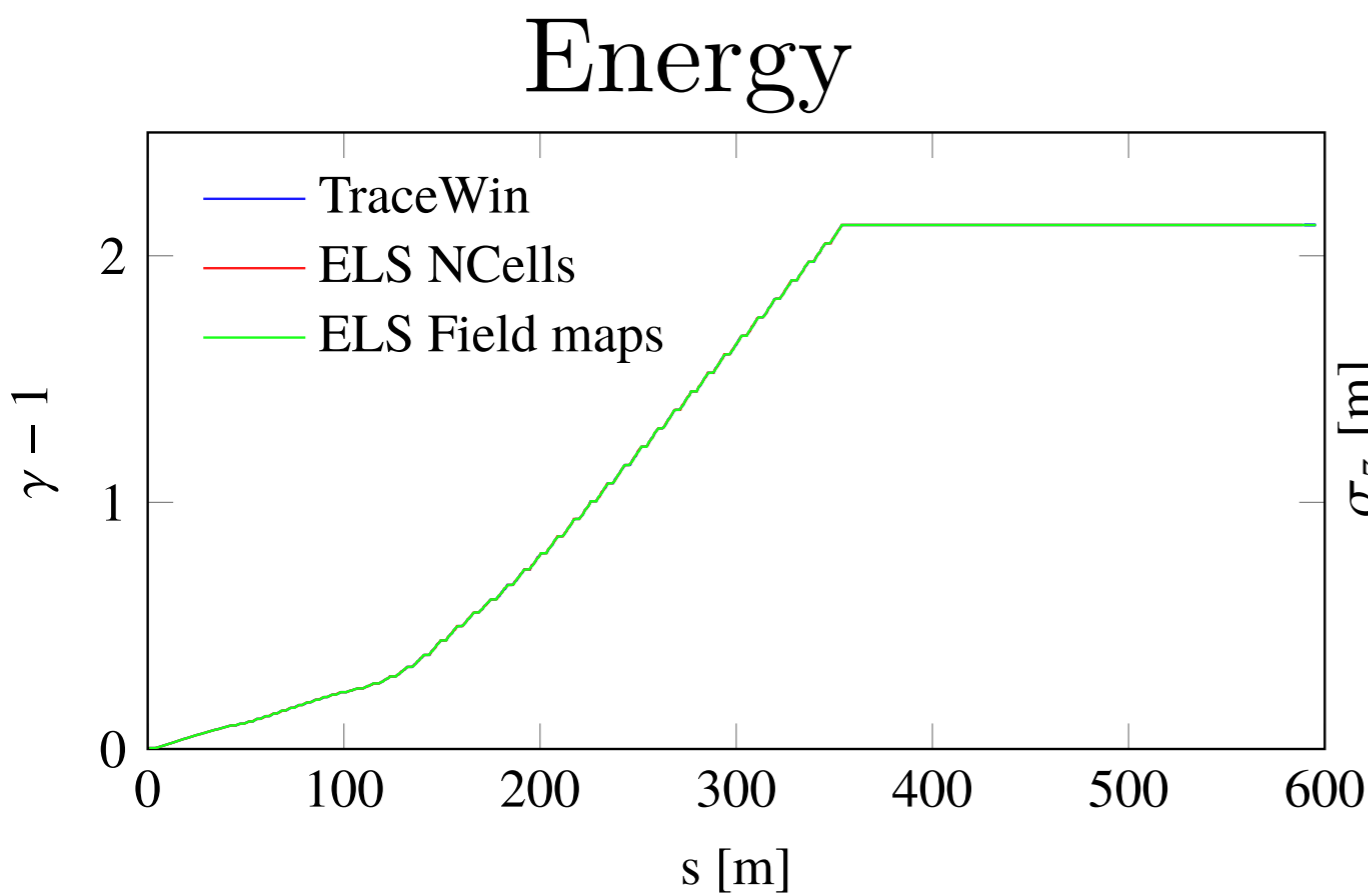
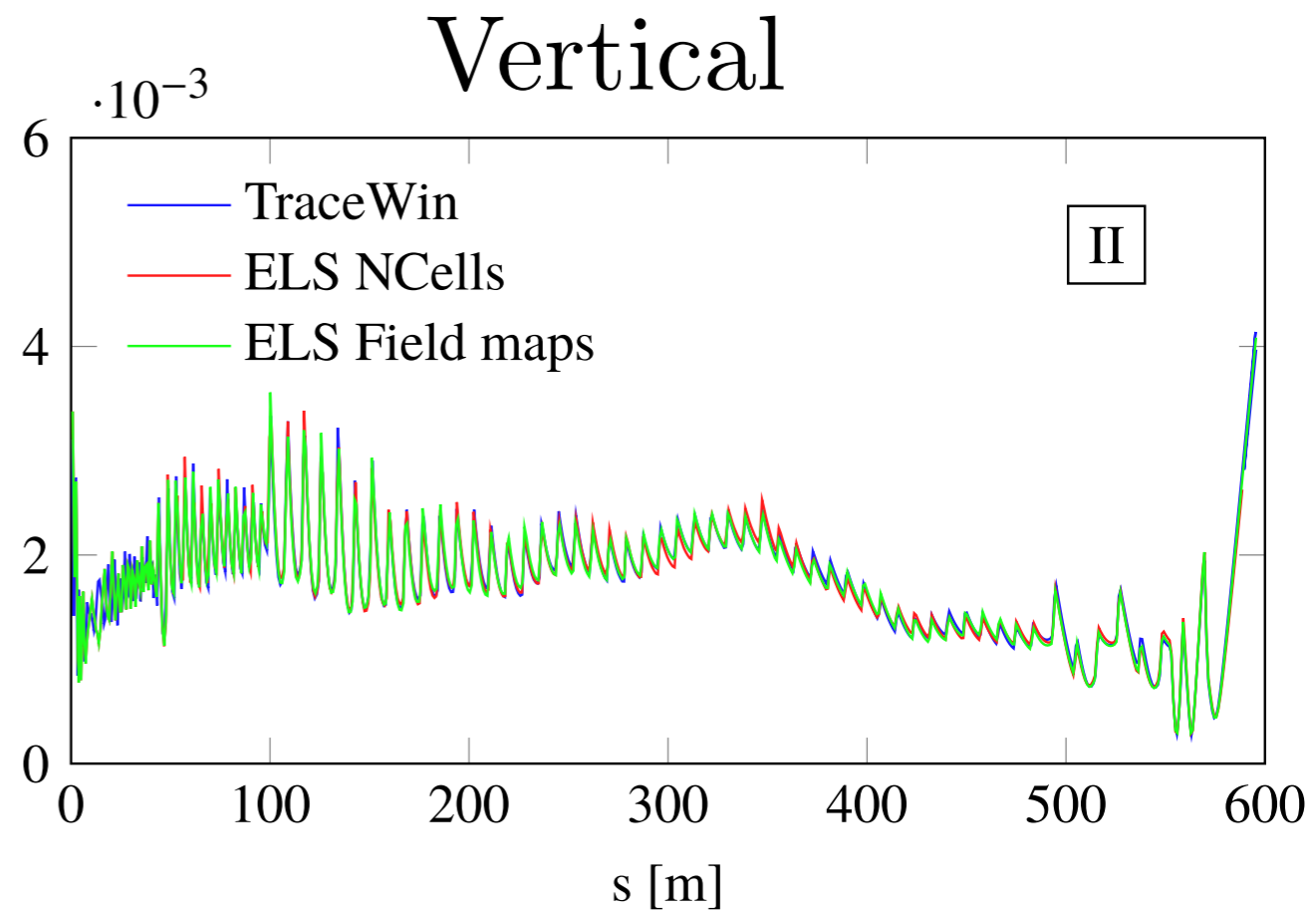
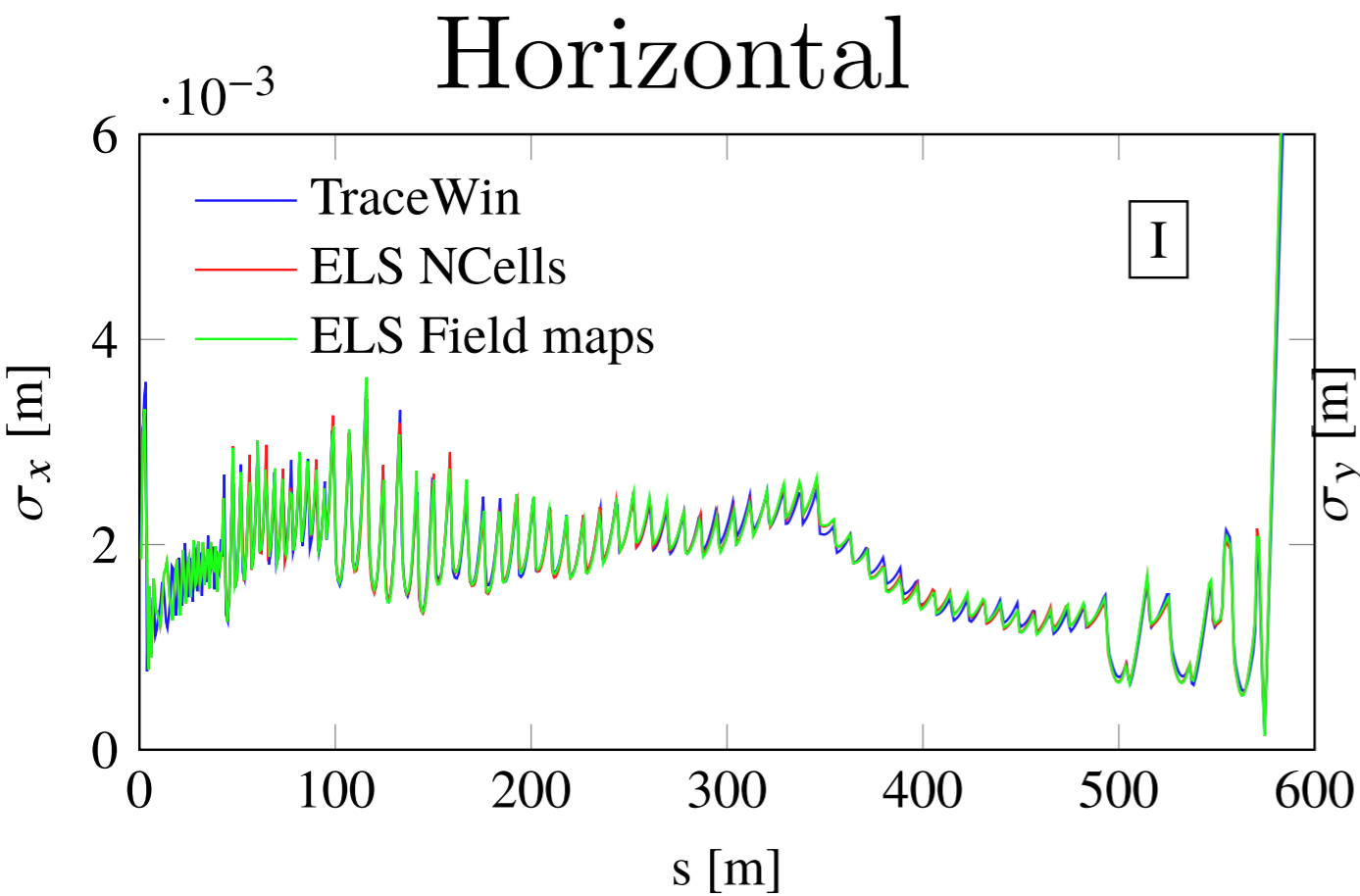
infrastructure integration

# OpenXAL model (ELS)

The model was rewritten in the space charge part and the acceleration. Today it includes a KV space charge and the linearization of a gaussian kick. It also has a NCELL acceleration mechanism and a Filed Map integrator for cavities.

Many issues in other elements (such as bending magnets) were reviewed and corrected.

The model was extensively tested vs. TraceWin.



# OpenXAL model (ELS)

We had also the possibility to test it at SNS. Two set of measurements were performed:

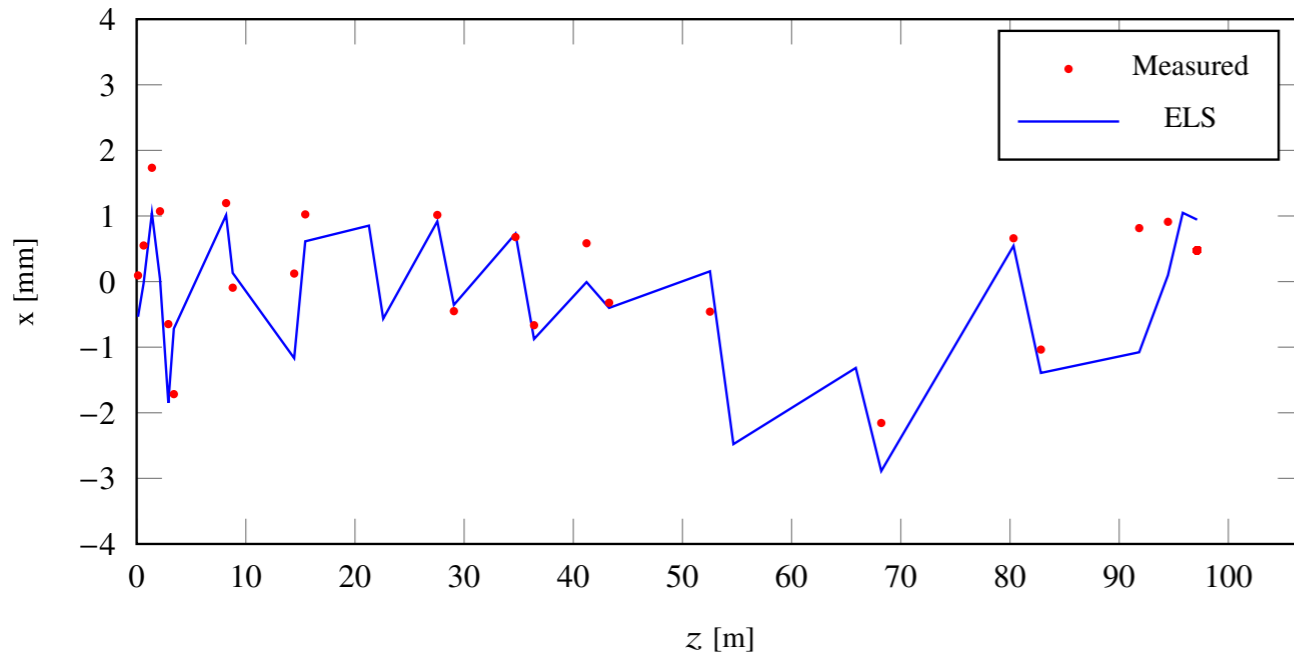
the excitation of a kicker at the beginning of the accelerator to see the beam oscillation downstream;

the phase scan of four CCL cavities;

# Kick of the beam in the MEBT

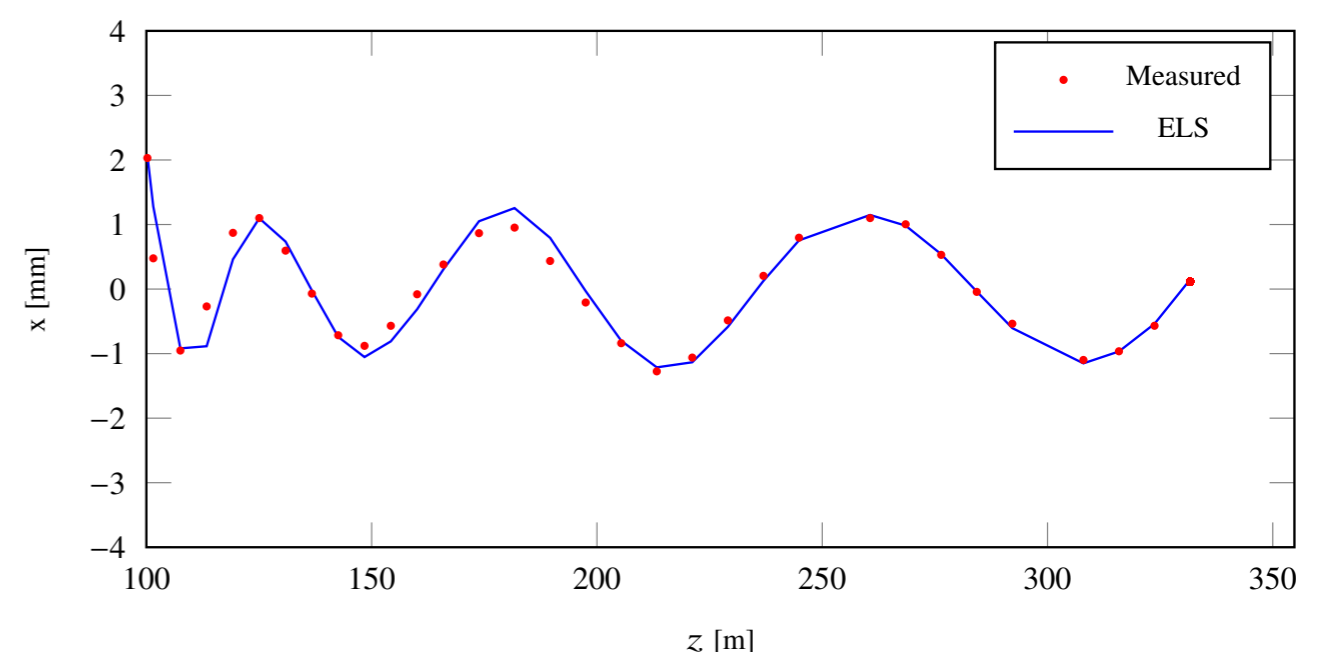
Normal conducting

Horizontal

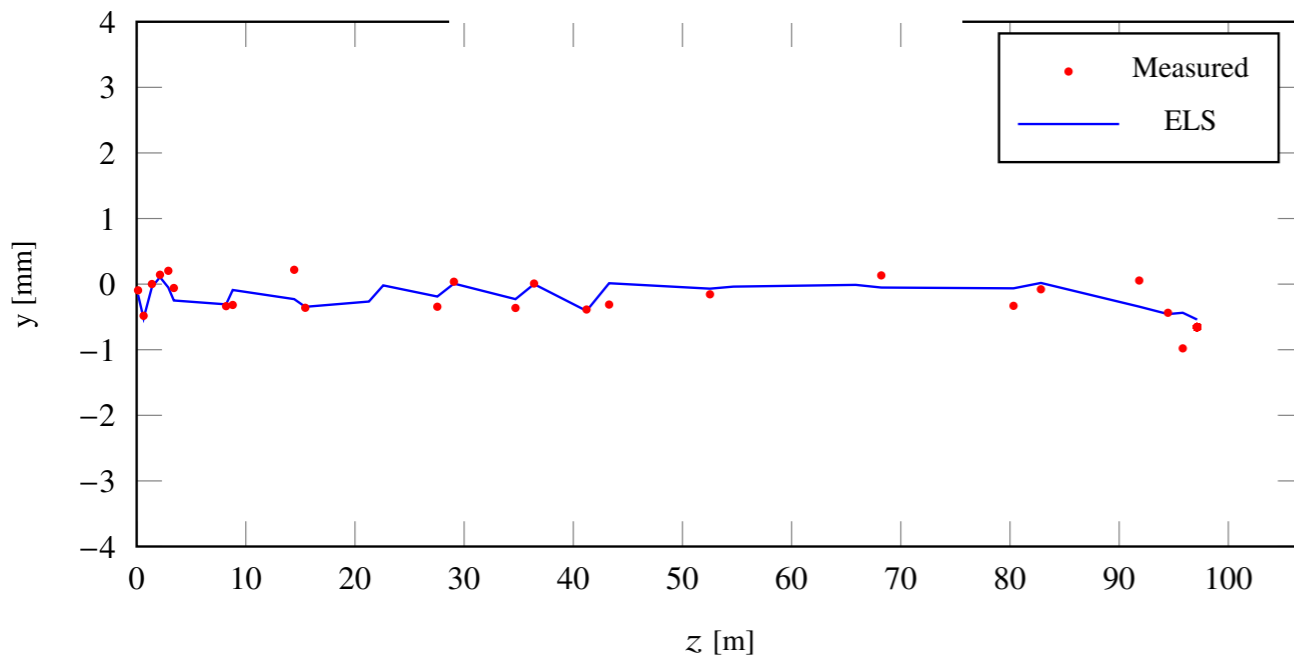


Super conducting

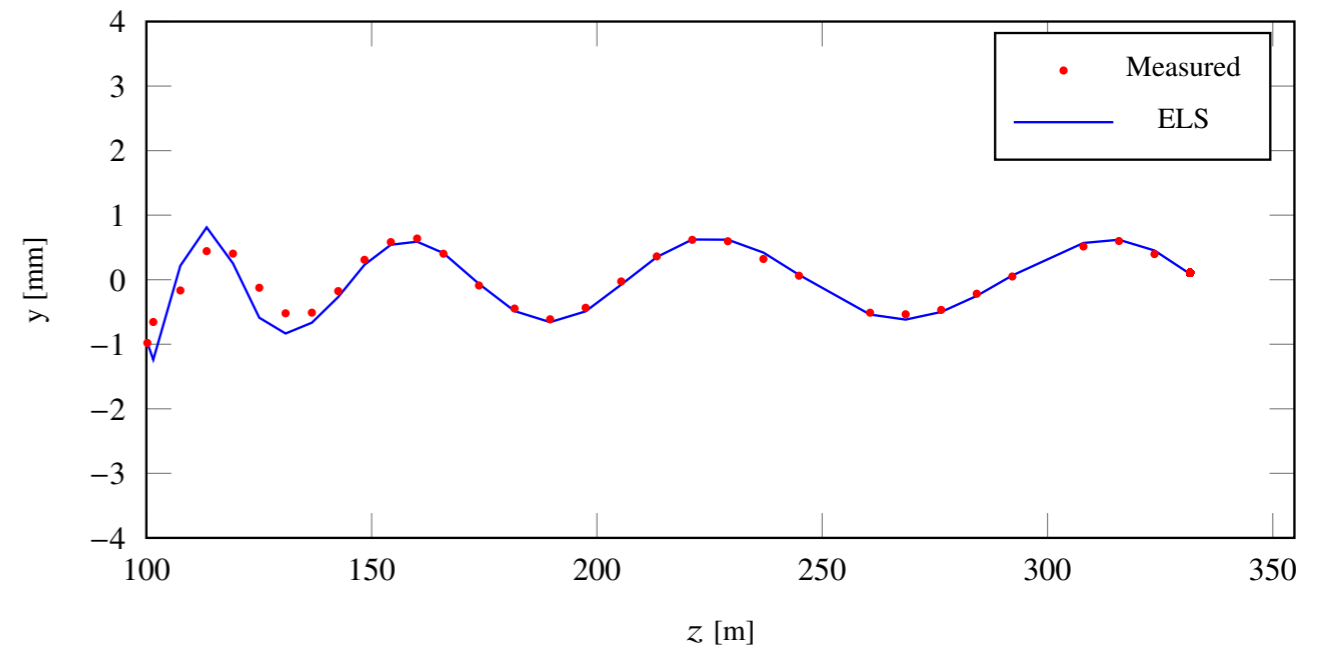
Horizontal



Vertical

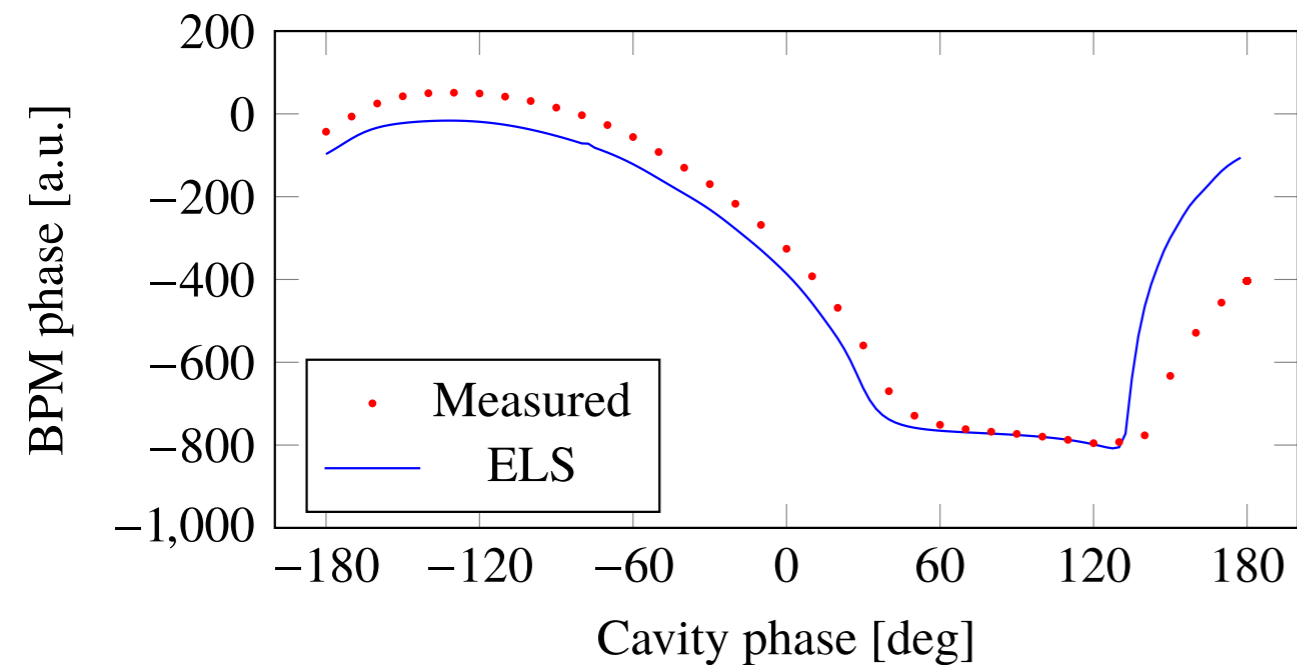


Vertical

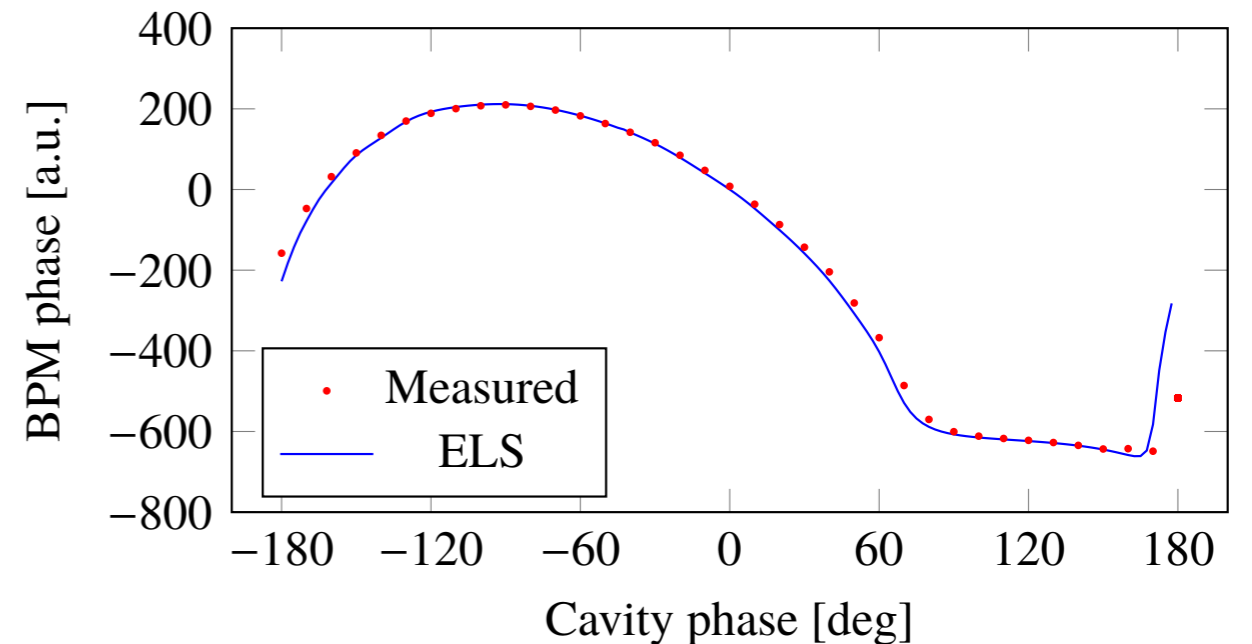


# Phase scan of four CCL cavities.

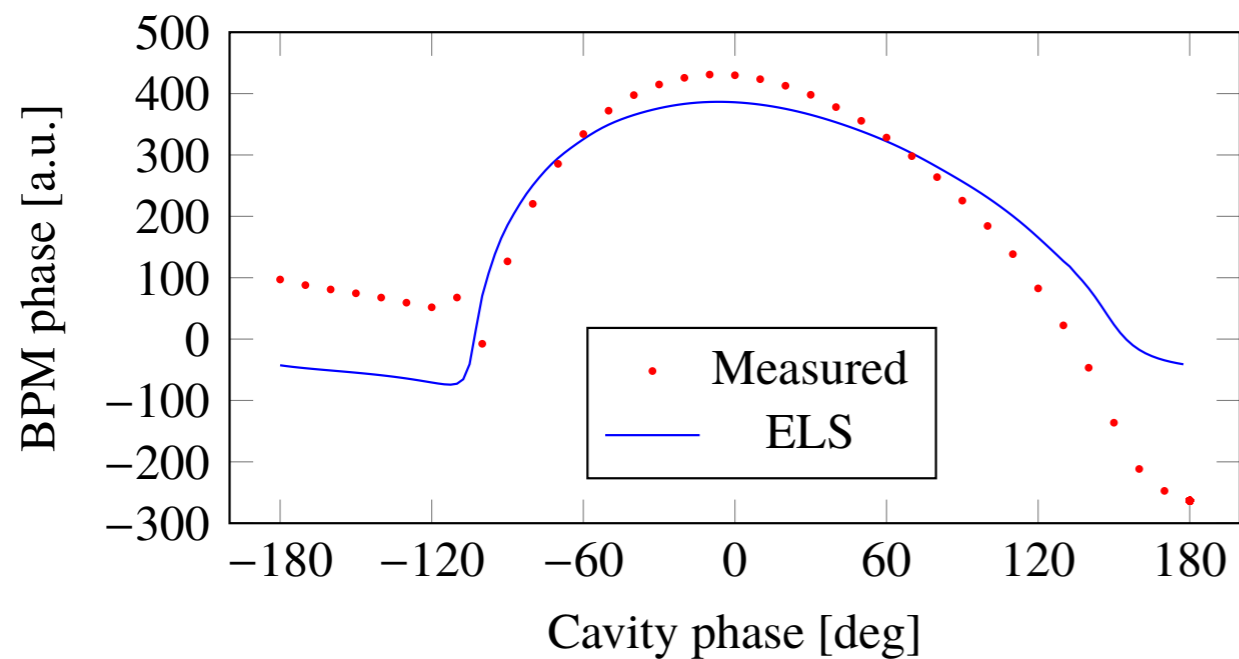
Copuled-Cavity 1



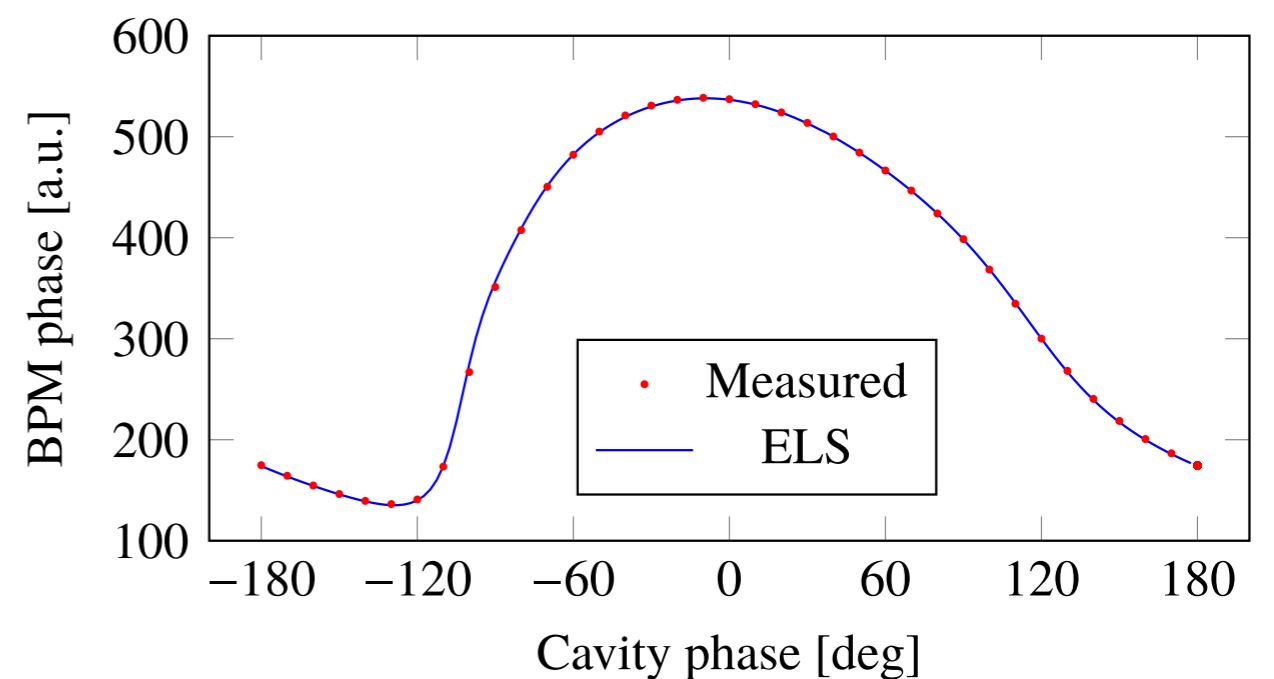
Copuled-Cavity 2



Copuled-Cavity 3



Copuled-Cavity 4





# Scripting

OpenXAL is in Java but Beam Physics requires a scripting environment to speedup creation of tools.

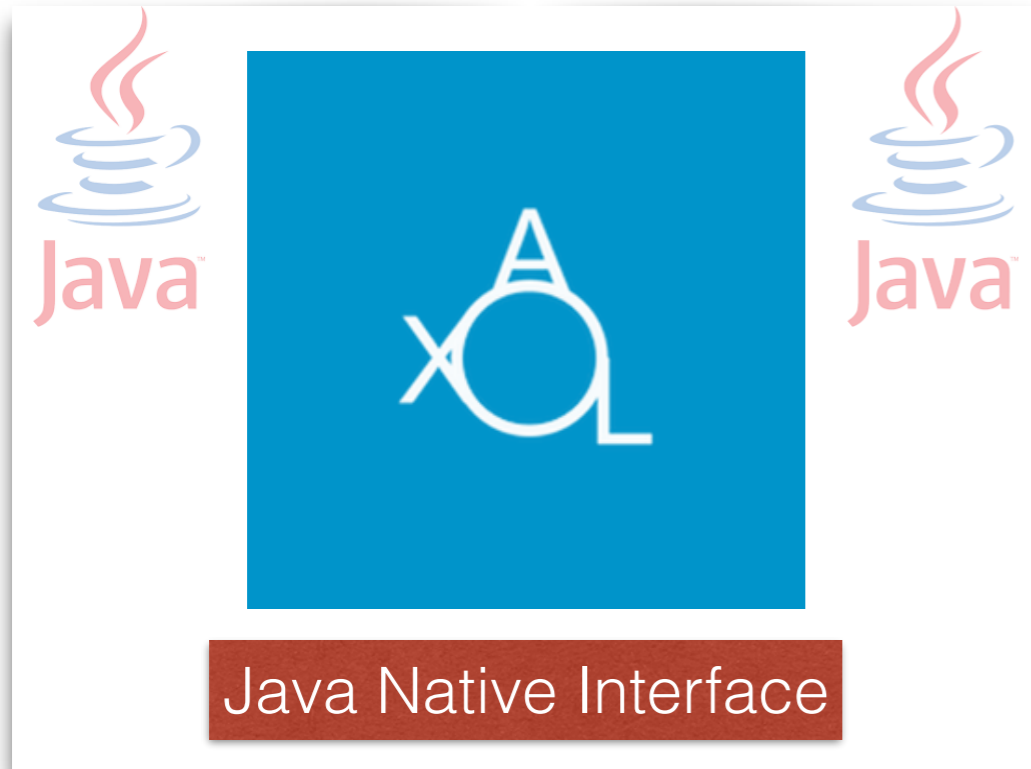
The solution adopted is to invoke OpenXAL from Python through the Java Native Interface (JNI).

The Java Classes are connected to Python Classes using the JType library.

The result is a pure Python environment capable to interact with OpenXAL.

This service is centralised and accessible through web browser in a Jupyter Hub installation.

# Scripting



Access  
from any  
browser.



Java Classes to  
Python Classes



Python infrastructure

# Infrastructure

OpenXAL is integrated in the ecosystem of ESS applications and relies on different services.



European Spallation Source

## LinacLego

XML based Lattice Description



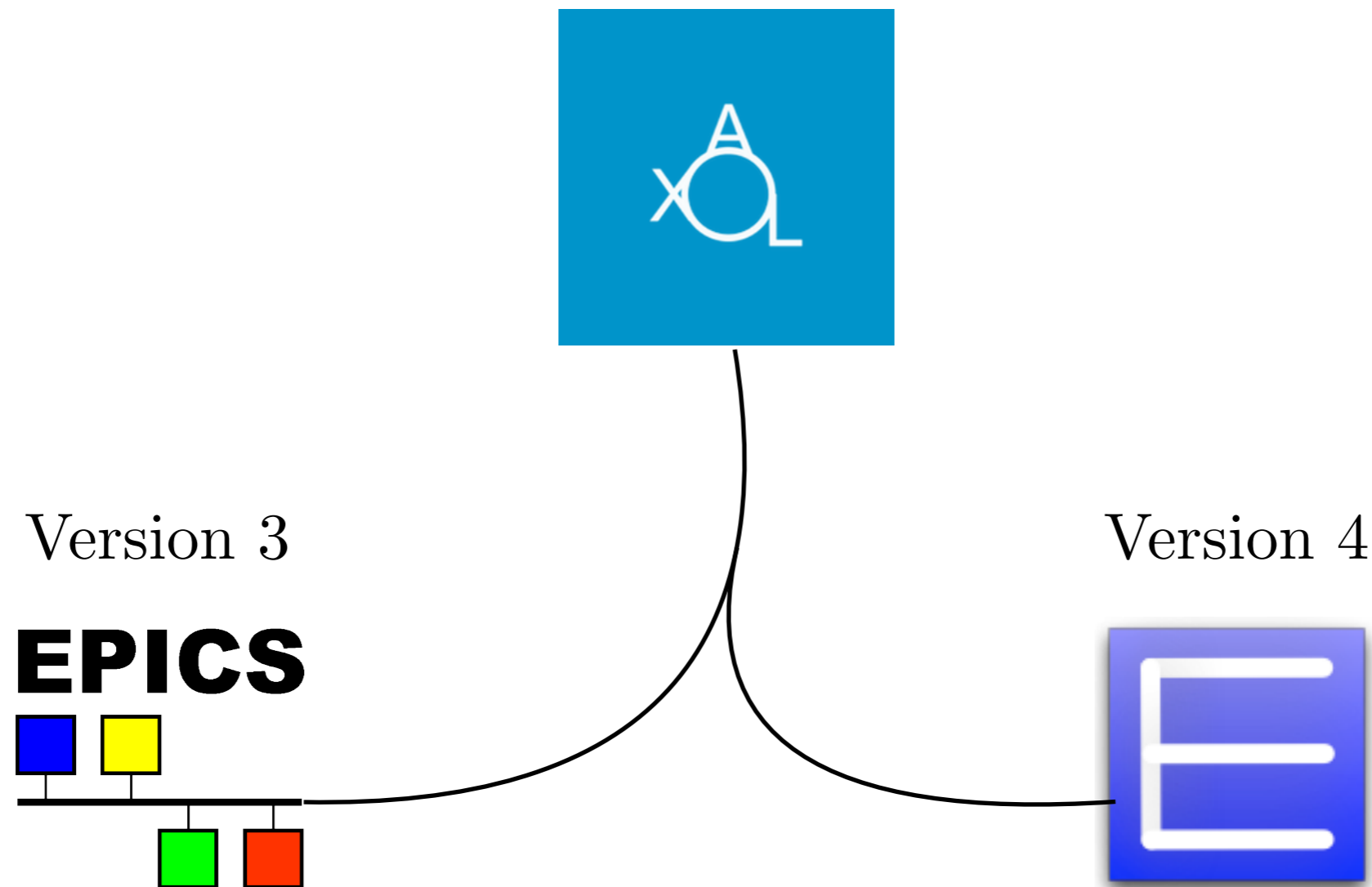
Role Based Access  
Control (RBAC)

ICS databases



# Infrastructure

The current version of OpenXAL support both EPICSv3 and EPICSv4 (Channel Access and PV Access).



# Applications

# Planned applications

Application	Similar applications	First needed	Comments	Priority
Launcher	Launcher	LEBT	Already works well	1
Correlation Tool	Scan1D Scan2D	LEBT	Existing applications perhaps sufficient for commissioning	4
Phase Scan	Pasta (SNS)	MEBT		2
Trajectory Correction	Orbit Correction	MEBT	Existing already useful	2
Matching Tool	Optimisation (GANIL)	MEBT or later		4
Model Manager	Model Manager (SLAC)	LEBT?	Already feature rich. Requires database	3
Virtual Accelerator	Virtual Accelerator	MEBT		1
Optics Editor	Optics Editor		Primarily use TraceWin or Lina-cLego to edit optics	5
Aperture+Envelope display		After Commissioning	To look at max beam size in the accelerator when e.g. scrapers are moved. Might be covered by A06	6
Raster Control	TargetBeamSizeCont (SNS)	A2T	CSS might be sufficient	3



# Planned applications

1. Orbit Display and Fitting. Plot beam monitors' X, Y, TMIT data by Z, with orbit fitting; save such orbits; load past orbits and compare to present
2. Orbit Correction, aka "Steering." GUI to help user plot beam monitor data and find corrector settings to minimize orbit RMS (absolute or difference to a saved orbit from 1 above) [3]
3. Correlation Tool. GUI to help user select and scan PVs in 1 or 2 dimensions and acquire many PVs; plot, fit, save/load data for offline analysis [2]
4. Model optics. Track lattice with design or existing PV values, plot, save Twiss and R-mats to database. Model service allows other applications to get optics from that database
5. Bumps. Calculates corrector settings to achieve user desired local orbit offsets and angles; settings then deployed using "knobs" so user can finely control extent of implementation
6. Wire scans. GUI to help user select type of scan (quad etc); make scan, plot and fit results; save/load data for offline analysis
7. Emittance scans. GUI to help users measurement of slice or projected emittance at selected wire or profile monitor; scan, plot, fit, save/load data for offline analysis
8. Profile Monitor. GUI to help user select camera or profile monitor, display transverse beam profile, select region of interest, fit giving beam sigmas; save/load data for offline analysis
9. Z-plot. Simply plot PV values by Z, for example all quad settings, or all vacuum. User gives PV name pattern, then all matching PVs are plotted by Z position
10. Linac Energy Management (LEM). Calculates and systematically corrects quadrupole settings for changes in beam rigidity due to changes in phase or amplitude of RF
11. Feedback. GUI to help calculate and set orbit and energy etc feedback setpoints.
12. Archive Viewer. A GUI to help users get the past recorded values of one or more PVs, between some start to end time, from the archive data store, and to display those values. Should be able also to plot all 1 or more PVs against common time axis, values of simple expressions by time (eg  $PV1 / \sin PV2$ ), one PV against the other (scatter plot), histogram of PV
13. Configuration data save and restore. GUI to help operations save the values (actual and desired) of all PVs of a given device type in a given region. E.g. all magnets in MEBT, or even in whole machine. Ideally do BPM and other beam pulse synced device values too – i.e. saved reference orbits (see Orbit Display above) may be handled by this tool.

# Available Applications Today

## Launcher

- Lists all installed applications
- Monitors running applications
- Removes need for menu items in OS
- Does not show script-based applications from JType

The top screenshot shows the 'Run' tab of the XAL Launcher. It displays a list of installed applications with the following columns: Label, Last Launch T..., Notes, Kind, Version, and Author. The list includes applications like ArrayPVs' Waveform Viewer, Beam Matcher, BPMs' Waveform Viewer, Bricks, Bricks Application Demo, bsmanalysis, Database Browser, Diagnostic Timing Application, Emittance Analysis, Energy Manager, Energy Meter, Experiment Automator, External Lattice Generator, Fingerprint, Injection Dump Wizard, Knobs, Labbook, Launcher, Machine Recorder, Machine Simulator, Magnet Cycling, Model Manager Application, My Tuner Viewer, Optics Editor, Optics Switcher, Orbit Correction, PASTA Application, PV Correlator, PV Histogram, PV Logger, PV Timestamp Testing Applicat..., RF Phase Shaker, SADDAM Application, Save Compare REstore (SCORE...), Scan 1D, Scan 2D, and SCL Monitor Application.

The bottom screenshot shows the 'Monitor' tab of the XAL Launcher. It displays a table with the following columns: Application, Host Name, Total Memory, Launch Time, and Heartbeat. The table lists three running applications: Launcher, Scan1D, and Virtual Accelerator.

Application	Host Name	Total Memory	Launch Time	Heartbeat
Launcher	ynqve-t430	113664.0	Sun Feb 26 13:53:56 CET 2017	Sun Feb 26 13:58:57 CET 2017
Scan1D	ynqve-t430	99840.0	Sun Feb 26 13:57:48 CET 2017	Sun Feb 26 13:58:57 CET 2017
Virtual Accelerator	ynqve-t430	99840.0	Sun Feb 26 13:58:24 CET 2017	Sun Feb 26 13:58:57 CET 2017

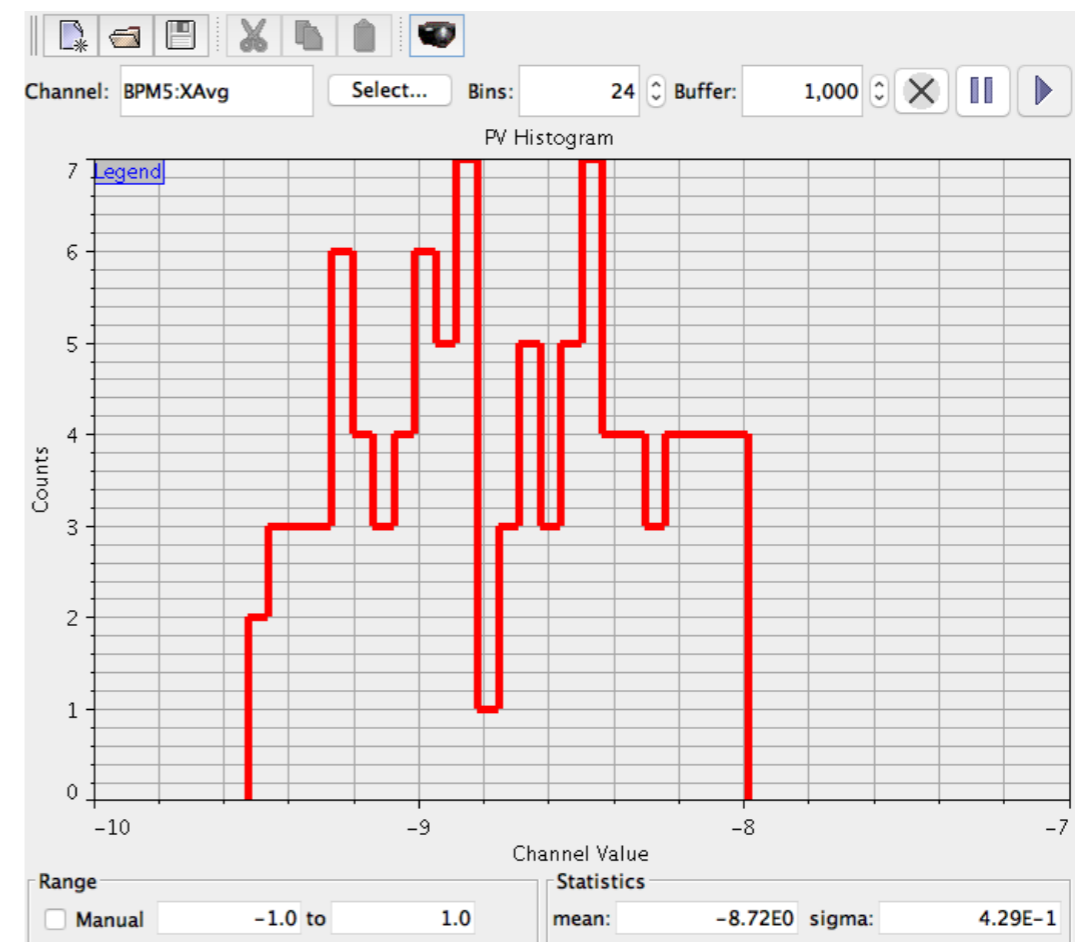




# Available Applications Today

## PV Logging

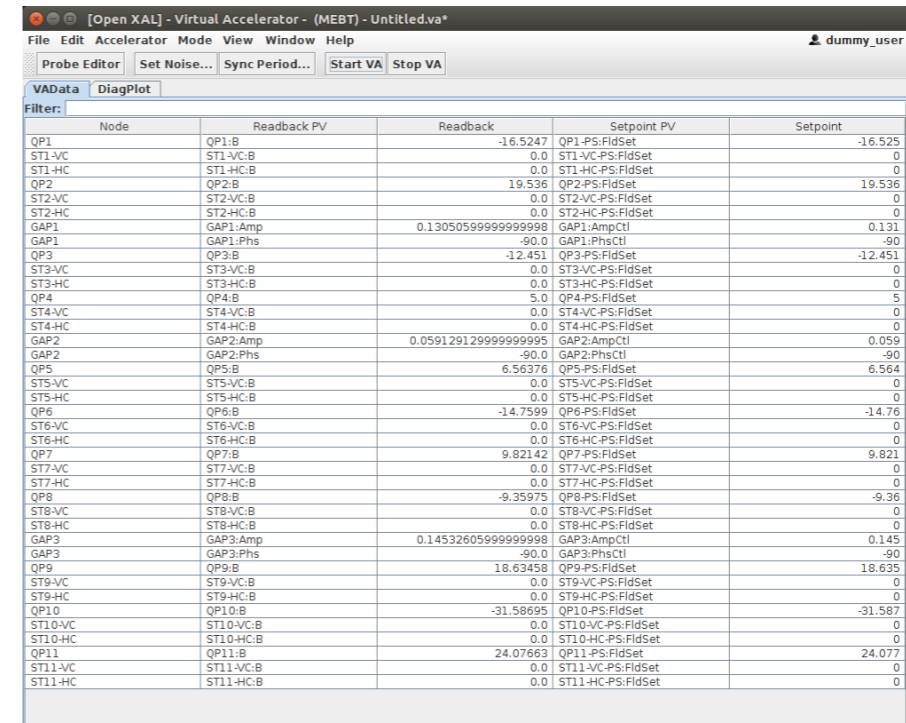
- Generic PV access applications
- Data logger, histograms, correlations
- Of these, only PV Histogram works out of the box



# Available Applications Today

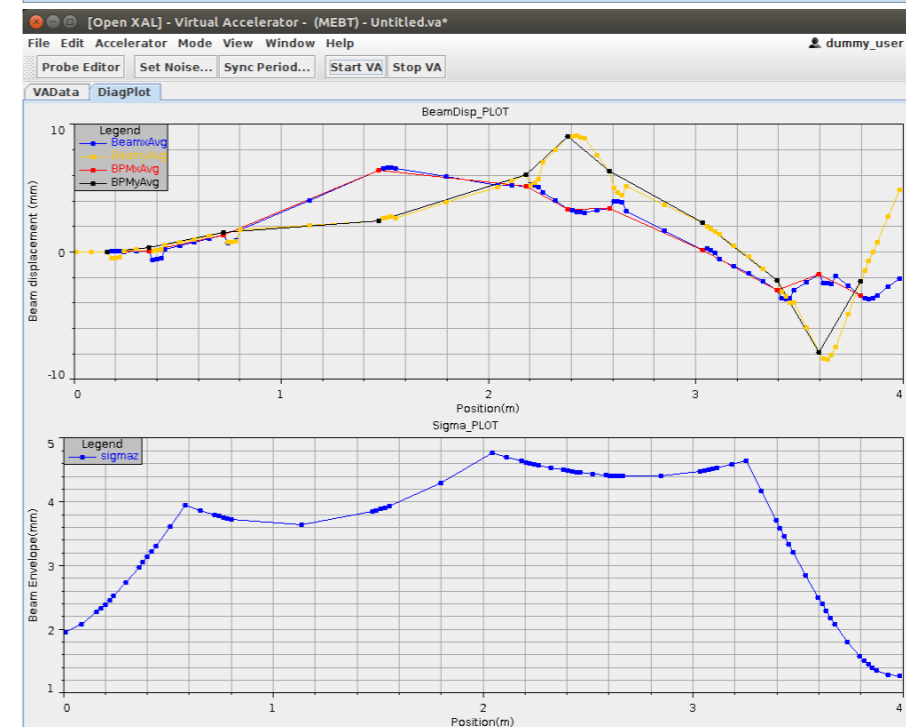
## Virtual Accelerator

- Runs a virtual machine based on model
- Displays simulated beam displacement and envelope
- EPICS channels which other applications can communicate from/to
- Misalignments and signal noise (static and dynamic)
- BPM positions compared to simulated orbit



The screenshot shows the 'VADData' tab in the Virtual Accelerator software. It displays a table with columns for Node, Readback PV, Readback, Setpoint PV, and Setpoint. The table lists various components like QP1, ST1-VC, ST1-HC, QP2, ST2-VC, ST2-HC, GAP1, QP3, ST3-VC, ST3-HC, QP4, ST4-VC, ST4-HC, GAP2, QP5, ST5-VC, ST5-HC, QP6, ST6-VC, ST6-HC, QP7, ST7-VC, ST7-HC, QP8, ST8-VC, ST8-HC, GAP3, QP9, ST9-VC, ST9-HC, QP10, ST10-VC, ST10-HC, QP11, ST11-VC, and ST11-HC, along with their respective readback and setpoint values.

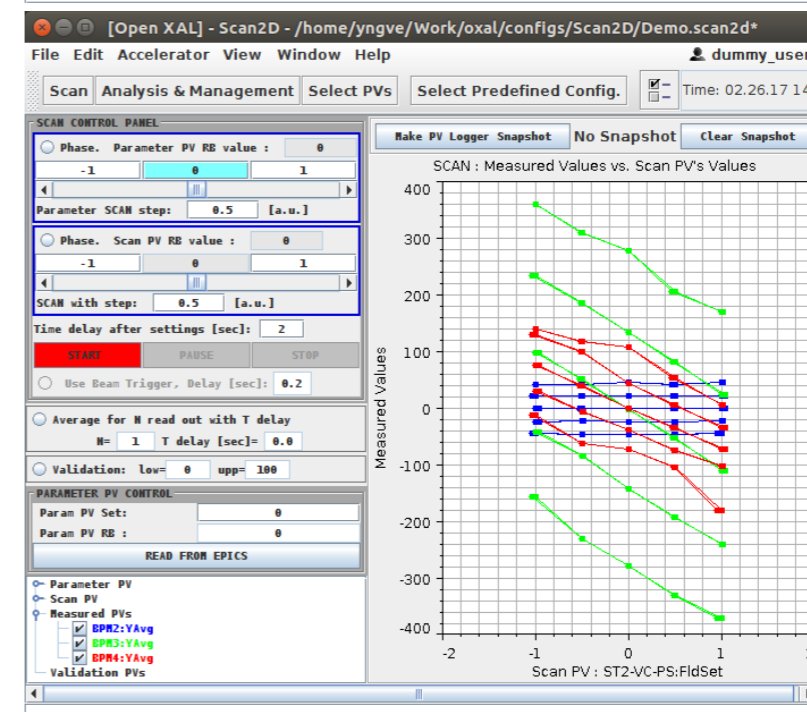
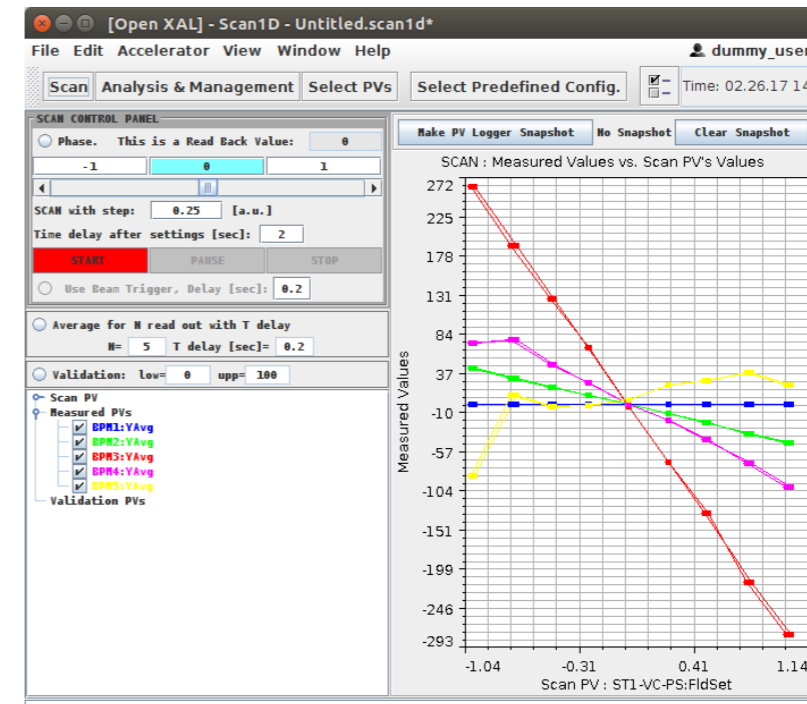
Node	Readback PV	Readback	Setpoint PV	Setpoint
QP1	QP1:B	-16.5247	QP1-PS:FidSet	-16.525
ST1-VC	ST1-VC:B	0.0	ST1-VC-PS:FidSet	0
ST1-HC	ST1-HC:B	0.0	ST1-HC-PS:FidSet	0
QP2	QP2:B	19.536	QP2-PS:FidSet	19.536
ST2-VC	ST2-VC:B	0.0	ST2-VC-PS:FidSet	0
ST2-HC	ST2-HC:B	0.0	ST2-HC-PS:FidSet	0
GAP1	GAP1:Phs	0.13050599999999998	GAP1:PhsCtl	0.131
GAP1	GAP1:Phs	-90.0	GAP1:PhsCtl	-90
QP3	QP3:B	-12.451	QP3-PS:FidSet	-12.451
ST3-VC	ST3-VC:B	0.0	ST3-VC-PS:FidSet	0
ST3-HC	ST3-HC:B	0.0	ST3-HC-PS:FidSet	0
QP4	QP4:B	5.0	QP4-PS:FidSet	5
ST4-VC	ST4-VC:B	0.0	ST4-VC-PS:FidSet	0
ST4-HC	ST4-HC:B	0.0	ST4-HC-PS:FidSet	0
GAP2	GAP2:Phs	0.059129129999999998	GAP2:PhsCtl	0.059
GAP2	GAP2:Phs	-90.0	GAP2:PhsCtl	-90
QP5	QP5:B	6.56376	QP5-PS:FidSet	6.564
ST5-VC	ST5-VC:B	0.0	ST5-VC-PS:FidSet	0
ST5-HC	ST5-HC:B	0.0	ST5-HC-PS:FidSet	0
QP6	QP6:B	-14.7599	QP6-PS:FidSet	-14.76
ST6-VC	ST6-VC:B	0.0	ST6-VC-PS:FidSet	0
ST6-HC	ST6-HC:B	0.0	ST6-HC-PS:FidSet	0
QP7	QP7:B	9.82142	QP7-PS:FidSet	9.821
ST7-VC	ST7-VC:B	0.0	ST7-VC-PS:FidSet	0
ST7-HC	ST7-HC:B	0.0	ST7-HC-PS:FidSet	0
QP8	QP8:B	-9.35975	QP8-PS:FidSet	-9.36
ST8-VC	ST8-VC:B	0.0	ST8-VC-PS:FidSet	0
ST8-HC	ST8-HC:B	0.0	ST8-HC-PS:FidSet	0
GAP3	GAP3:Phs	0.14532605999999998	GAP3:PhsCtl	0.145
GAP3	GAP3:Phs	-90.0	GAP3:PhsCtl	-90
QP9	QP9:B	18.63458	QP9-PS:FidSet	18.635
ST9-VC	ST9-VC:B	0.0	ST9-VC-PS:FidSet	0
ST9-HC	ST9-HC:B	0.0	ST9-HC-PS:FidSet	0
QP10	QP10:B	-31.58695	QP10-PS:FidSet	-31.587
ST10-VC	ST10-VC:B	0.0	ST10-VC-PS:FidSet	0
ST10-HC	ST10-HC:B	0.0	ST10-HC-PS:FidSet	0
QP11	QP11:B	24.07663	QP11-PS:FidSet	24.077
ST11-VC	ST11-VC:B	0.0	ST11-VC-PS:FidSet	0
ST11-HC	ST11-HC:B	0.0	ST11-HC-PS:FidSet	0



# Available Applications Today

## Scan

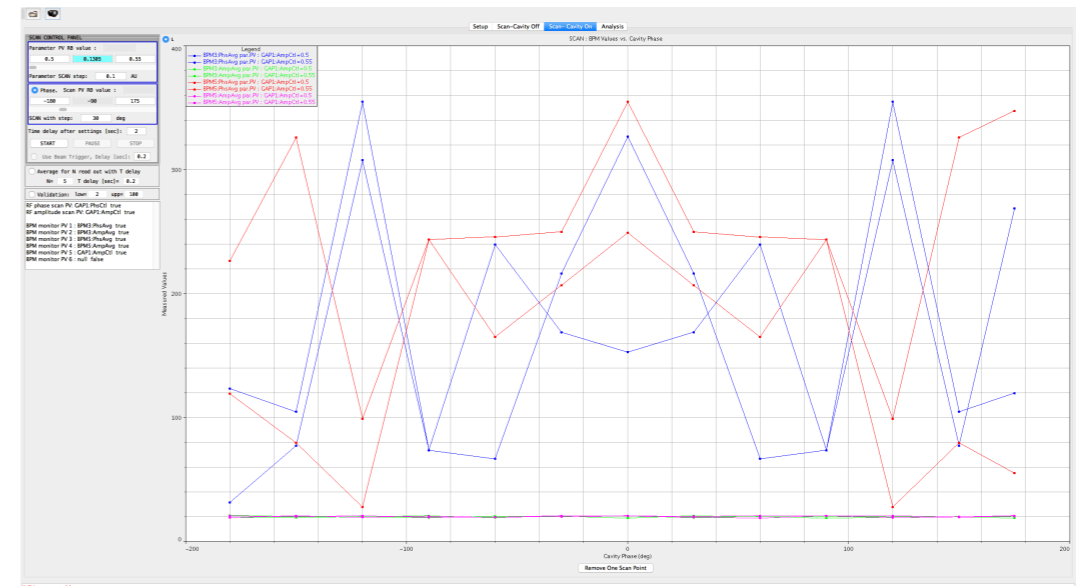
- Scan1D, Scan2D, Scan1D-Scatter
- Allows to scan 1 or 2 variables
- Allows simple data editing (remove point, curve etc)
- Generic
- Expect to use this frequently during commissioning
- Merge into one application?



# Available Applications Today

## RF Scan

- PASTA, SCL Wizard, WL RF Wizard
- PASTA seems to be mostly functional
  - ▶ We do not have BCM in our current model
  - ▶ VA currently does not simulate BPM phase&amplitude
- Wizard scripts (jython) will be useful as templates for our own automated procedures



BPM	Z[m]	Use	Cavity	Z[m]	Use	A <sub>design</sub>	φ <sub>design</sub>	A <sub>live</sub>	φ <sub>live</sub>	BPM <sub>1</sub>	BPM <sub>2</sub>
SCL-BPM00a	0.203		Cav01a	3.176		14.9...	-88...	0	0		
SCL-BPM00b	1.505		Cav0...	4.399		14.9...	-80...	0	0		
SCL-BPM01	7.574		Cav01c	5.558		14.9...	-78...	0	0		
SCL-BPM02	13.41		Cav02a	9.015		14.9...	-73...	0	0		
SCL-BPM03	19.249		Cav0...	10.238		14.9...	-57...	0	0		
SCL-BPM04	25.088		Cav02c	11.397		14.9...	-64...	0	0		
SCL-BPM05	30.926		Cav03a	14.854		14.9...	-59...	0	0		
SCL-BPM06	36.766		Cav0...	16.077		14.9...	-54...	0	0		
SCL-BPM07	42.609		Cav03c	17.236		14.9...	-50...	0	0		
SCL-BPM08	48.442		Cav04a	20.693		14.9...	-45...	0	0		
SCL-BPM09	54.286		Cav0...	21.916		14.9...	-41...	0	0		
SCL-BPM10	60.123		Cav04c	23.075		14.9...	-37...	0	0		
SCL-BPM11	65.96		Cav05a	26.532		14.9...	-33...	0	0		
SCL-BPM12	73.852		Cav0...	27.755		14.9...	-29...	0	0		
SCL-BPM13	81.743		Cav05c	28.914		14.9...	-25...	0	0		
SCL-BPM14	88.634		Cav0...	32.373		14.9...	-21...	0	0		



# Available Applications Today

## Model Manager

[Open XAL] - ModelManager - /opt/openxal/openxal-installation/optics/design/main.xal

Beamline: **DEFAULT** Initial parameters: Edit Init Twiss... Matching... Reset Run WS Machine parameters: Source: **Design** Fetch and Edit Reset Run Model Save Make SEL Gold Help Exit

Z Plot Model Details Machine Parameters

**Selected Machine Model**  
Selected Model ID: RUN Run Source: DESIGN Created Date: 2017-02-02 16:14:49

Select A Plot Function :  
ALPHA X & Y  
**BETA X & Y**  
PSI X & Y  
ETA X & Y  
ETAP X & Y  
R11 & R33  
R12 & R34

Comparison:  
 Overlay Reference  
 Plot Diff from Reference

Configure:  
 Show Z Position  
 Show Element Names  
 Show Device Points

2/2 16:14:51 **INFO** The new XAL machine model's ID is "RUN" !

Saved Models: From: Jan 02, 2017 16:14:12 To: Now Set End Time Find Restore to Default

ID	RUN_ELEMENT_DATE	RUN_S...	MODEL...	COMMENTS	GOLD	REF	SEL
RUN	2017-02-02 16:14...	DESIGN	MEBT-...	Run DESIGN Model on MEBT-DOG-A2T beam line. And the Energy is 2.92839099126 GeV.	RUN	<input type="checkbox"/>	<input checked="" type="checkbox"/>
25	2015-09-27 19:29...	DESIGN	from-...	Run DESIGN Model on from-mebt beam line. And the Energy is 2.93063399818 GeV.	PRESENT	<input type="checkbox"/>	<input type="checkbox"/>
24	2015-07-20 16:06...	EXTANT	from-...	Run EXTANT Model on from-mebt beam line. And the Energy is 2.93063399818 GeV.	PRESENT	<input type="checkbox"/>	<input type="checkbox"/>
23	2015-07-20 16:00...	DESIGN	from-...	Run DESIGN Model on from-mebt beam line. And the Energy is 2.93063399818 GeV.	PREVIOUS	<input type="checkbox"/>	<input type="checkbox"/>
22	2015-06-11 10:40...	DESIGN	from-...	Run DESIGN Model on CATHODE to Main Dump beam line. And the Energy is 2.93063399818 GeV.		<input type="checkbox"/>	<input type="checkbox"/>
21	2015-06-11 09:53...	DESIGN	from-...	Run DESIGN Model on CATHODE to Main Dump beam line. And the Energy is 2.93063399818 GeV.		<input type="checkbox"/>	<input type="checkbox"/>

Database Access Status: User "MACHINE\_MODEL" connected to "5432/machinemodel" Database. Model Query Status: The new XAL machine model's ID is "RUN" Done !

Thanks