SNS Application Programming Infrastructure and Physics Applications

(Java based!)

Paul Chu

Oct. 7, 2005

Contributors

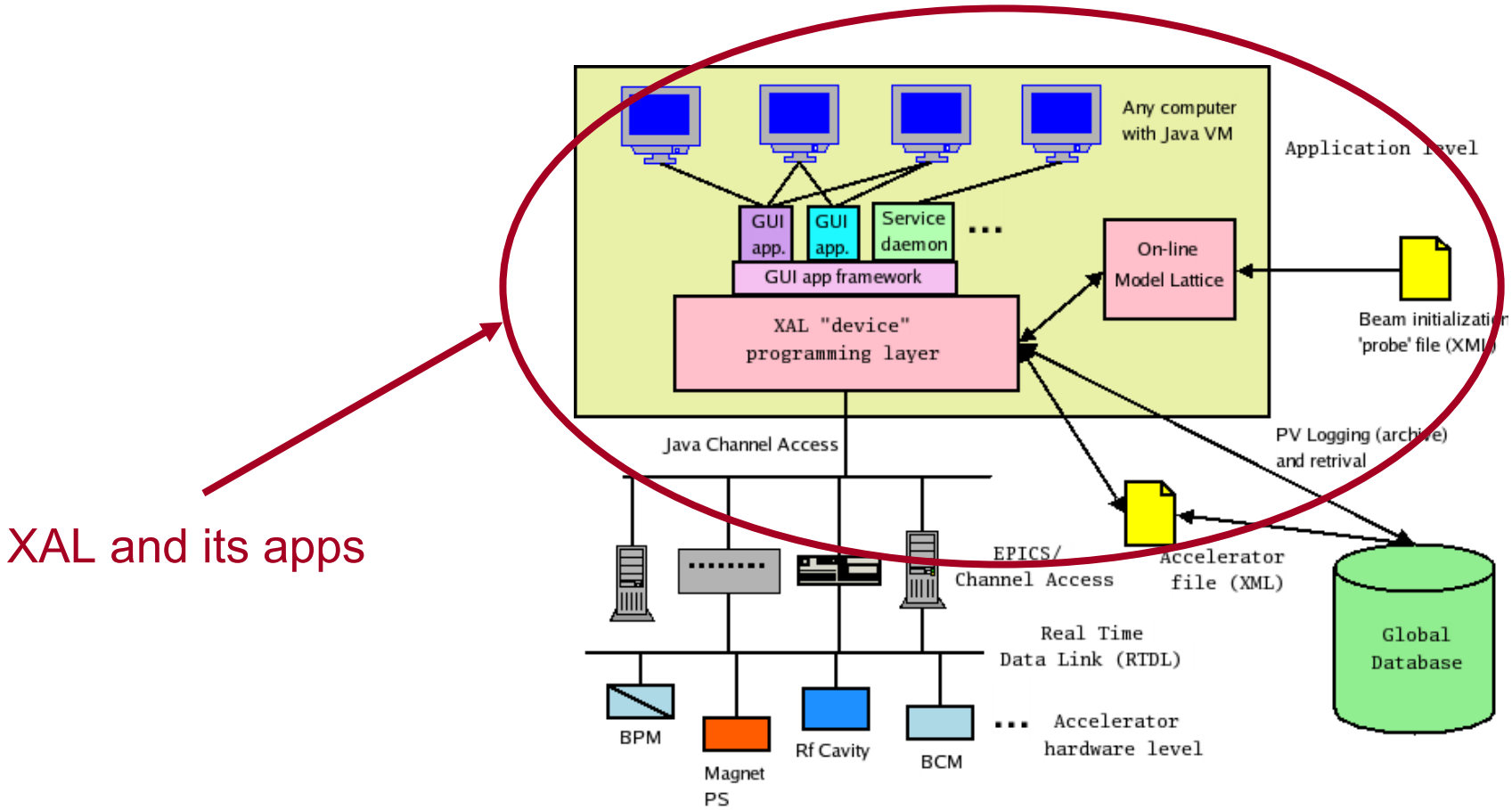
- SNS Application Programming Team: P. Chu, J. Galambos, T. Pelaia, A. Shishlo
- Active application programmers at SNS: D. N. Armstrong, S. Chevtsov, S. Cousineau, V. Danilov, Y. Zhang
- Other contributors: A. Aleksandrov, C.K. Allen, S. Bunch, I. Campisi, R. Dalesio, K. Danilova, A. Feshenko, D. Gurd, S. Henderson, J. Holmes, D. Jeon, R. Kennedy, W.D. Klotz, Y. Kiselev, I. Kriznar, A. Leahman, C. McChesney, N. Malitsky, D. Ottavio, N. Pattengale, M. Plesko, M. Plum, A. Pucelj, H. Sako, C. Sibley, E. Tanke, J. Wei, E. Williams, and A. Zupanc…

Outline

- SNS application infrastructure (XAL)
  - Overview
  - Accelerator hierarchy
  - Database
  - Connections
  - Data Correlation
  - Online Model
  - GUI framework
  - Utility tools
- Applications

XAL Overview

- High level physics application software is for modeling, integrated operation and accelerator physics studies
- SNS application software environment --



XAL Accelerator Hierarchy

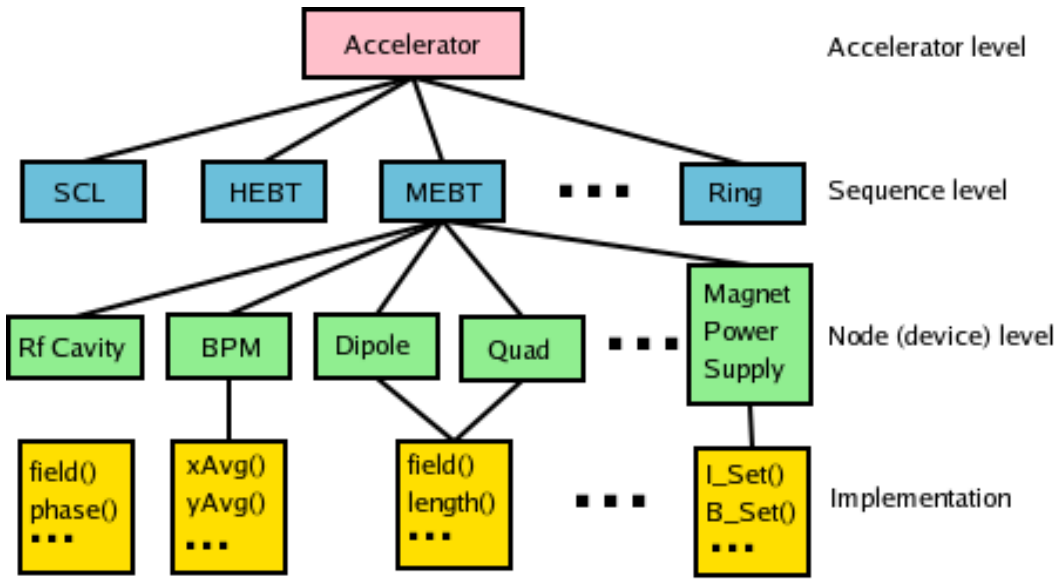
- XAL is Java based
- Includes a class hierarchy describing the accelerator structure
- Methods exist to directly work with accelerator devices

Java.lang.Object

AcceleratorNode (base class)

AcceleratorSeq

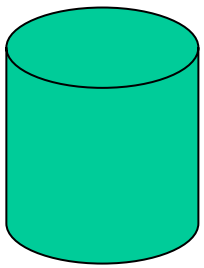
Accelerator



The Database Connection

- XAL uses “Beamline Device”, “Device Setting” and other hardware related tables in the global SNS database
- Creates the accelerator hierarchy
- Serves as a common configuration for all applications
- Provides the “map” from the flat list of EPICS signals to the accelerator hierarchy
- Use an intermediate XML file

Database ⟶ XML configuration files



```
<node type="QH" id="MEBT_Mag:QH01" pos="0.135" len="0.061">
  <attributes>
    <magnet len=“.061" polarity=“-1" dfltMagFld=“-34.636"/>
    <align x="10000" y="2000.046" z="19546.440844" pitch="0" yaw="0“ …/>
  </attributes>
  <ps main="MEBT_Mag:PS_QH01" />
  <channelsuite name="magnetsuite">
    <channel handle="fieldSet" signal="MEBT_Mag:QH01:fieldSet“ …/>
  </channelsuite>
</node>
```

•On-the-fly editing for quick across the board fixes

The Control System Connection

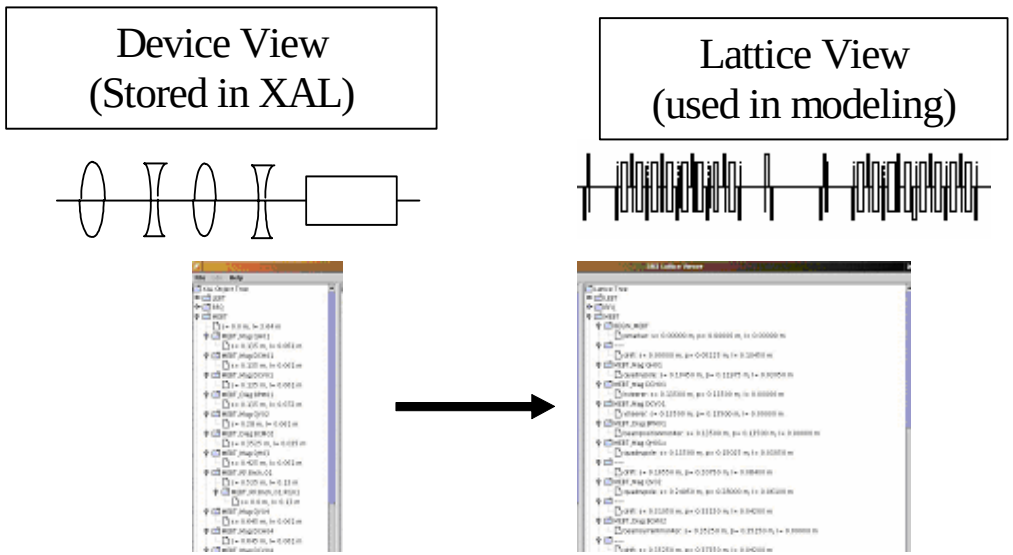
- Channel Class
  - An abstract class that provides an interface to the control system.
  - Includes convenience functions to hide details of the connection mechanism.

- JcaChannel
  - A concrete class that uses the Java Channel Access (JCA) interface to EPICS channel access protocol -- each EPICS signal is called a *process variable* **(PV)**.

- Transformations: allows modification of the value of the signal coming from the control system
  - Can map one signal to > one “Channel” object, with and without the transformation.
  - Facilitates quick fixes, changes to signals
    - Magnetic field calculated from power supply current.
    - BPM polarity fixes.

The Online Model

- Calculate beam parameters.
- A lattice view of the machine is constructed from the “device” structure (via a set of rules.
  - Drifts are added, elements are split.
  - Device view -> intermediate lattice -> online model lattice
- Lattice element values can be updated from the machine, design or logged values.
- Can do ‘what-if’ with any one of the above data sources.
- Mostly use an envelope model for single-pass linac tracking or closed orbit for ring.



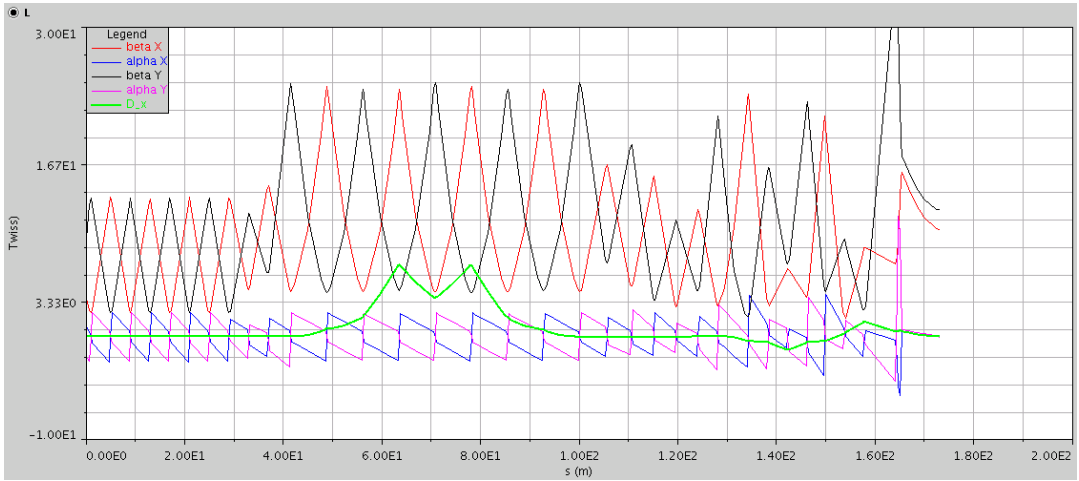
- Single entry per element

- Only physical devices

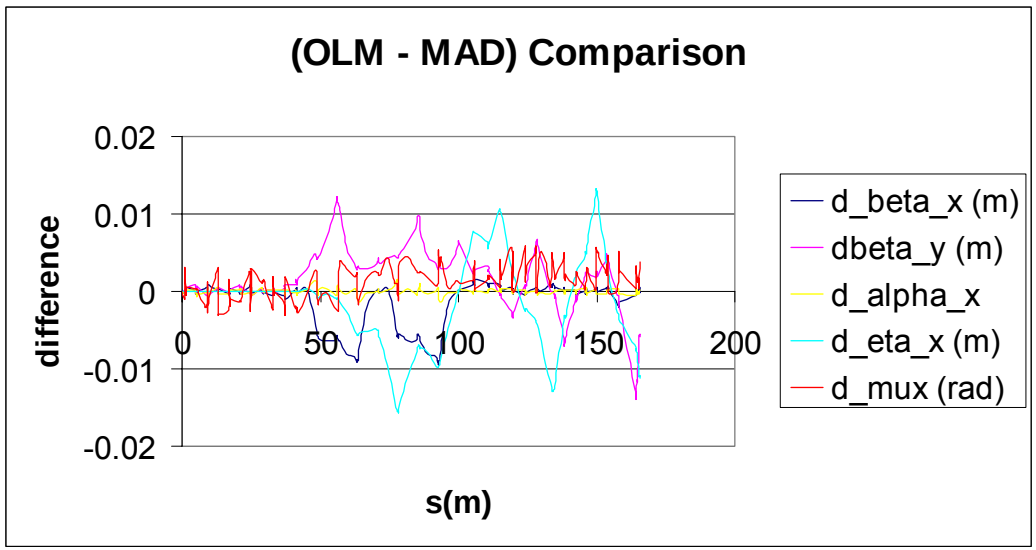
- Elements may be split

-Includes drifts

Online Model vs. MAD



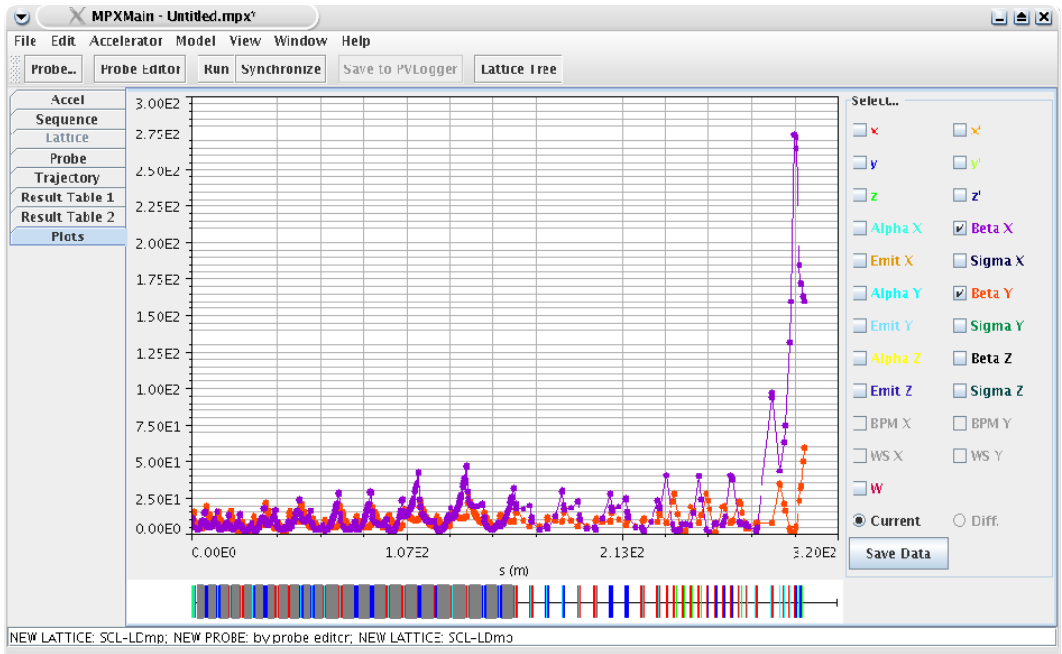
Online model HEBT results (design setting)



Comparison of online model and MAD results

Online Model (cont.)

- Many applications based on the online model.
- A ‘virtual accelerator’ application using online model and a portable channel access server (PCAS) as the engines.



•Beta functions through the SNS SCL and Linac dump line for a machine snapshot during Sep. 05 commissioning.

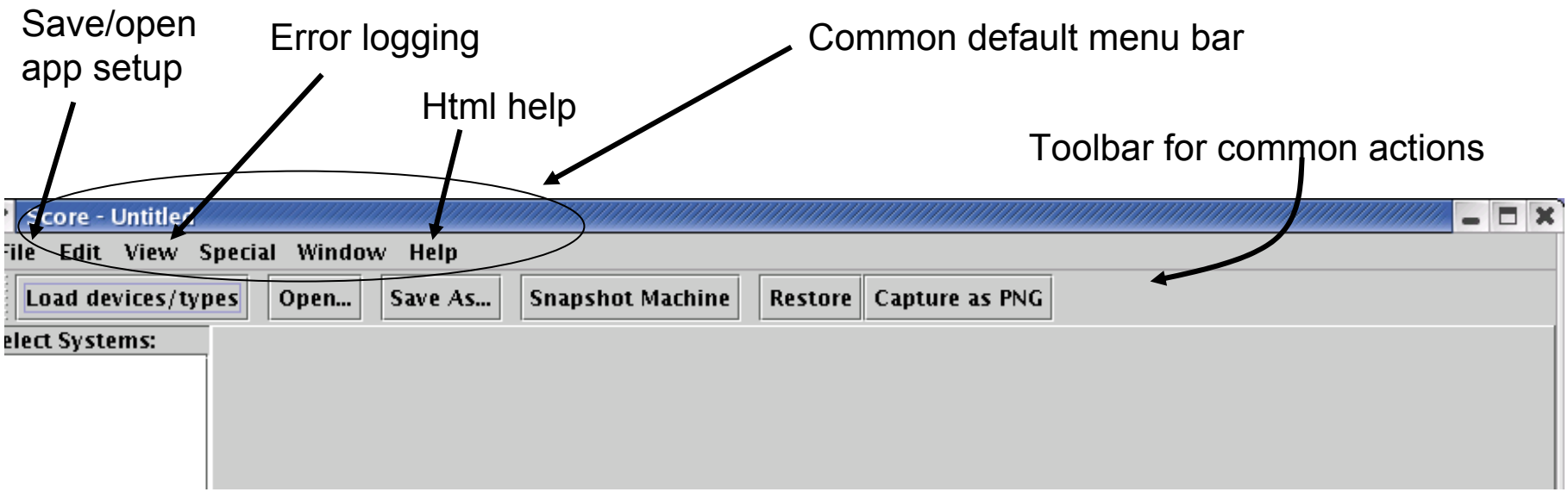
•The app can server as orbit difference tool with live BPM and profile monitor data.

Applications based on online model

- Orbit difference
- Orbit correction (also has empirical algorithm)
- Online model application
- Linac tuning apps
  - PASTA (for linac phase/amplitude)
  - SLACS (for superconducting phase setting)
  - Delta-T procedure
- Ring tuning apps
  - Injection
  - Ring measurement and optics tuning (beta-function, tune, etc.)

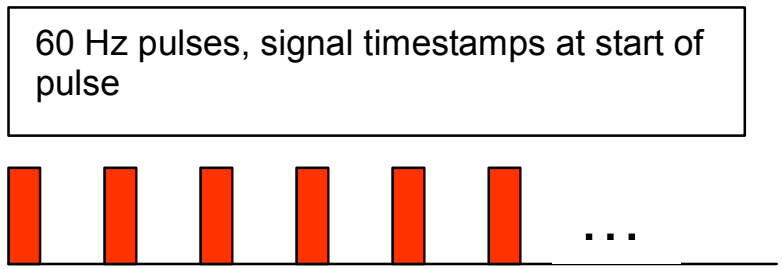
Application Programming Framework

- A GUI Application Framework is developed and used as a common starting point for application programs
  - Provides a common look feel for all apps
  - Quick jump-start for application development
  - Easy retro-fixes across many apps
  - Use familiar “windows” look feel paradigm



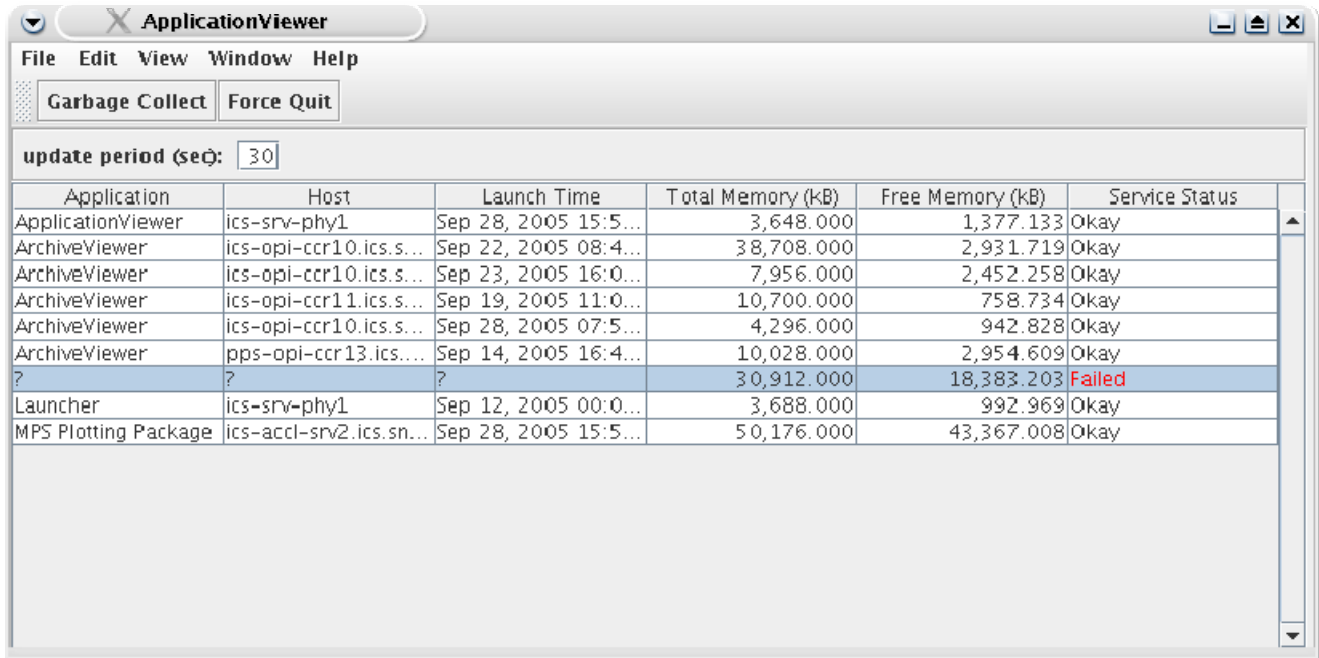
Tools (Channel Correlator)

- Channel Correlator
  - SNS is a pulsed machine (up to 60Hz of rep rate)
  - Correlator gathers sets of signals from the same pulse
  - Different modes: stream correlation sets to listeners or periodic posting
  - Can use filters (triggered data acquisition)
  - RTDL (Real Time Data Link) ensure correct time-stamps for PV correlation



Tools (cont.)

- Charting package
  - Designed for scientific purpose.
  - Can be light-weight and fast (e.g. for digital scope application).
- Communication tool (based on XML-RPC) ready for client-service implementation.



Application	Host	Launch Time	Total Memory (kB)	Free Memory (kB)	Service Status
ApplicationViewer	ics-srv-phy1	Sep 28, 2005 15:5...	3,648.000	1,377.133	Okay
ArchiveViewer	ics-opi-ccr10.ics.s...	Sep 22, 2005 08:4...	38,708.000	2,931.719	Okay
ArchiveViewer	ics-opi-ccr10.ics.s...	Sep 23, 2005 16:0...	7,956.000	2,452.258	Okay
ArchiveViewer	ics-opi-ccr11.ics.s...	Sep 19, 2005 11:0...	10,700.000	758.734	Okay
ArchiveViewer	ics-opi-ccr10.ics.s...	Sep 28, 2005 07:5...	4,296.000	942.828	Okay
ArchiveViewer	pps-opi-ccr13.ics....	Sep 14, 2005 16:4...	10,028.000	2,954.609	Okay
?	?	?	30,912.000	18,383.203	Failed
Launcher	ics-srv-phy1	Sep 12, 2005 00:0...	3,688.000	992.969	Okay
MPS Plotting Package	ics-accl-srv2.ics.sn...	Sep 28, 2005 15:5...	50,176.000	43,367.008	Okay

Tools (cont.)

- DataTable
  - More powerful than the standard Java collections
  - Provides database like functionality with easy interface
- XML DataAdaptor
  - Easy file i.o. in XML format, for any hierarchy
  - Used in applications for saving settings etc.
- Math Tools
  - Optimization
  - Matrix
  - Fitting
  - …
- Can export other modeling input files (via intermediate lattice)
  - Trace-3D, MAD
  - DYNAC, IMPACT are in progress

Scripting Interface to XAL

- Scripting interfaces are available with Jython (www.jython.org) and Matlab
  - No glue code, or extra compile steps etc needed!!! Mix XAL java classes seamlessly with scripting language
- Providing simple code examples.
- Coding up on-the-fly experiments.
- http://www.sns.gov/APGroup/appProg/xal/scripts/jythonScripts.html

Jython

```
# read the accelerator
#acc_xml = "file:/user1/chu/xaldev/xal_xmls/sns.xml"
acc_xml = "file:./sns.xml"
acc = XmlDataSource.parseUrlAt(acc_xml, 0)

# get the some primary sequences from the accelerator

mebt = acc.getSequence("MEBT")
dtl1 = acc.getSequence("DTL1")
dtl2 = acc.getSequence("DTL2")

print " There are ", mebt.getAllNodes().size(), "nodes in the
sequence", mebt.getId()
```

MatLab

```
%  scan the first quad
% monitor beam positions in the last MEBT BPM

for i =1:10
      fld(i) = field;
                  quad.setField(field);
                  va_chan.putVal(1); %  for virtual accelerator
                  pause(1); %  for virtual accelerator
                  xpos(i) = bpm.getXAvg;
                  ypos(i) = bpm.getYAvg;
                  field = field * 1.015; % increment field value
end

% Plot results
plot(fld, ypos)
```

XAL Applications

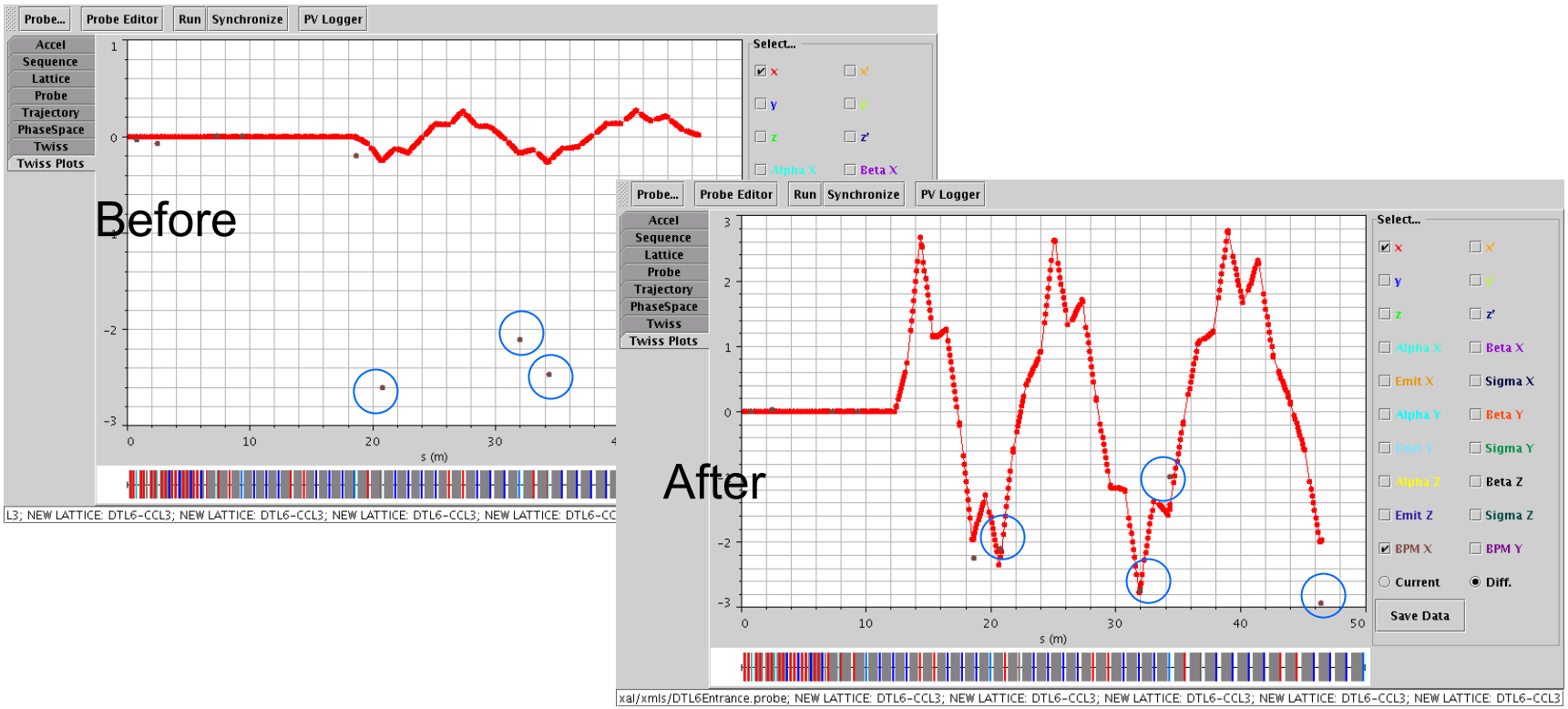
- Accelerator physics apps
  - Accelerator tuning
  - Physics experiment
- General purpose apps
  - Hardware monitor or diagnosis
- Service daemons
  - Minimize network traffic as multiple apps accessing the same PVs
  - Always running in the background
  - Examples: PV Logger, MPS first fault

Accelerator Physics App Examples

- Orbit difference – check steer and BPM polarities with online model.
- Orbit correction – flatten trajectory.
- Energy manager – find a good lattice when energy changed.
- Linac RF phase and amplitude tuning app.
- Emittance analysis – process raw data from emittance device.
- Wire scanner analysis – process raw data from wire scanner and compare with online model.
- Ring injection – phase space painting.
- Ring measurement – measure tune, β-function, dispersion chromaticity.
- Virtual Accelerator – machine simulator.

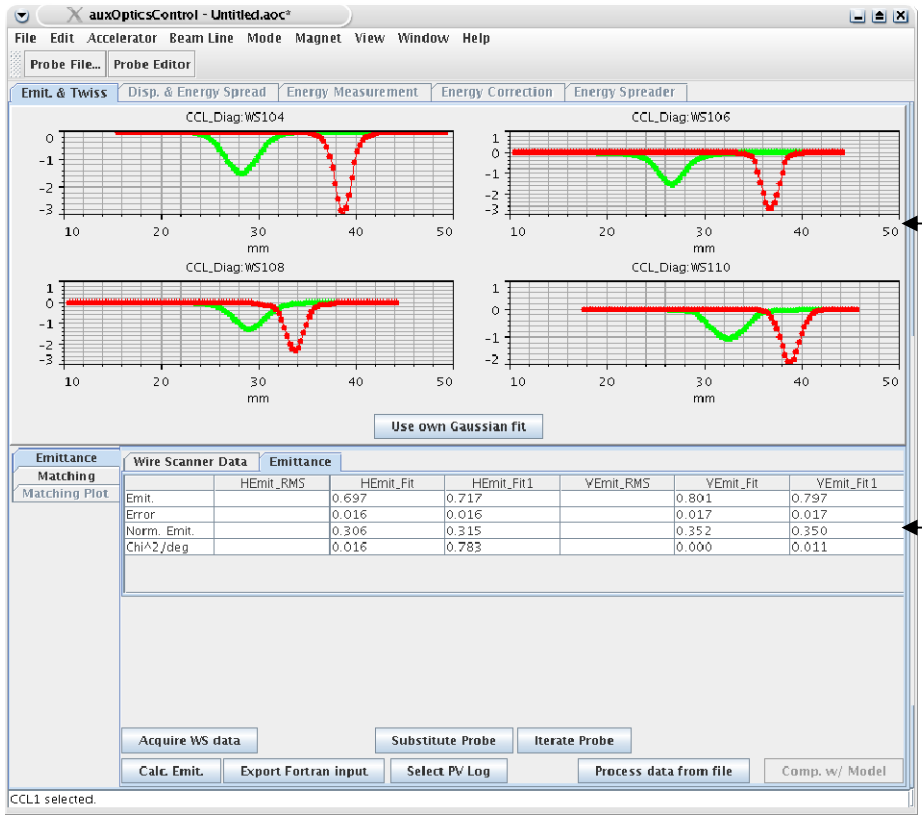
Orbit Difference App

- Use the online model app for orbit difference purpose (run it twice with a steer changed).
- Found CCL steer field wrong.



Linac Transverse Tuning Apps

- Use 3+ wire scanners for emittance measurement.
- Perform transverse matching using online model.
- Can work both on-line and off-line.

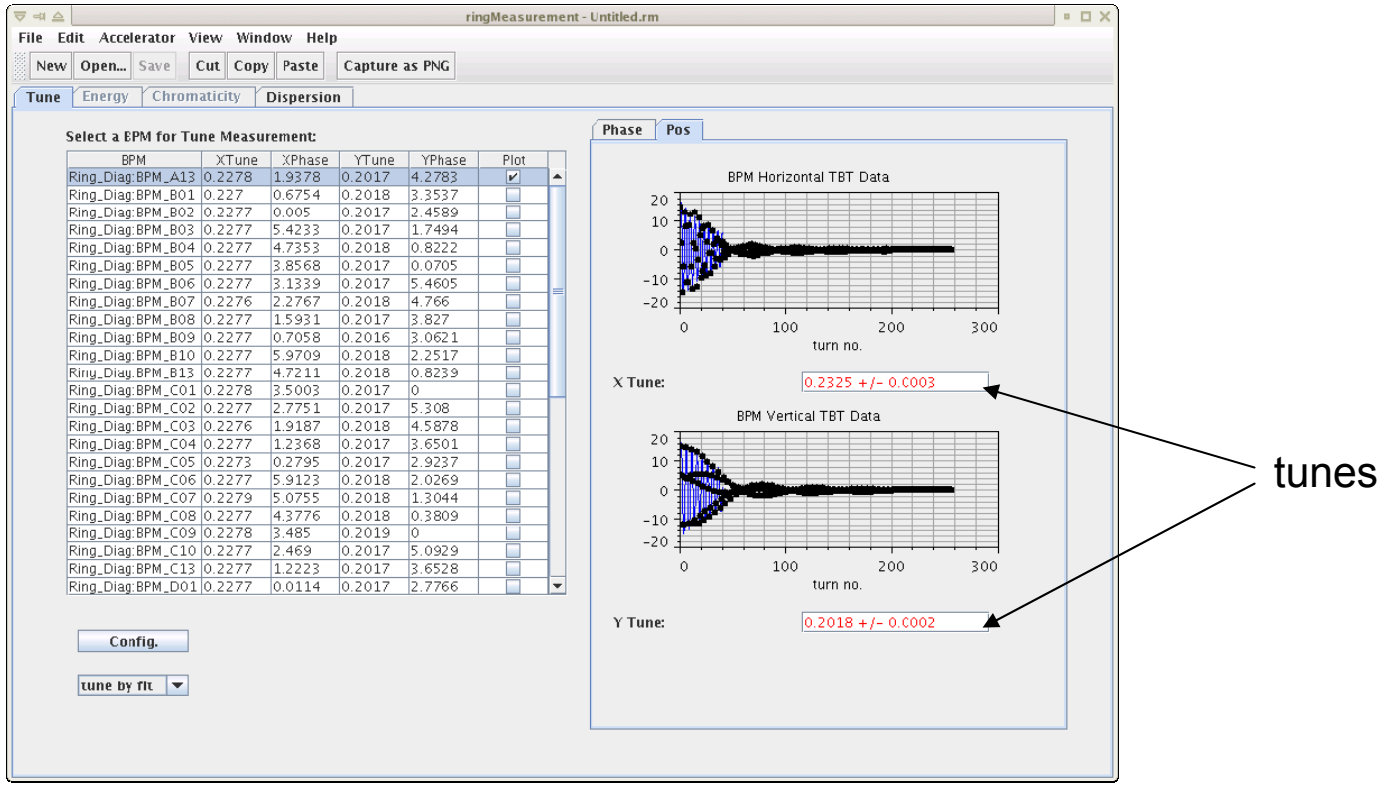


Wire profiles

emittances

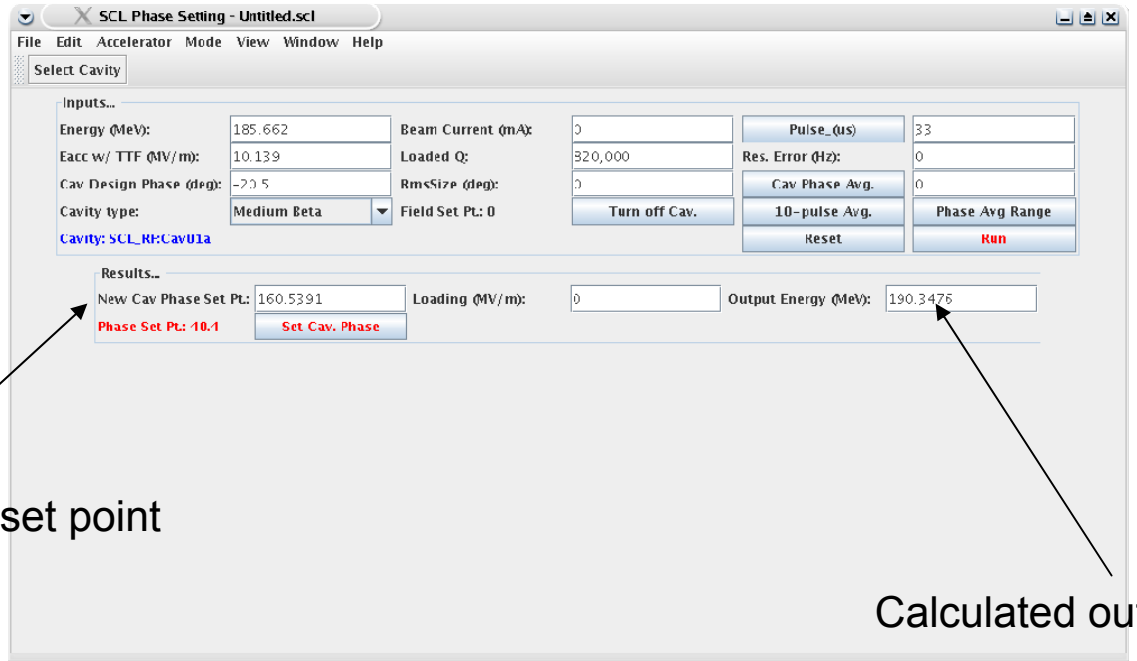
Ring Measurement

- Measure tunes with BPM turn-by-turn data.
- Measure dispersion
- Perform quad tuning with betatron phase advance (in progress).



Superconducting Linac Tuning

- Use drifting beam (RF cavity off) induced field for RF phase setup.

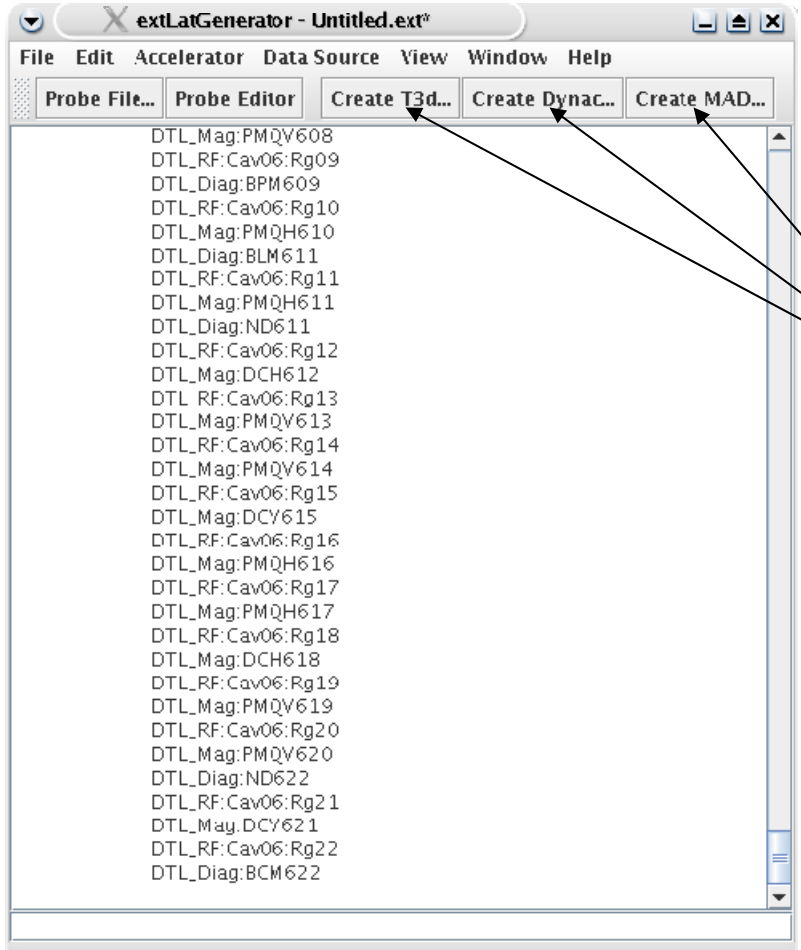


Calculated phase set point

Calculated output energy

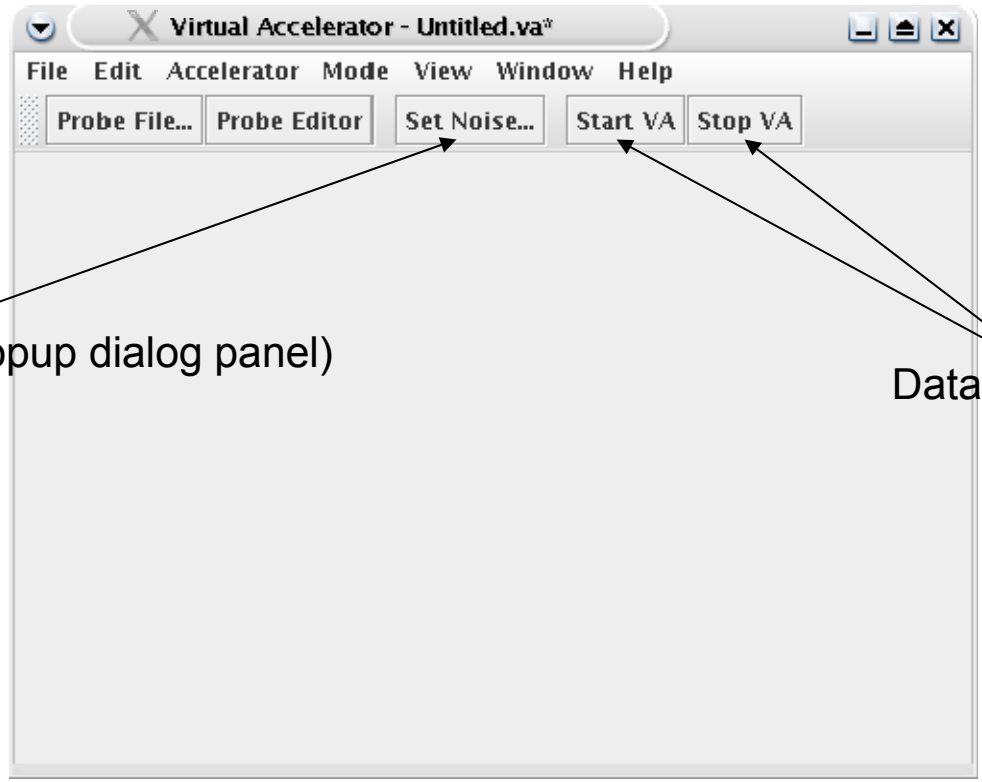
External (to XAL) Lattice Generator

- Can generate MAD, Trace-3D, DYNAC input files on the fly.



Virtual Accelerator

- Application test tool when the machine is not running.
- Based on online model.
- Can set noise, off-set.

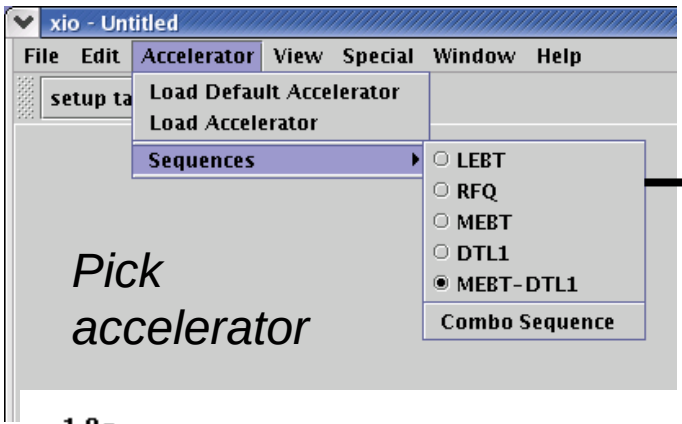


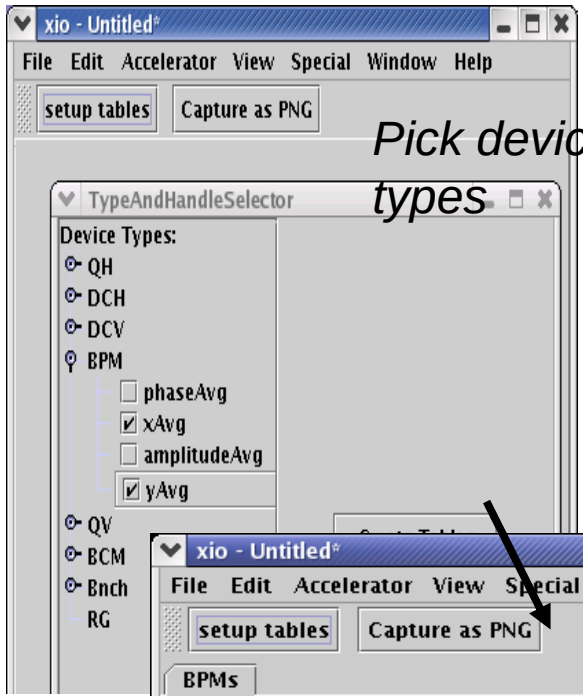
General Purpose App Examples

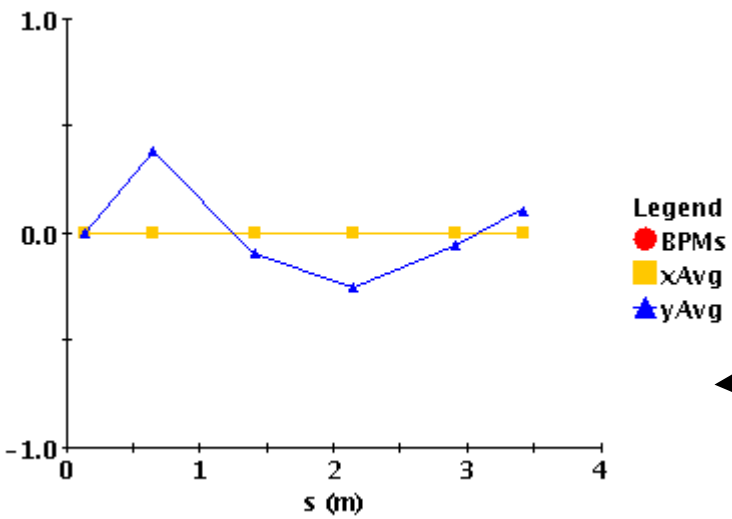
- XIO – XAL I/O diagnostic tool, monitoring and plotting any beam-line device PVs.
- PV correlator – display 2 or 3 PVs from the same beam pulse.
- Beam loss viewer – display beam loss monitor readings.
- Scan apps – scan 1 or 2 PVs and monitor some other PV(s).
- Scope – a digital scope-like app.
- PV timestamp test – display PV timestamps and plot them.
- Diagnostics device timing – display and set timing for diagnostics devices.
- Archive viewer – display archived data.

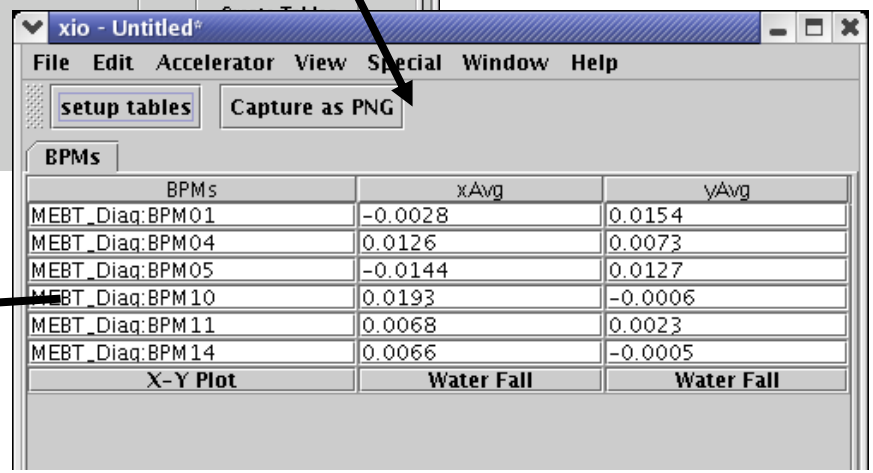
Xio Application

- General purpose value displayer (tables, and or plots).
- Browser the accelerator hierarchy to select what you are interested in.



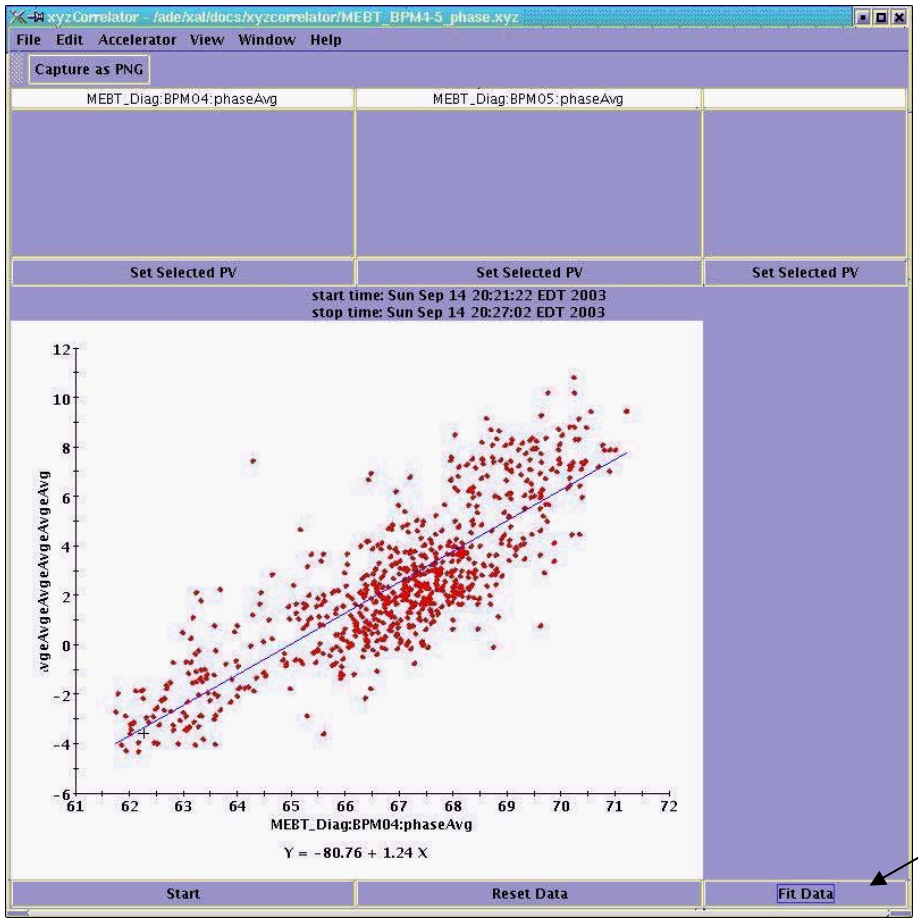






XYZ Correlator Application

- Pick 2 (or three) signals and monitor them together.
- Uses the time correlator to ensure signals are from the same pulse.
- Can export or fit the acquired data.

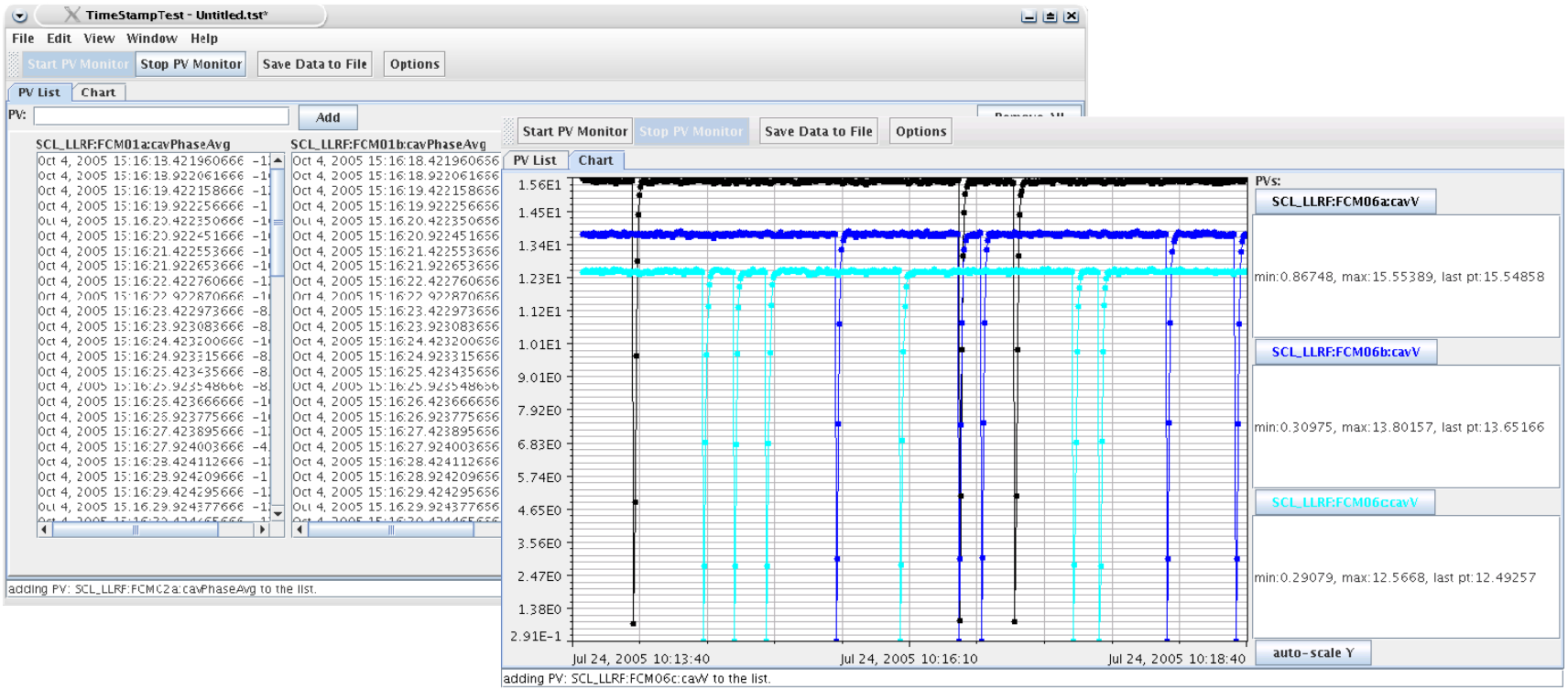


Correlation between phase measurements of 2 BPMs.

Can fit the data to a polynomial

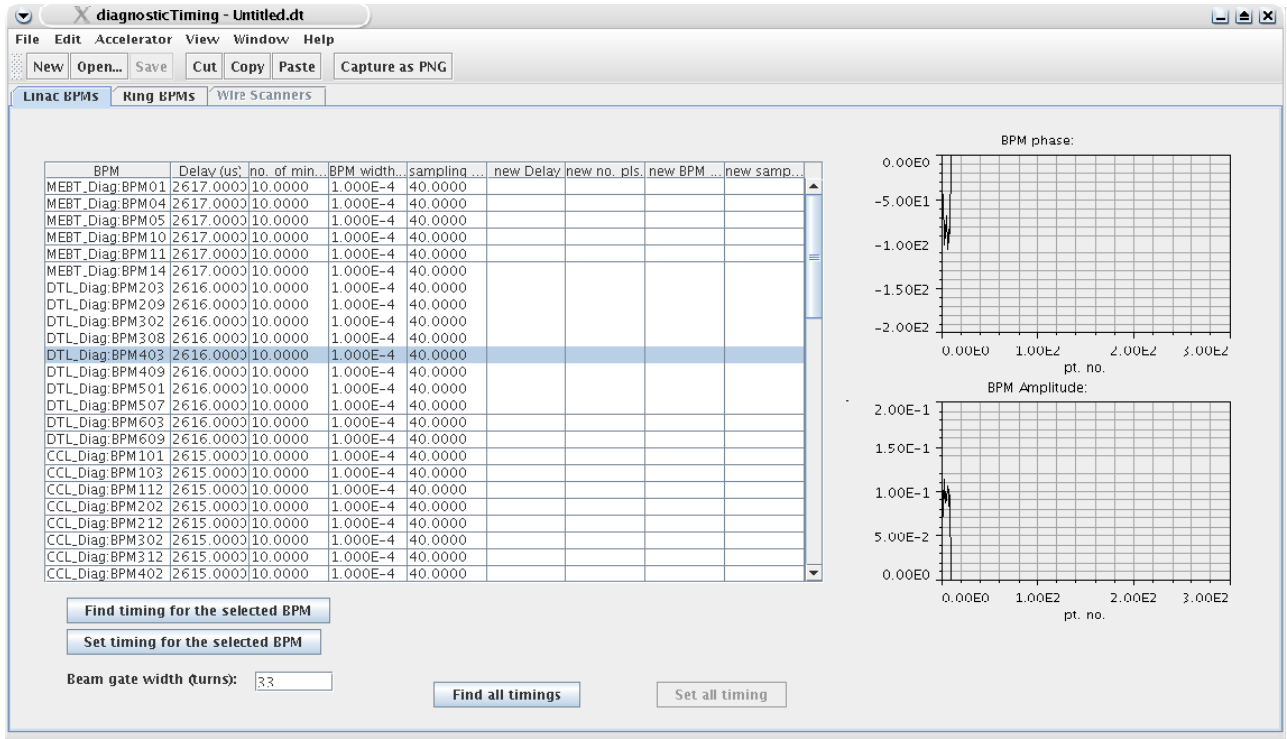
PV Timestamp Test

- Show multiple PV timestamps side by side.
- Can serve as a strip tool.
- Use Channel Access monitor.



Diagnostics Device Timing

- Display multiple diagnostics device timings in one place.
- Can set timing automatically or manually.

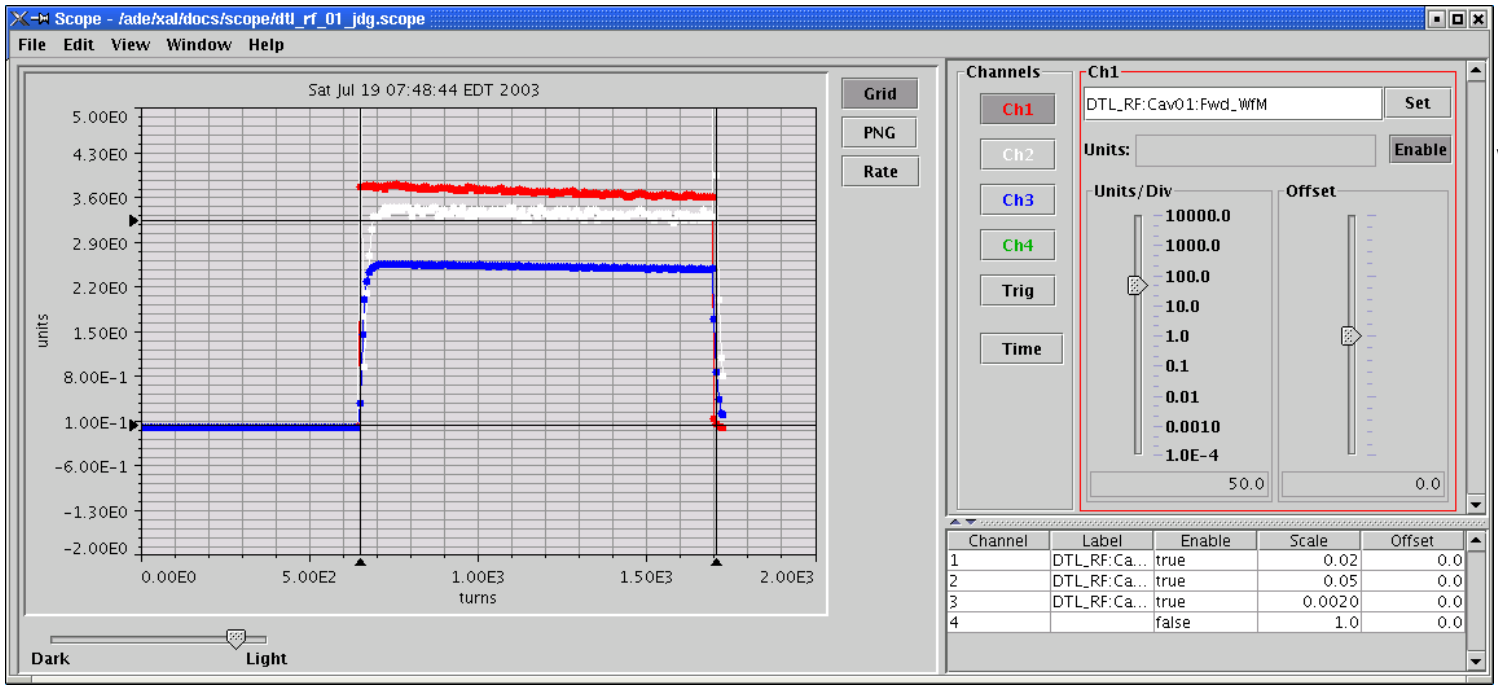


Summary

- XAL is a Java based hierarchal framework SNS is using to write high level applications.
  - Online modeling is available for both linac and ring.
  - The framework is matured: > 800 classes so far.
- Uses a database to initialize the hierarchy.
- Many tools are available.
- Applications are written and being used in the SNS commissioning.
  - > 40 applications written.
- Directions:
  - Adding more Ring applications.
  - Adding more ring online model features.
  - Adding more detailed information to the database.
  - Moving towards service applications.

Scope Application

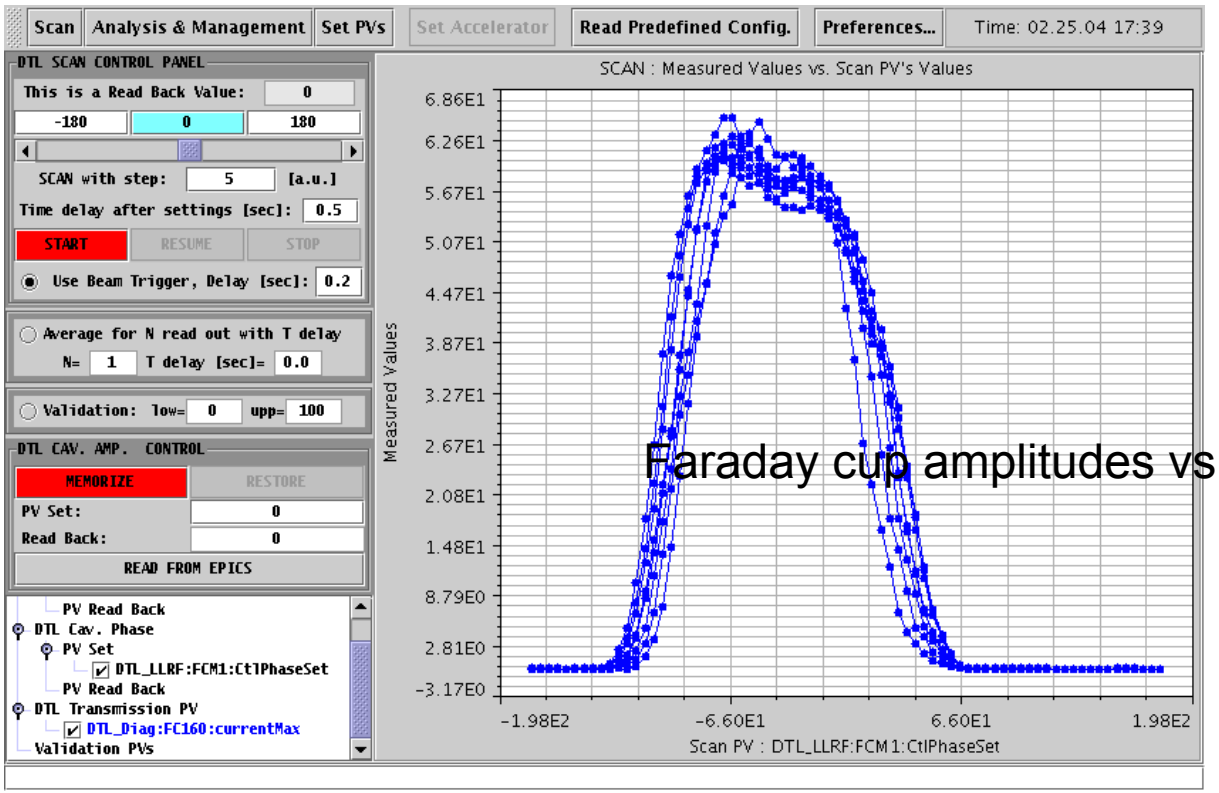
- A Digital Oscilloscope – with a similar user interface as analog scopes.
- Displays array waveforms vs. time (NOT vs arbitrary units).
- Uses the time correlator, has built-in math capability, triggered data acquisition+ many other features.
- Will use this for comparing waveforms from RF, diagnostics, etc.
- Requires input from signal providers describing how the array information is packaged, and offset from the cycle start.



DTL1 RF waveforms

1-D Scan Application

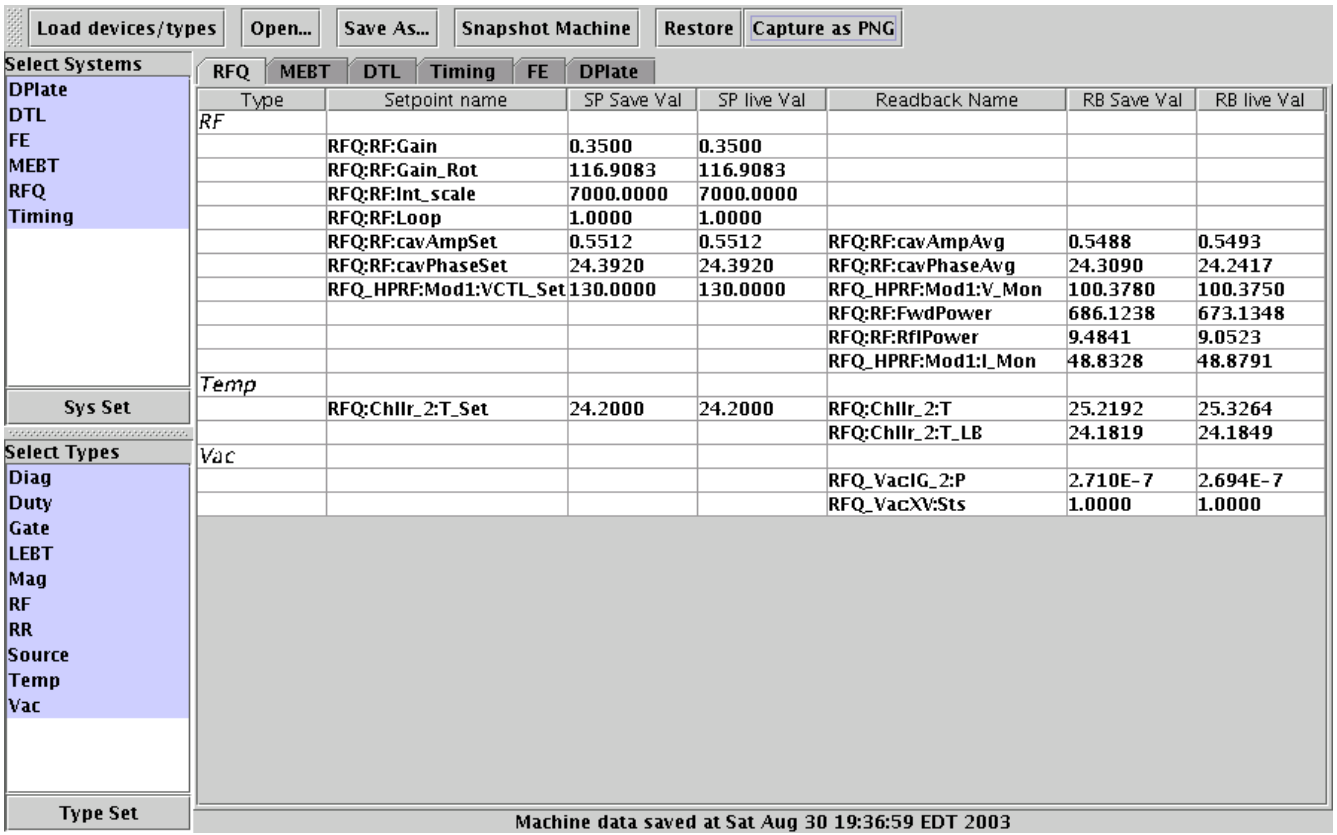
- Provides an easy way to scan one quantity and monitor others.
- Can average over pulses, scan multiple times, pause.
- Analysis includes fitting, intersection finding, min/max, etc.
- Easy way to do a quick unanticipated experiment.
- Predefined scans with specialized analysis are possible.
  - DTL and MEBT phase + amplitude setting applications.



Faraday cup amplitudes vs. DTL RF settings

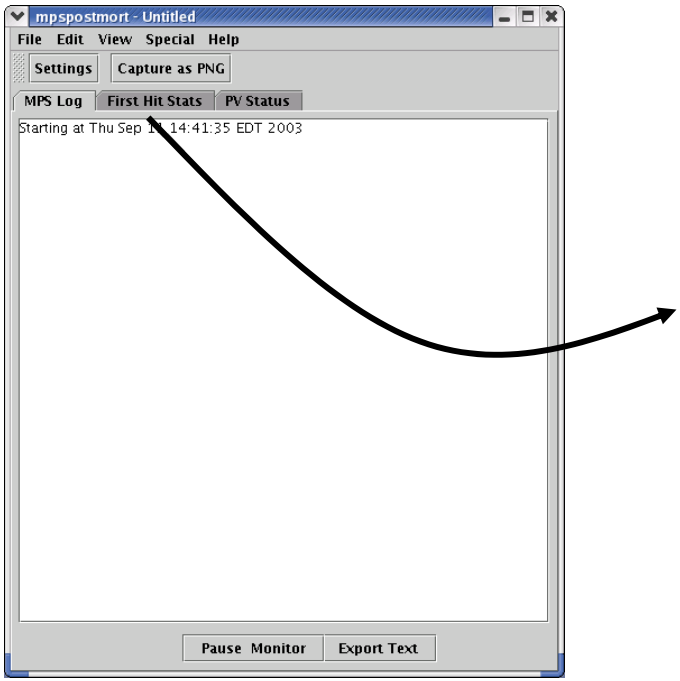
Save-Compare-Restore (Score) Application

- Provides a means to capture machine setup, compare live values to a saved set, and to restore values to a saved set.
  - Grabs settable + readback signals.
- Can sort by system and device type.
  - Uses DataTable classes for querying.

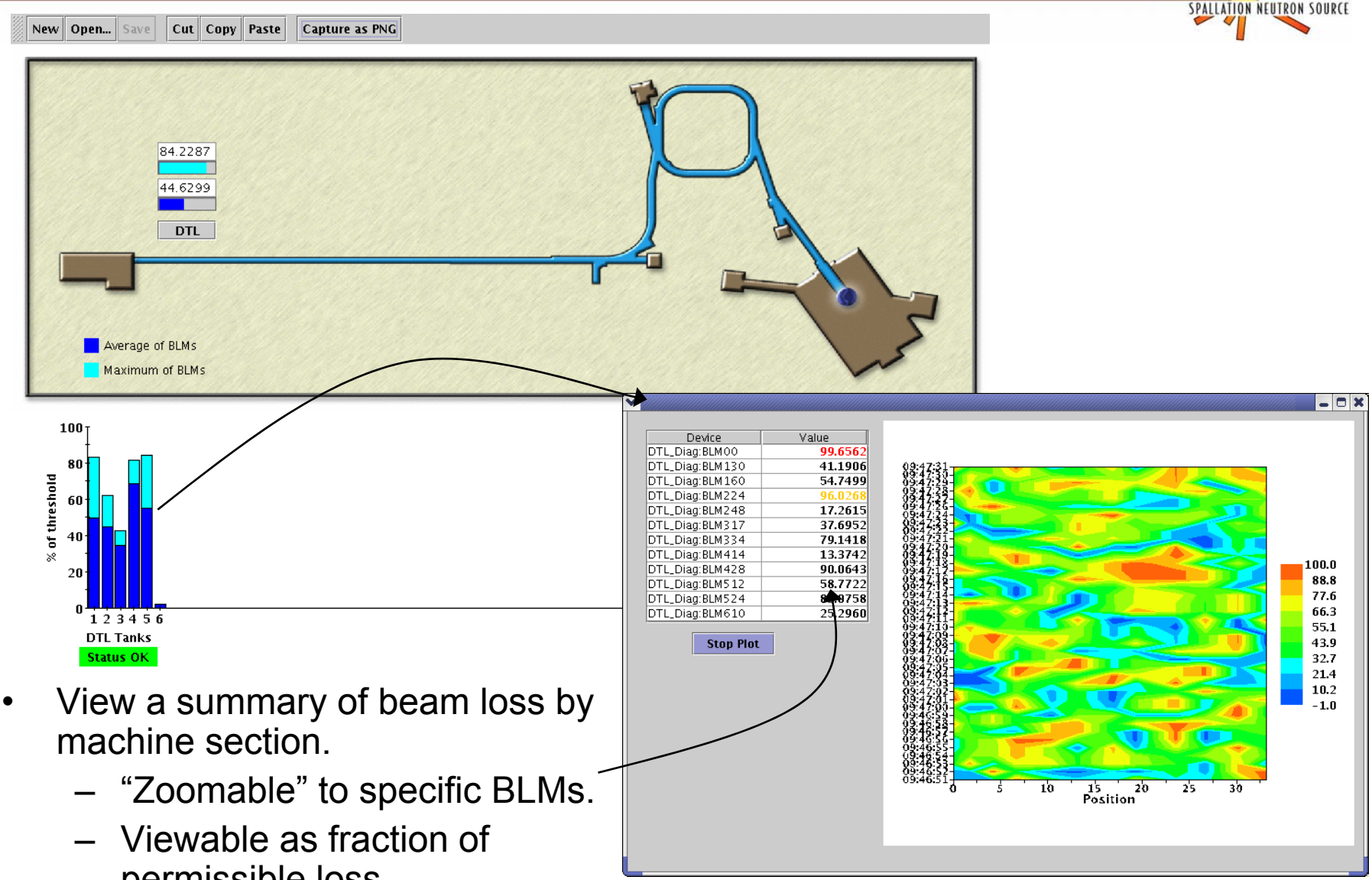


Machine Protection System (MPS) Post-mortem Application

- Captures MPS events, and sorts the signals in order of occurrence – i.e. determines the root cause of a trip (uses correlator).
- Logs mps events.
- Provides statistics.



Loss Viewer Application

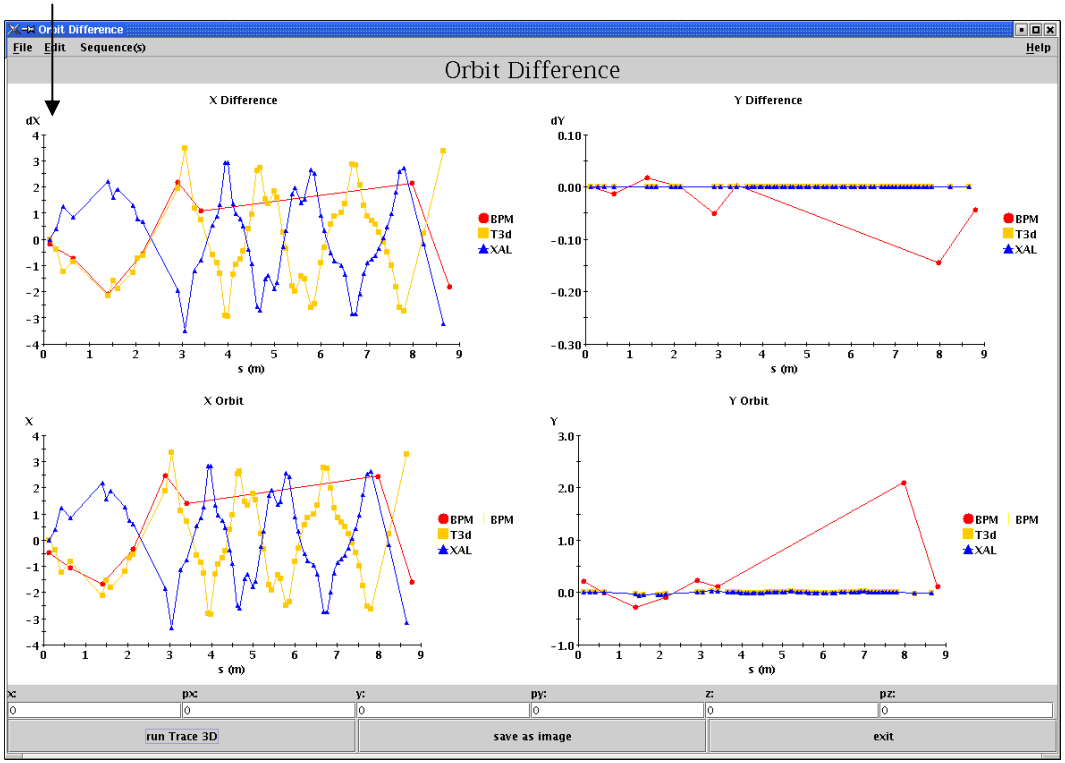


- View a summary of beam loss by machine section.
  - "Zoomable" to specific BLMs.
  - Viewable as fraction of permissible loss.

Orbit Difference Application

- Compares differences in beam orbits, for both BPMs and calculated.
- Online model is also used in the Orbit Difference Application, in addition to running Trace 3D (external fortran code).

Kick applied here



- Orbit difference example using the online model.
- Used to observe orbit difference in the horizontal direction.
- Helped resolve sign issue in BPMs.

Starting on Ring Apps

- Ring applications using XAL tools.
- HEBT matching algorithms.
- Ring Optics settings.
- Injection.