Beam Based Feedback for the Linac Coherent Light Source

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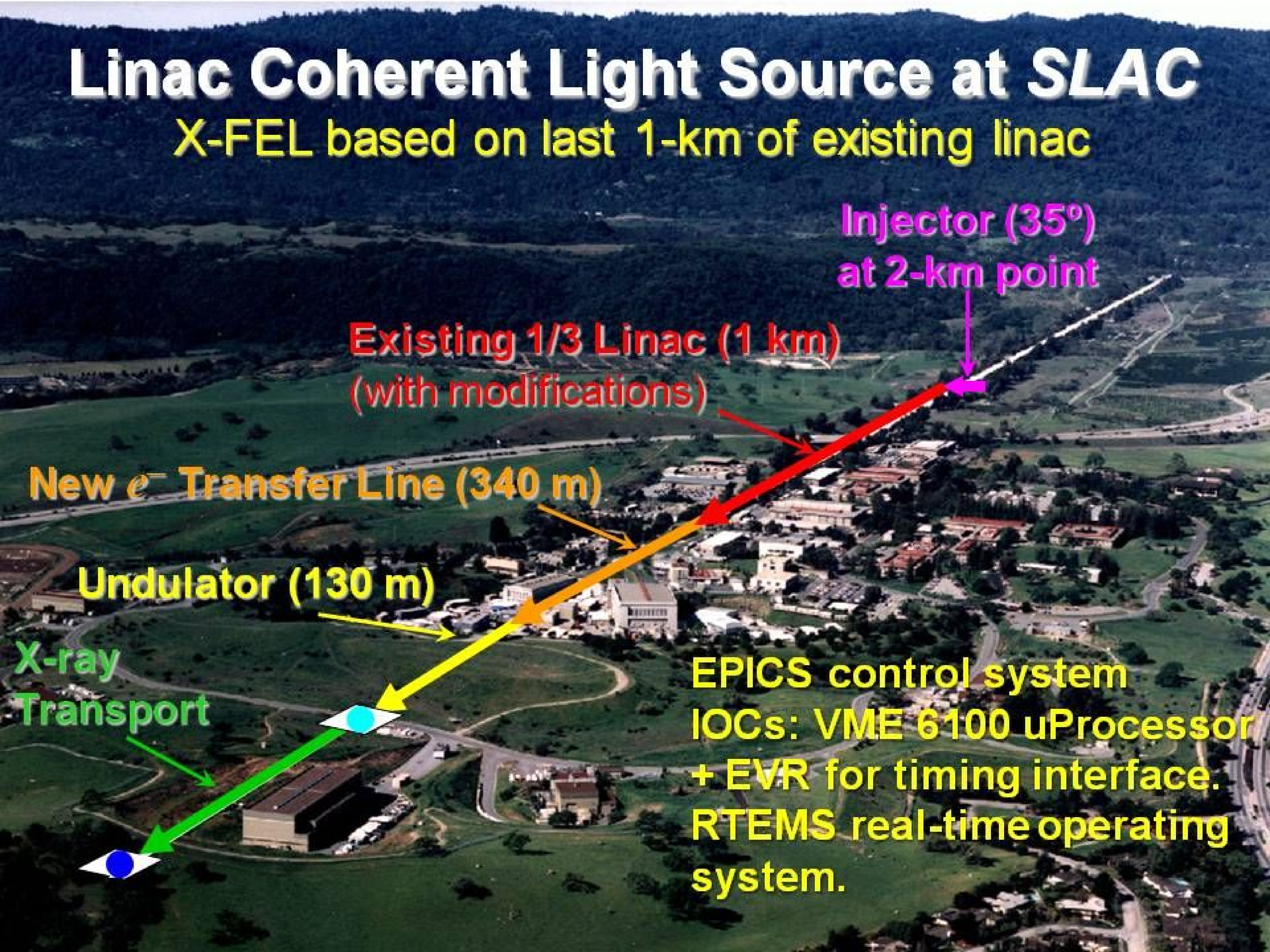
SLAC NATIONAL ACCELERATOR LABORATORY

Overview

- LCLS Feedback Requirements
- Prototyping in MATLAB
- 120Hz Feedback System for LCLS
  - Network
  - Timing System
  - Actuators and Sensors
  - Controller, software framework, algorithms
  - Configuration Tool
  - Runtime Display and Control

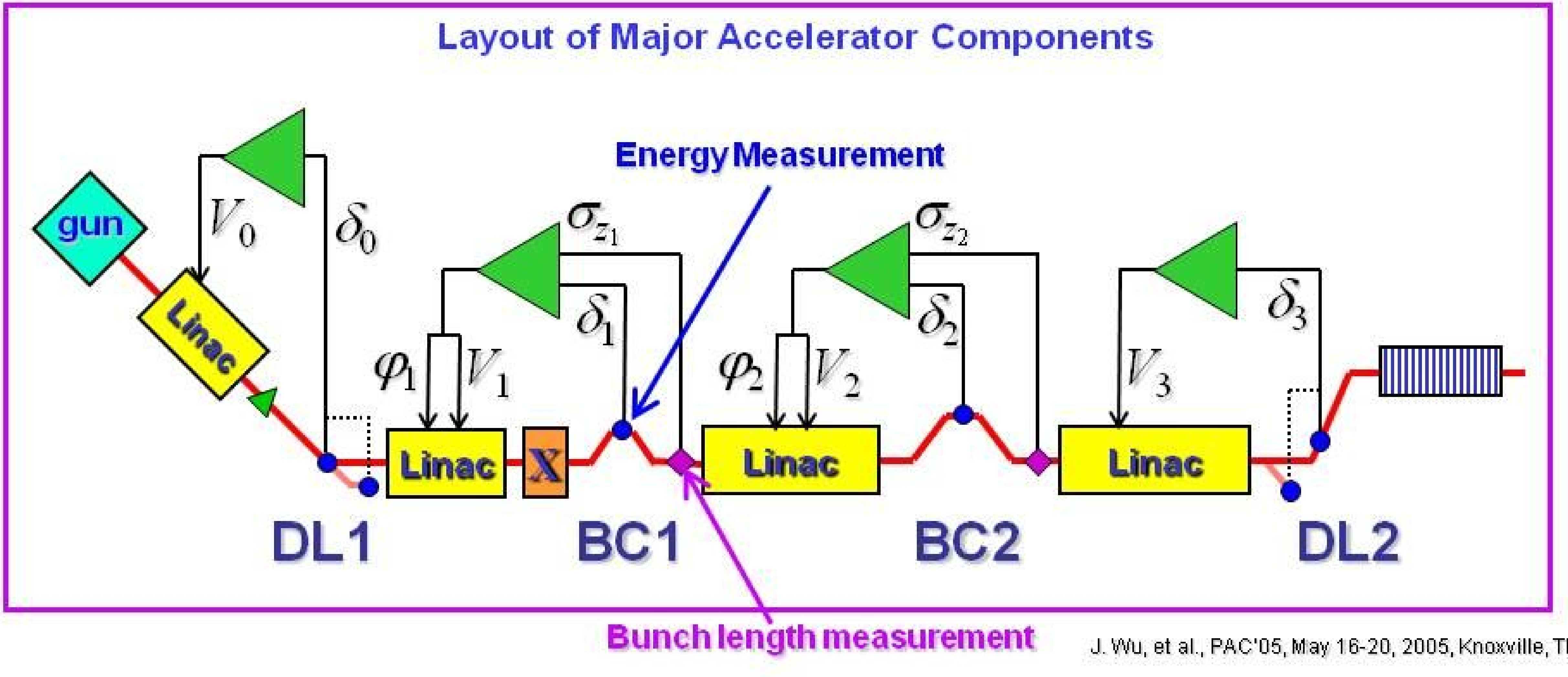

Linac Coherent Light Source at SLAC
X-FEL based on last 1-km of existing linac
Injector (35º)
at 2-km point
Existing 1/3 Linac (1 km)
(with modifications)
New e⁻ Transfer Line (340 m)
Undulator (130 m)
X-ray
Transport
EPICS control system
IOCs: VME 6100 uProcessor
+ EVR for timing interface.
RTEMS real-time operating
system.

LCLS Feedback Requirements

- A 6x6 Energy and Bunchlength Feedback
- Multiple Transverse Trajectory Feedbacks
- Bunch Charge Feedback
- Special Requirements for LCLS

Longitudinal Energy and Bunch length Feedback

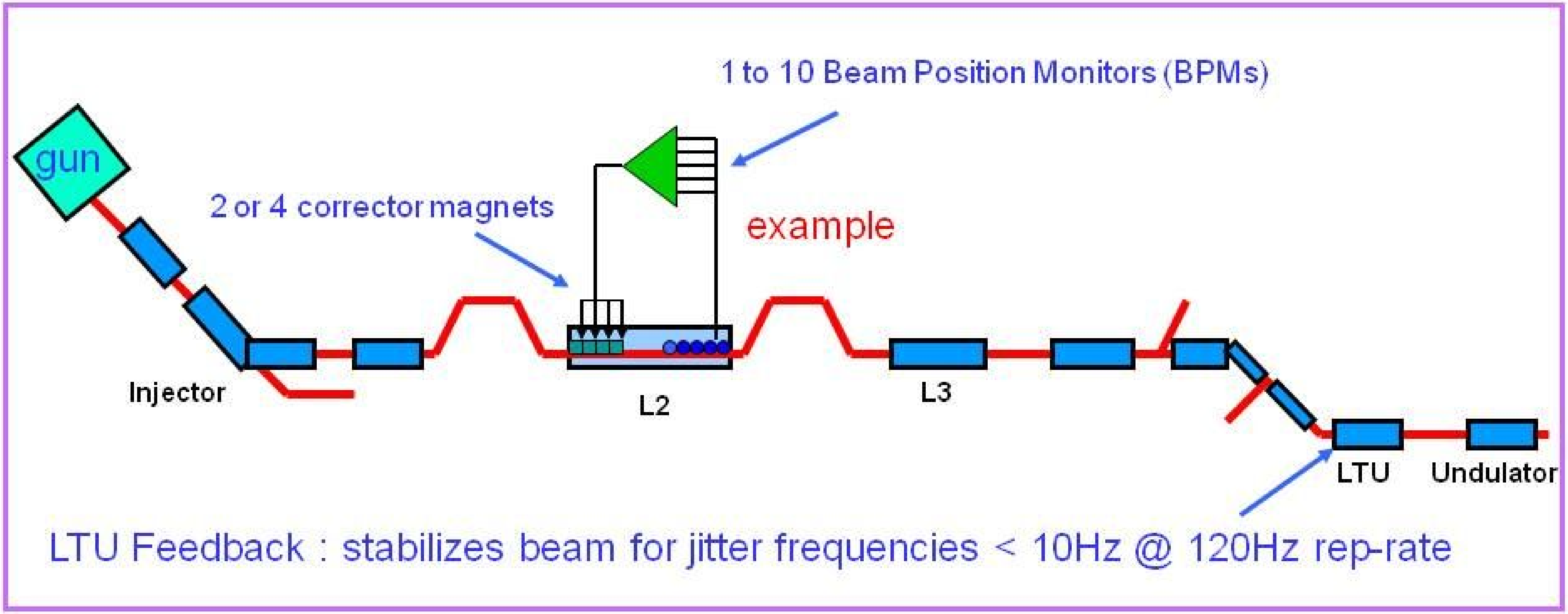
- Maintains 6 beam parameters of energy (δ) and bunch length (σ)
- Stabilizes beam for jitter frequencies < 10Hz @ 120Hz rep-rate



J. Wu, et al., PAC'05, May 16-20, 2005, Knoxville, TN.

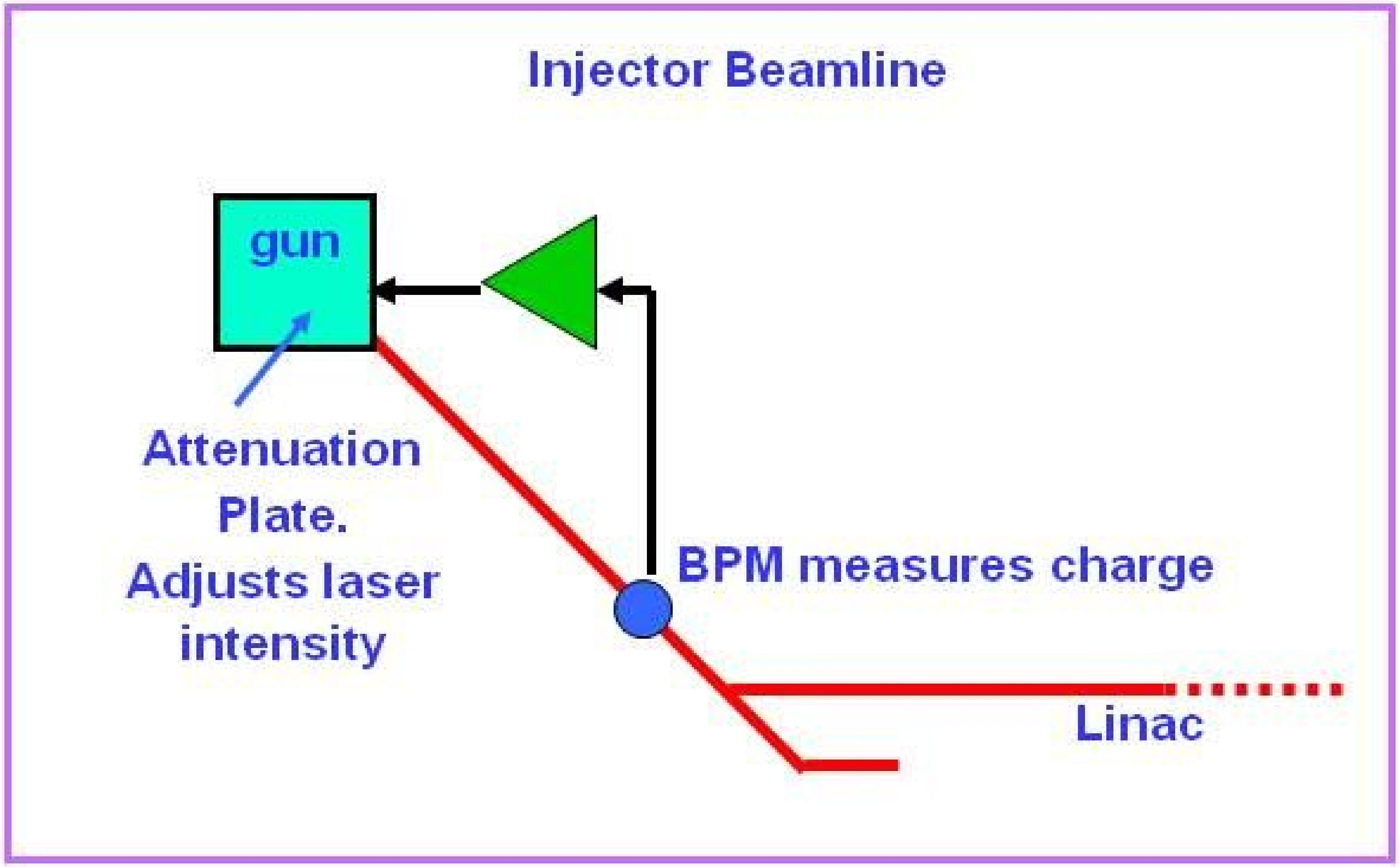
Transverse Trajectory Feedbacks

- Maintain position and angle in X and Y along the beamline
- 11 trajectory feedbacks commissioned - with more to come



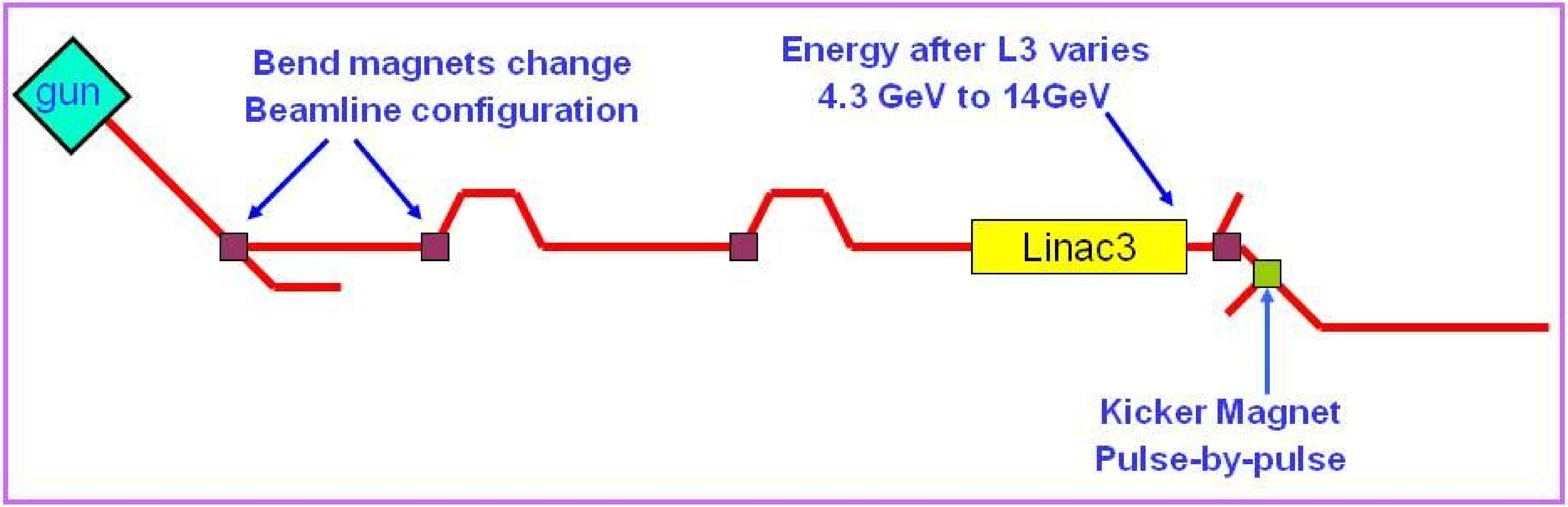
Bunch Charge Feedback

- Maintain bunch charge by adjusting a laser attenuation plate
- Simple; single sensor, single actuator, proportional feedback



Special Requirements for LCLS

- Energy Changes: on user request and within minutes
- Beamline Configuration Changes: pulse-by-pulse
- 120Hz Operation in 2010
  - 60 Hz Interference due to powerline noise



Prototyping in MATLAB

- Use simple PID control.
- Use Channel Access.
  - reading from sensor PVs, writing to actuator PVs.
  - work at rates above10Hz.
- Rapid prototyping kept pace with changing requirements over 3 years of commissioning.
  - identifying components of the feedback subsystem
  - testing algorithms
  - identifying techniques for managing energy changes and beamline changes

120Hz Feedback for LCLS

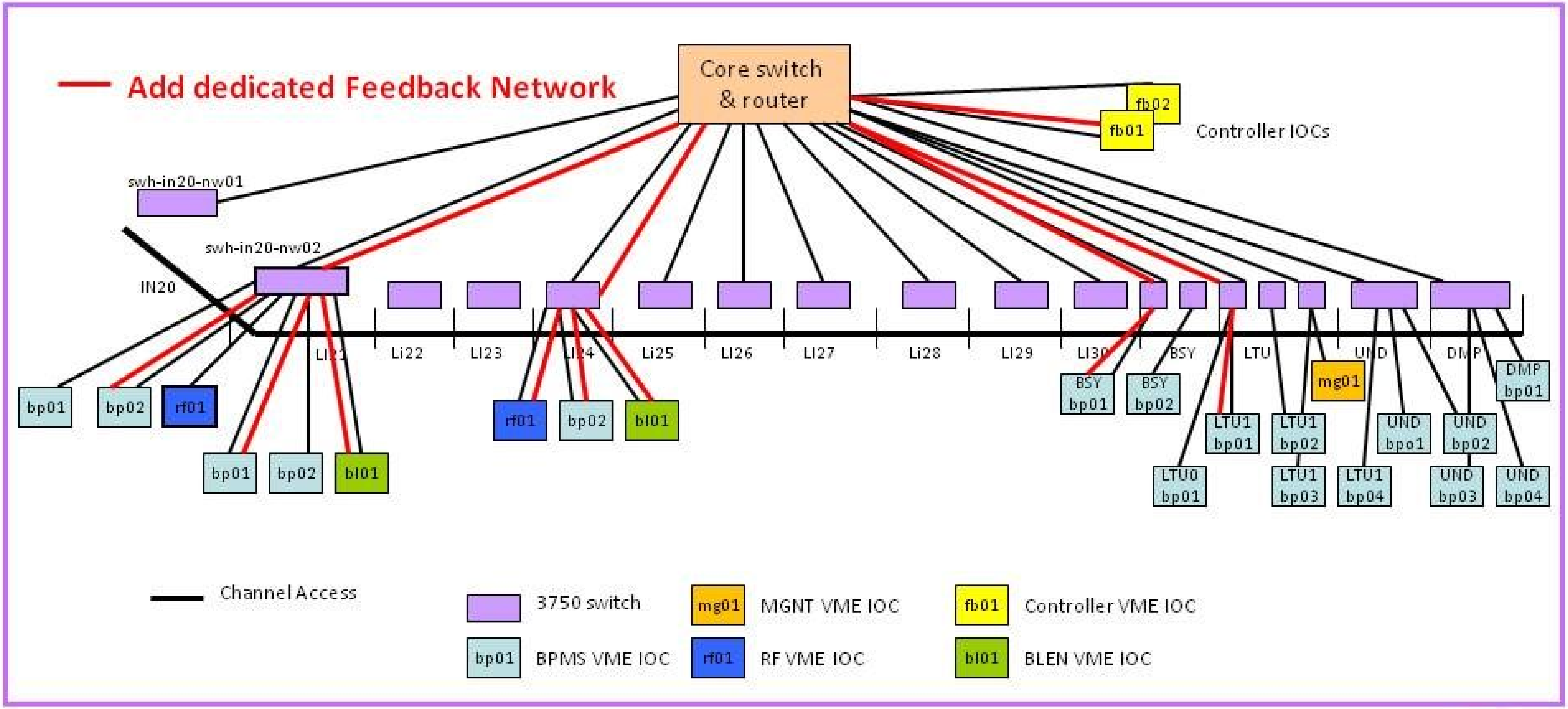
- Differences in the 120Hz production system compared to the MATLAB prototype:
- Faster network communications
- Interface to the timing system
- Faster feedback processing
- Modular design for future growth

Components of the LCLS Fast Feedback

- Dedicated Network
- Timing System
- Actuators and Sensors
- Controller, software framework, and algorithms
- Configuration Tool
- Runtime Display and Control

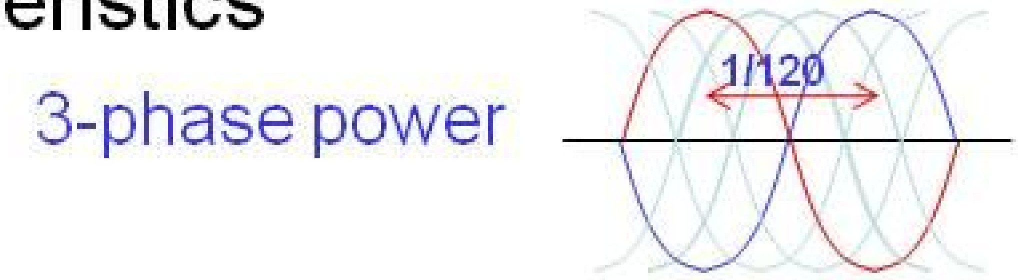
Feedback Network and IOCs

- Add dedicated multicast gigabit Ethernet network (about 15% of IOCs)
- Network interface software module developed to integrate easily into IOCs



Timing System Interface

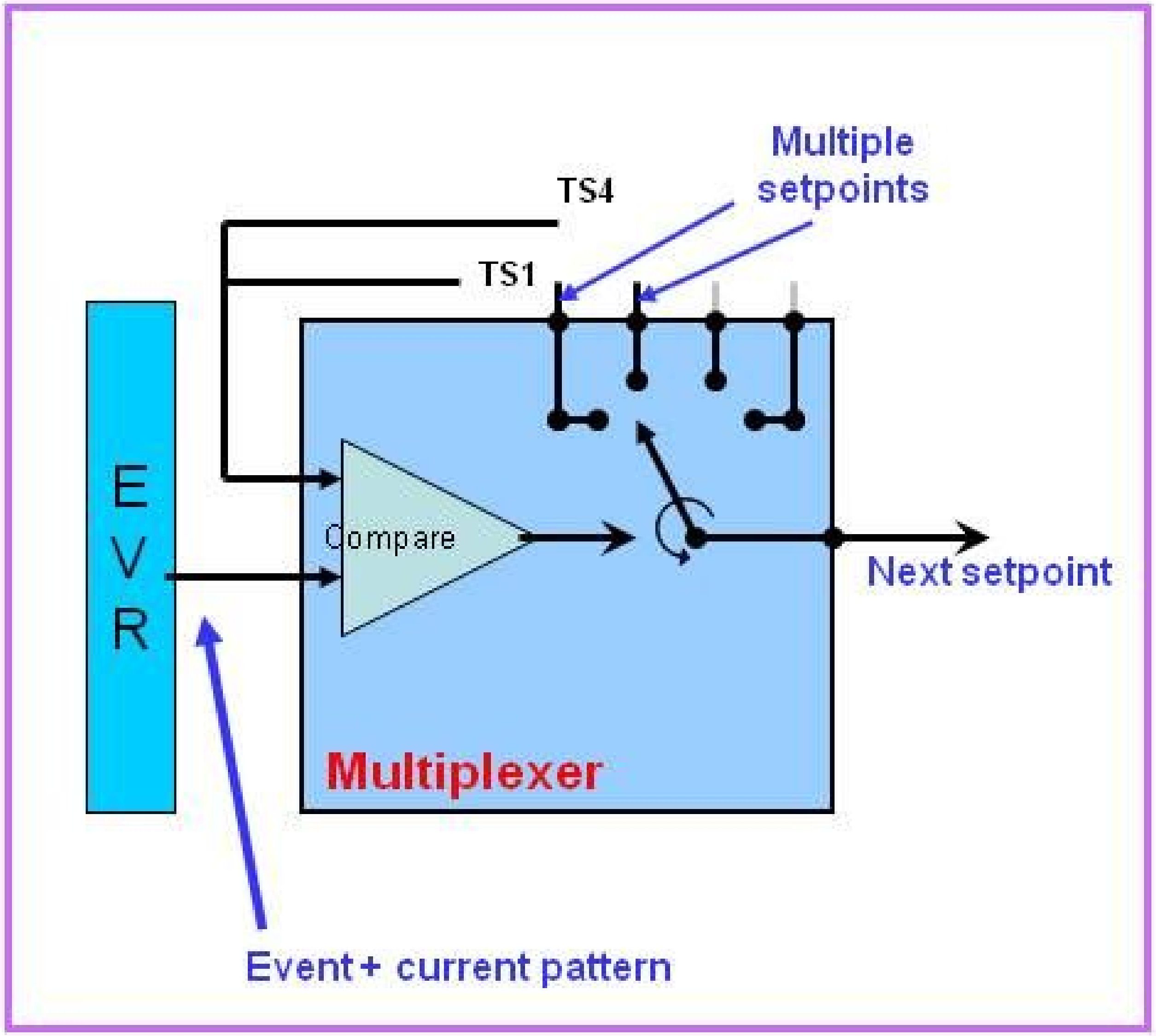
- Allows synchronization between feedback and beam pulses generated on different powerline phases.
  - 120 Hz beam operation draws power from two interleaved 60 Hz powerline phases
  - Beam generated on different 60 Hz powerline phases have differing noise characteristics



  - Noise on each powerline "timeslot" must be corrected independently by the feedback
  - Timing system labels each timeslot with a "pattern"

Timing System Interface

- Timing system *Event Receiver* allows beam synchronous feedback loops and actuator devices
- Each feedback loop and actuator has a setpoint multiplexer driven by the Event Receiver
- Pattern-based control software module



Controller, framework, algorithms

- Feedback Controller IOC runs multiple feedback loops
- Utilizes actuator pattern-based control to correct 60Hz disturbance
- 'software framework' handles common functions such as:
  - operating limits on sensors, actuators, and feedback states
  - gains and averages
  - receiving sensor data and sending actuator commands
  - alarms
- Configurable feedback algorithms.
- Growth: add loops to a single Controller IOC; add IOCs

Actuators and Sensors

- Actuators
  - Add pattern-based control to RF Stations
  - 4 New fast corrector magnets with pattern-based control
  - Integrate RF and magnet IOCs with new network
- Sensors
  - Integrate Beam Position Monitor and Bunch Length Monitor IOCs with new network

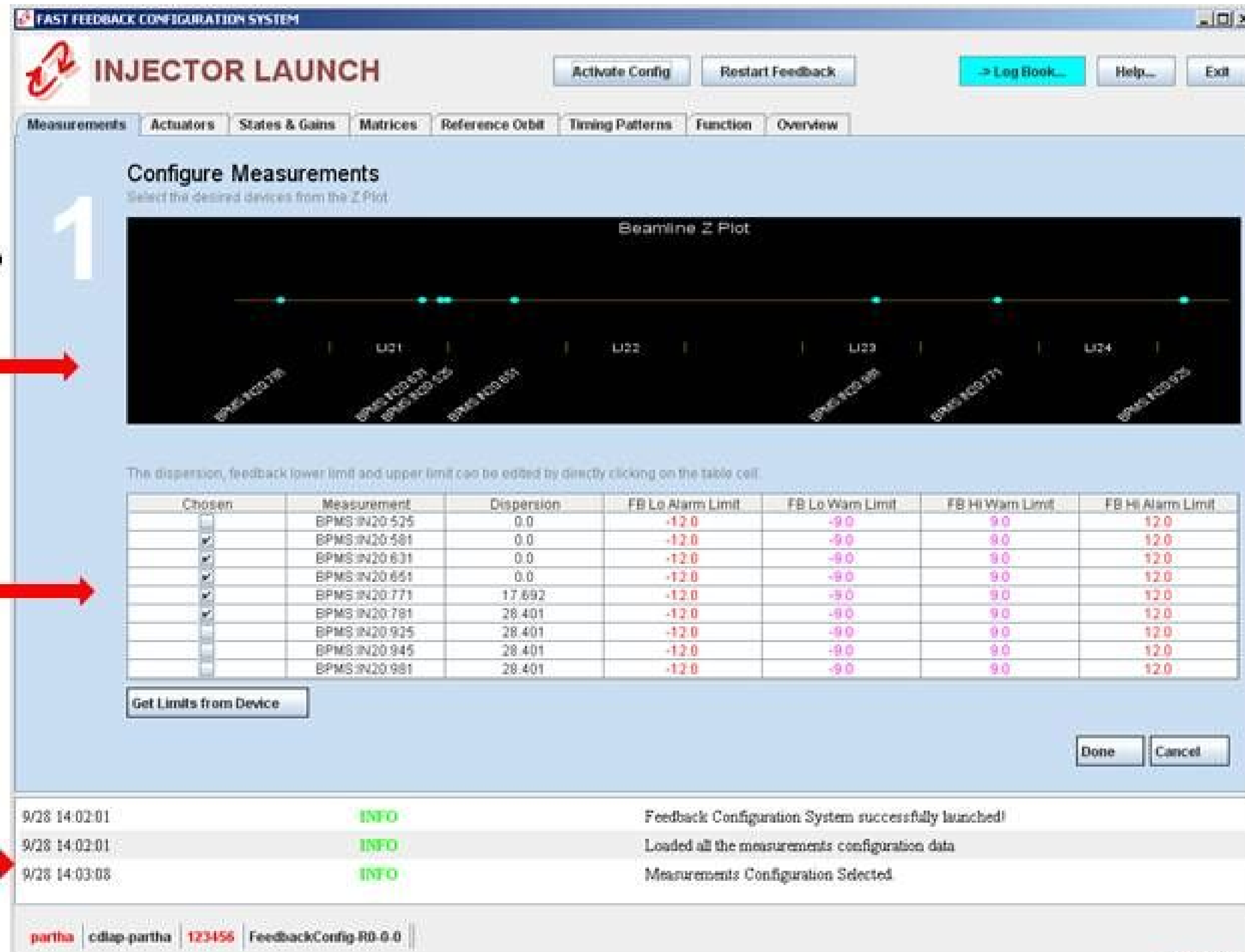
Configuration Tool

- Java application: allows user to create / configure feedbacks off-line.

Interactive beamline map

User editable fields

Message window



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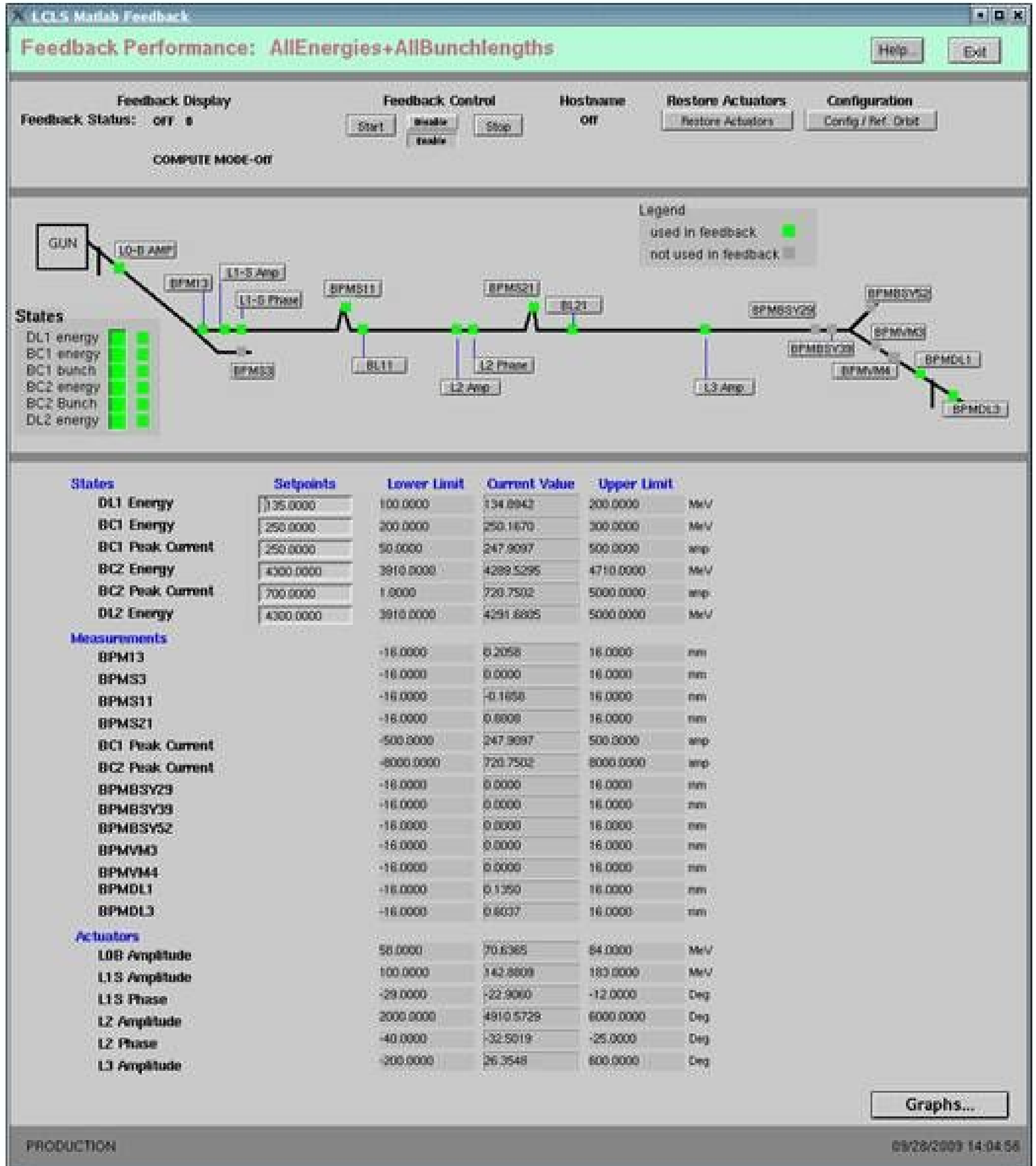
Runtime Control & Display

- EDM displays allow changes while feedback is running.
- start, stop, disable
- choose which parameters to stabilize
- setpoints, limits, gains.



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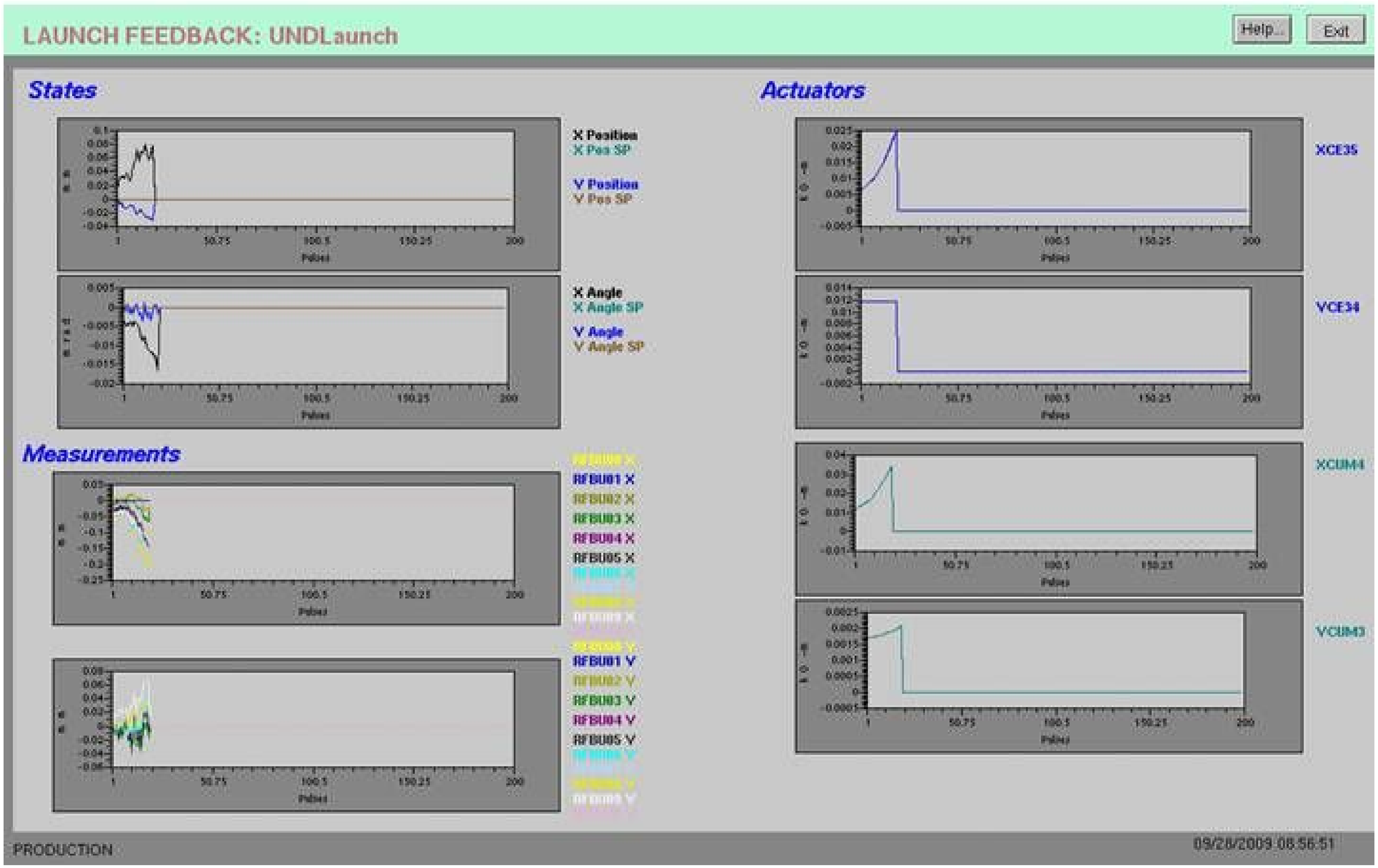
Runtime Display

- EDM displays show feedback performance



Fast Feedback Project Summary

- Provides pattern based control of RF stations and fast magnets
- Dedicated multicast Ethernet Fast Feedback network, fully integrated with feedback device controllers
- Two feedback loop Controller IOCs
- First Feedbacks:
  - 120Hz Energy and Bunchlength Feedback
  - 120Hz LTU Trajectory Feedback
  - Additional feedbacks phased in over the summer

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