HIGH LEVEL PHYSICS APPLICATIONS – THE BIG PICTURE

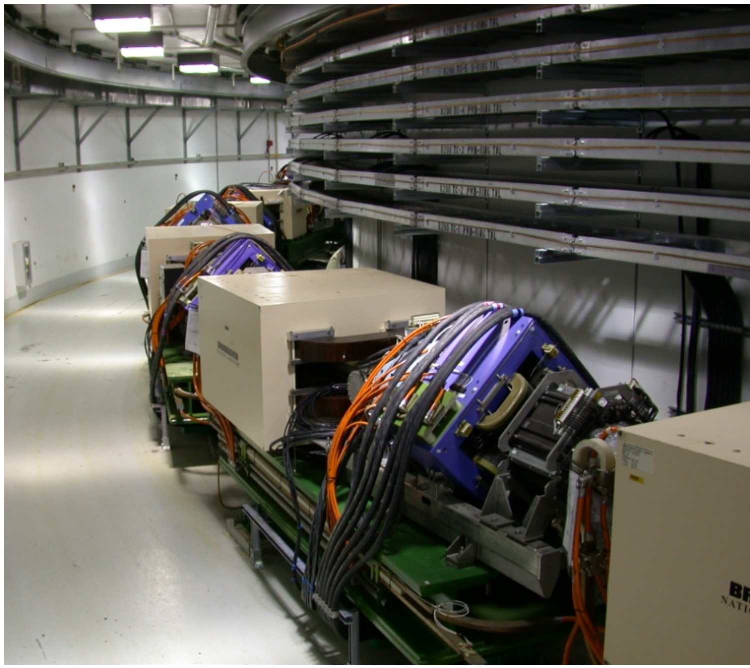
Day 1, Lecture 2

Relation of High Level Applications to Other Systems

Perspectives

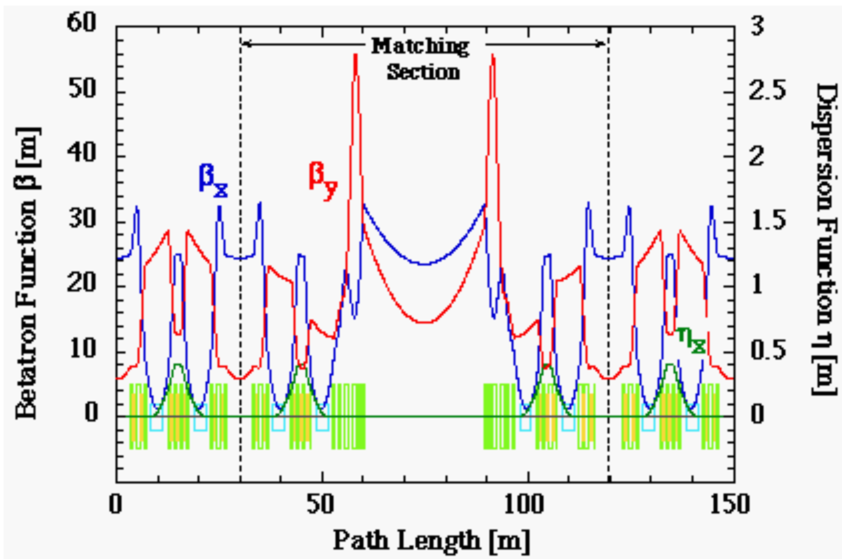
- Consider an accelerator system from the perspective of the customers
- How does the application fit in?
- Review accelerator systems providing observables and control variables for applications

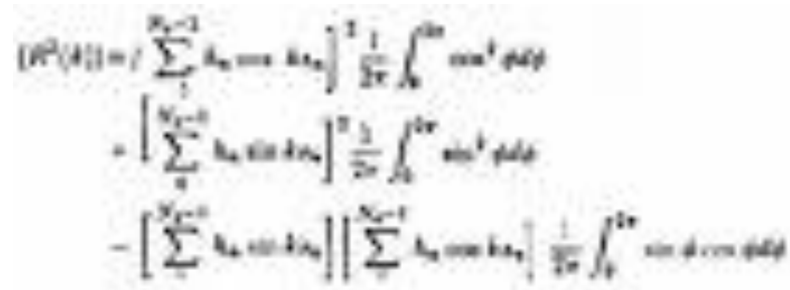
Accelerator View: Engineer

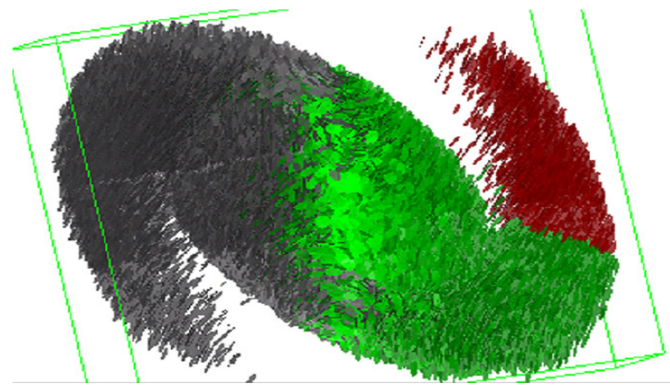


Engineers' view – Real hardware and software systems that must interface and meet design requirements

Accelerator View: Accelerator Physicist





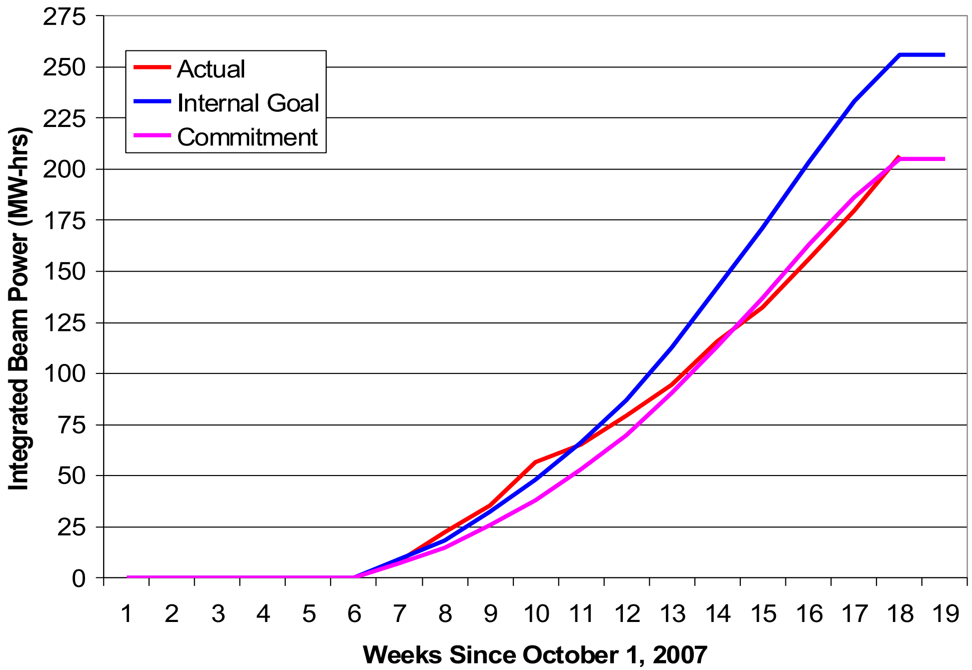


- An abstract object that performs manipulations on ideal beams under ideal conditions

Accelerator: Operations View

- A control room with interfaces to whatever is required for seamless accelerator operation.

Accelerator: Manager’s View

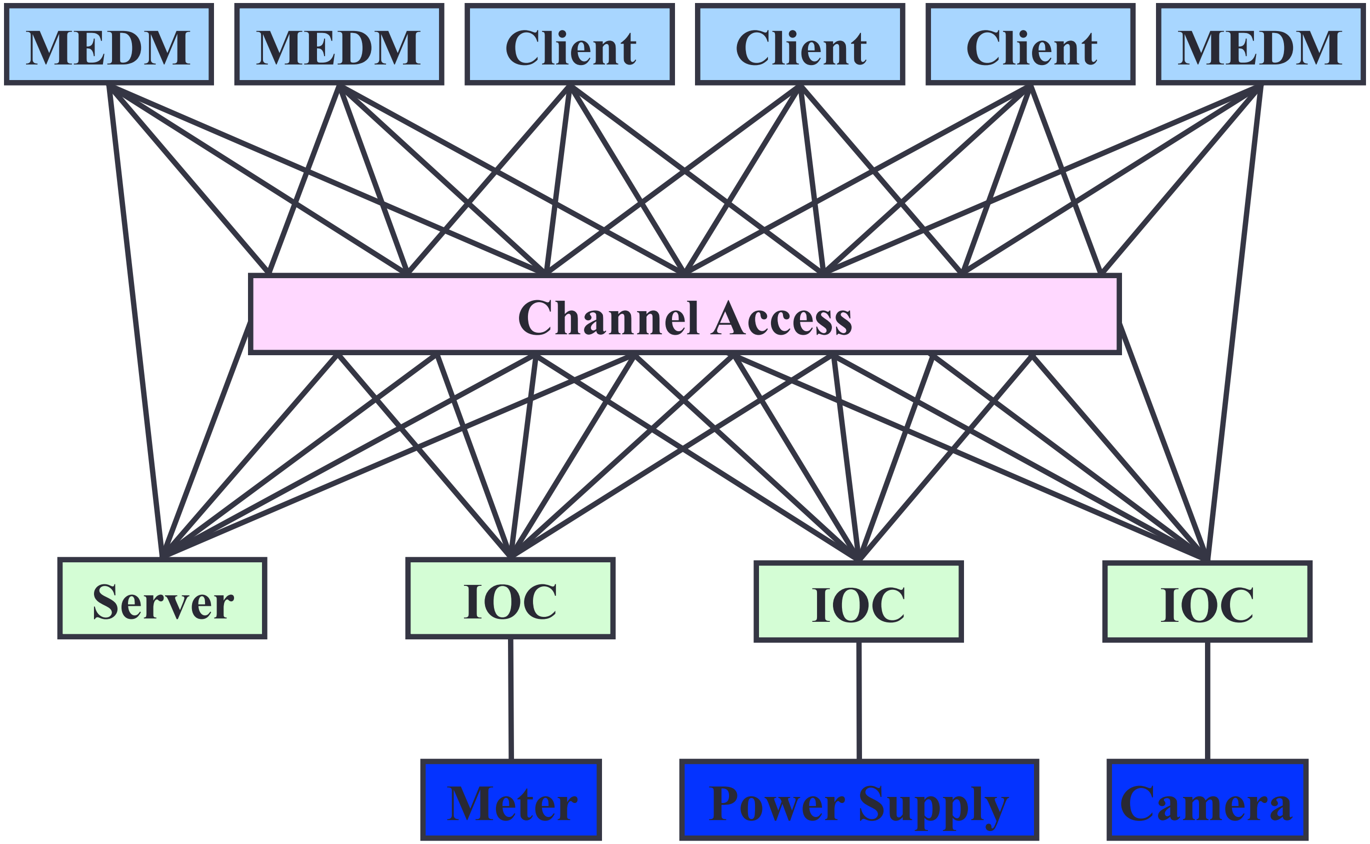


- A device that meets the promises made to the funding sponsor

High Level (Physics) Applications

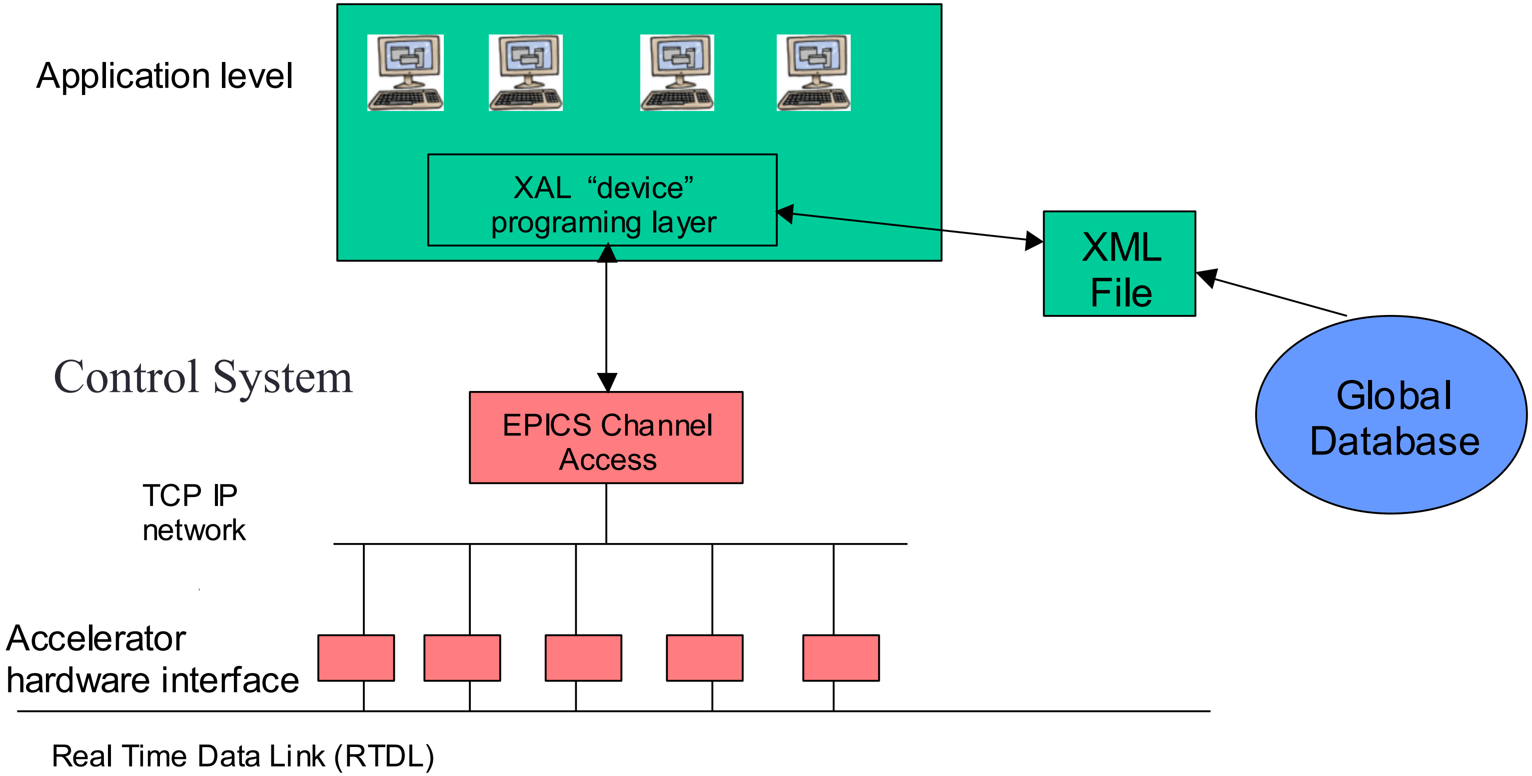
- Need to consider the many points of view of the disparate systems that an accelerator is composed of:
  - Magnets (optics)
  - RF systems
  - Diagnostics systems
  - Timing systems
  - Control systems
  - Data acquisition
- All of these provide input/output to the high level applications

EPICS View of the Data Flow



- Here XAL would be a client
- Most "MEDM" screens are preconfigured interfaces to hardware

Relation of High Level Applications to Control System and Accel. Hardware



- The high level applications communicate with hardware through a control system
- It's important to carefully spell out the requirements / interfaces for the control system and the underlying hardware.

High Level (physics) Applications

- High level applications typically integrate information from multiple systems over an extent of the accelerator
- These applications often require information about the beam (from beam diagnostics) and perform manipulations on the beam (magnets / RF)
- They communicate with these systems through a control system
- Often a physics based model is used to provide information how to control the beam
- Examples:
  - Orbit display and correction, orbit bumps, setting RF phase and amplitude, …

Specify Interfaces, and all should work

- In principle things are simple:
- Specify what you want to receive from measurement devices,
  - e.g. a measure of the horizontal beam position at some place and time and return its value in mm, with name "xyz"
- Specify what you would like to control
  - E.g. a magnet field level, in Tesla, for magnet xyz.
- Wire it all up and hit the "On" button

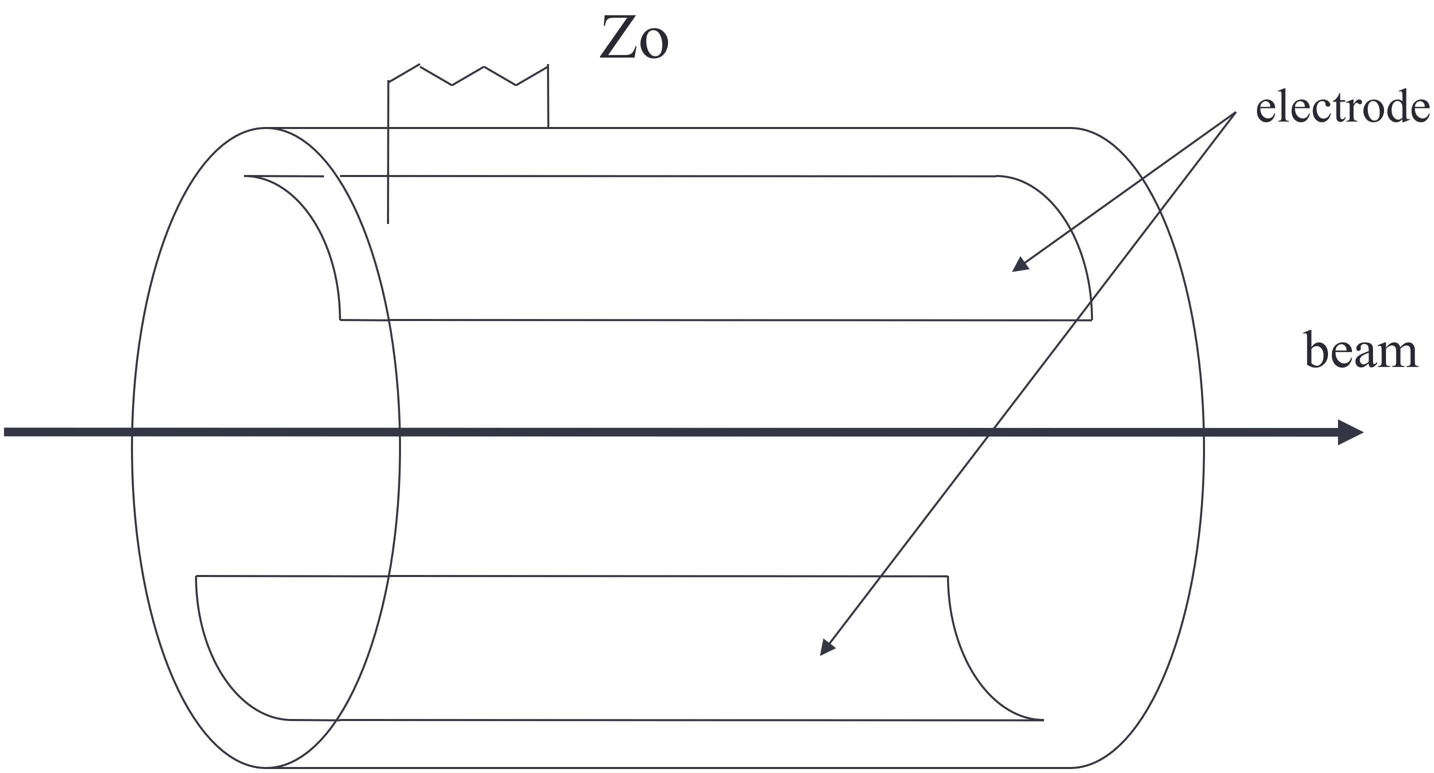
What Could Go Wrong???

- Since high level applications use information measured from many sources, it is important to understand the strengths and limitations of these sources
- It is also important to understand the limitations of equipment you may try and control
- There are inherent difficulties in trying to communicate quickly with many information sources – control systems are complicated and not consistently reliable.
- Often the majority of a high level application is exception handling – responding to events that are exceptions to normal operation.
- Let us examine some of the primary players in accelerator measurement and control

Diagnostics - Eyes and Ears to the Beam (Provide Observables)

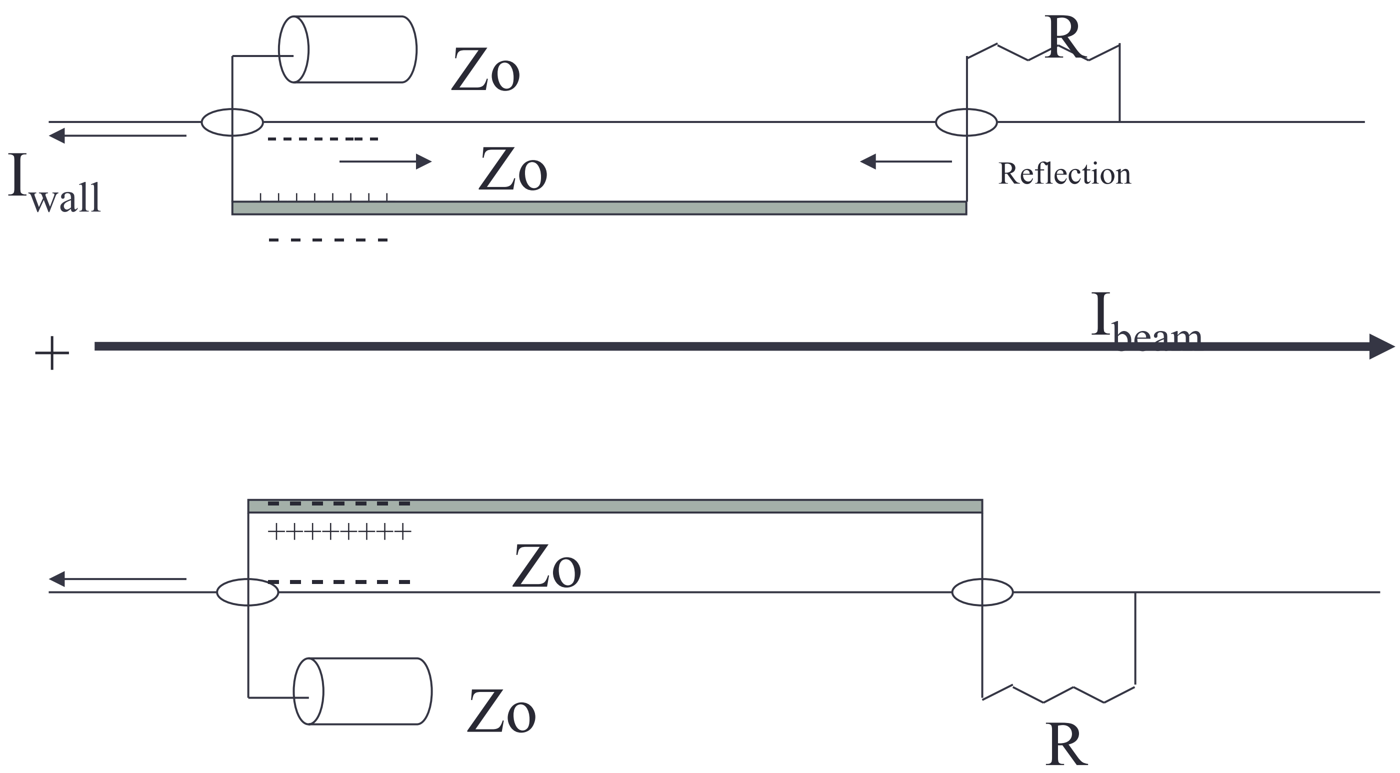
- BPM – Beam Position Monitor measure beam position
- BCM – Beam Current Monitor (current transformer)
- BLM - Beam Loss Monitor
  - Ionization chamber (IC)
  - Photomultiplier tube (PT)
- Profile measurement
  - Wires
  - Fluorescence screens
  - Residual gas stripping
  - Lasers

Beam Position Monitors



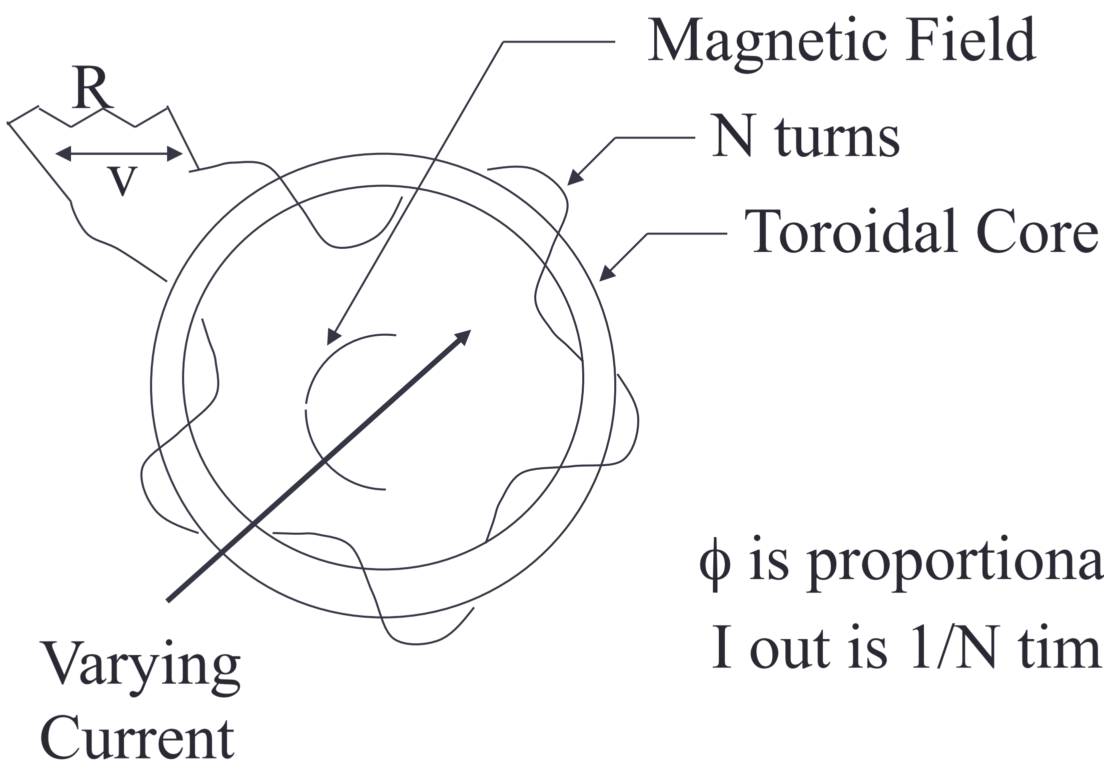
- Moving charge induces current in surrounding electrodes

BPM



- BPM

Beam Current Monitor (BCM)



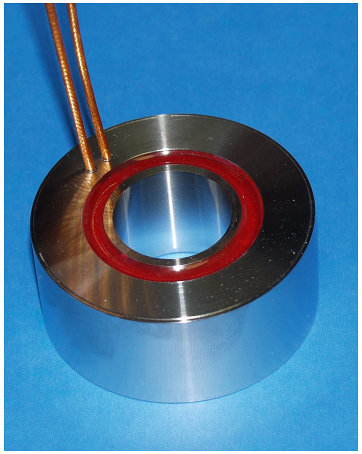
ϕ is proportional to I

I out is 1/N times I in

- A changing current induces a voltage on a current loop surrounding it:

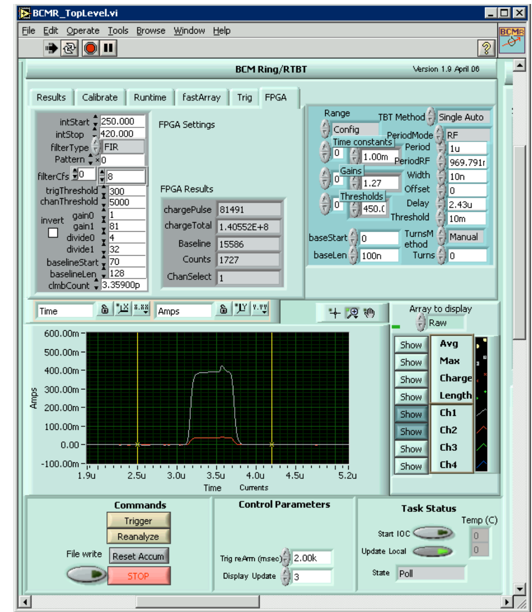
$$V = -{}^{d\phi}\!/_{dt}$$

BCMs



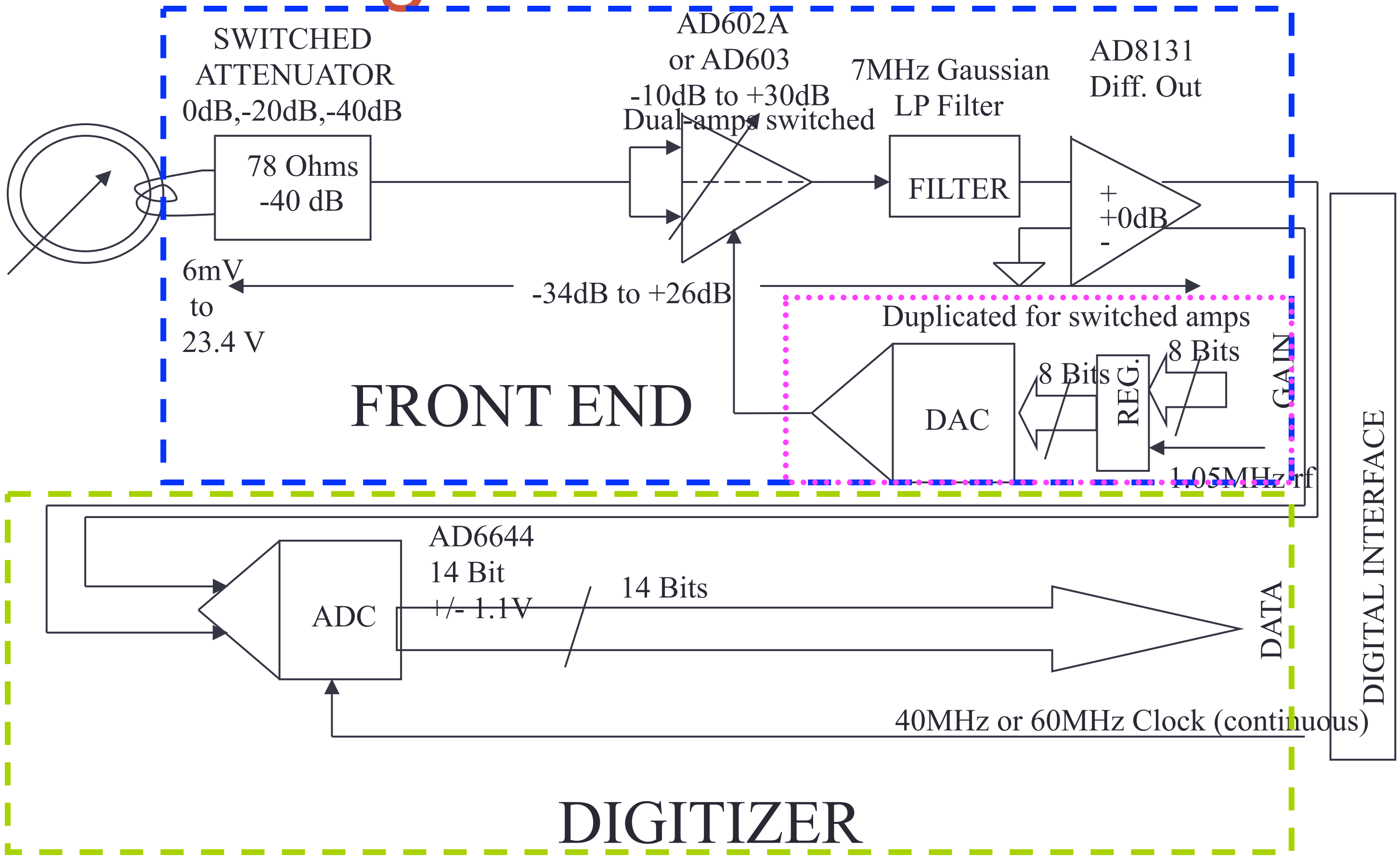
- BCMs are quite simple looking

Controllers for diagnostics are located in racks in service buildings



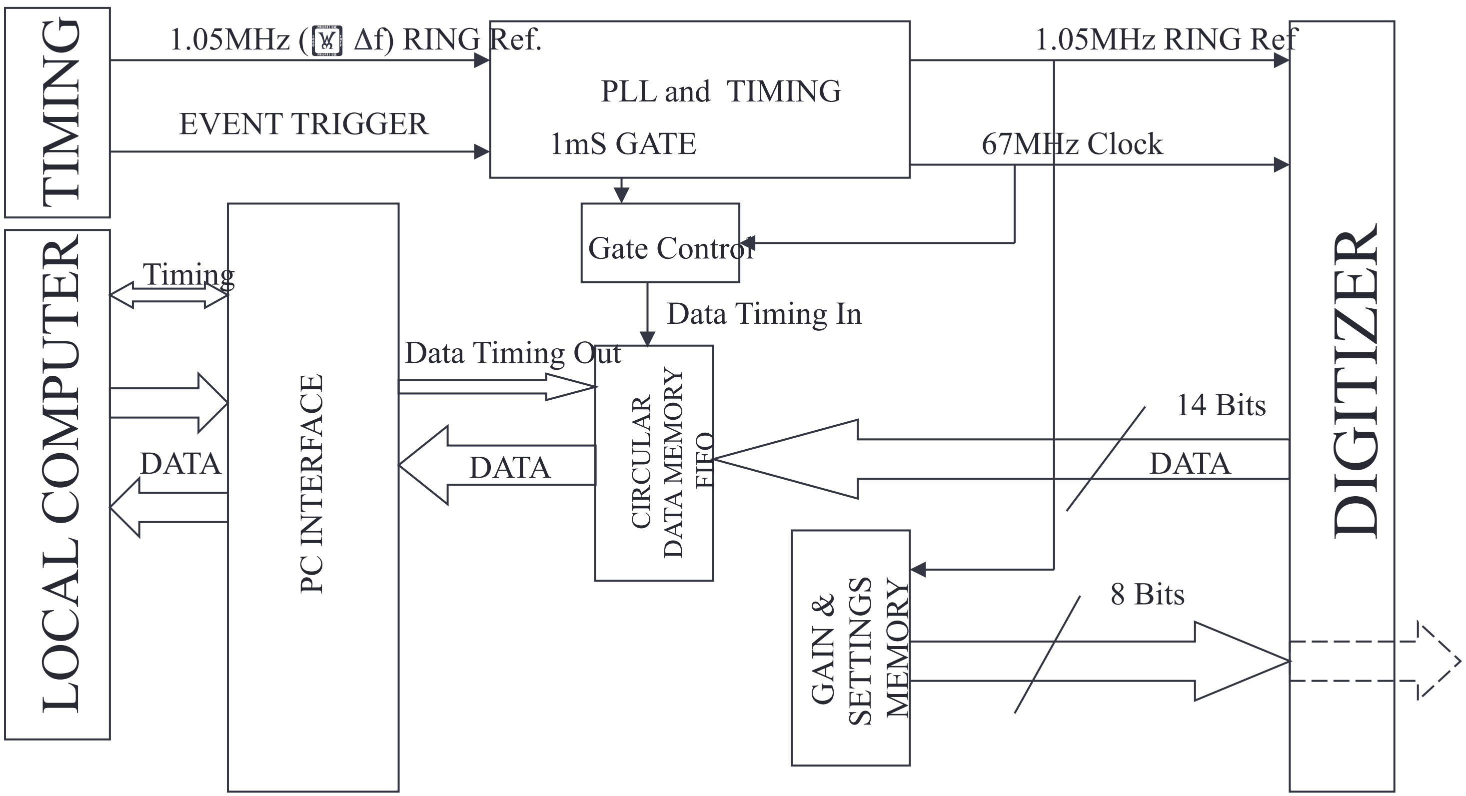
- Sometimes someone brushing against a cable can mess up things
- They have their own expert system interfaces (be careful that the proper values are restored after re-boots!)

Typical Analog Front End & Digitizer Block Diagram



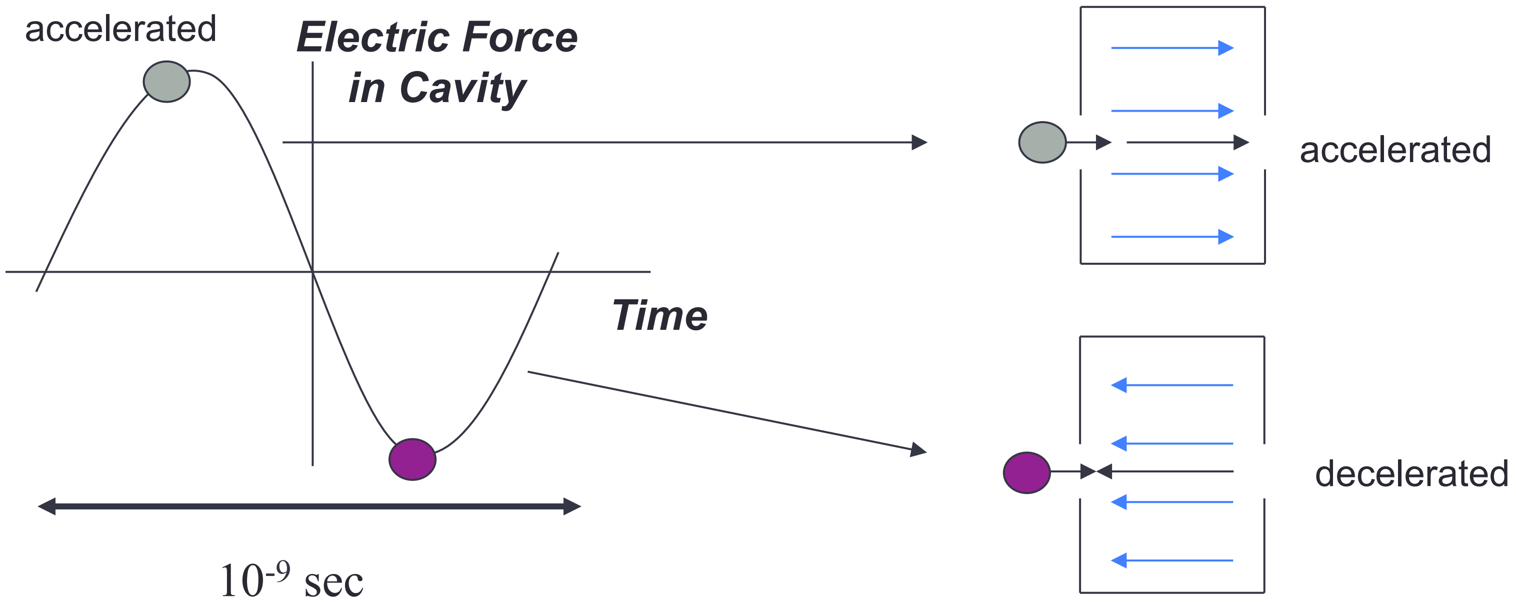
- There is typically a fair amount of information processing in the analog / digital conversion
- Often there are gain settings

Example Digital Interface



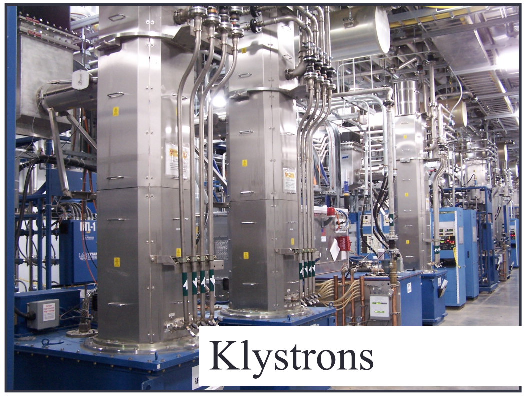
- Plenty of room for problems in the digitizer to control system interface as well
- Timing triggers are always an issue

RF Systems



- Use Oscillating Electric Fields to Accelerate a Charged Particle
  - High Voltage Convertor Modulators
  - High Power RF
  - Low Level RF

RF System Components


Klystrons


Klystrons


Ring Cavity

Transmitter


Linac LLRF


Reference Line System


Ring LLRF

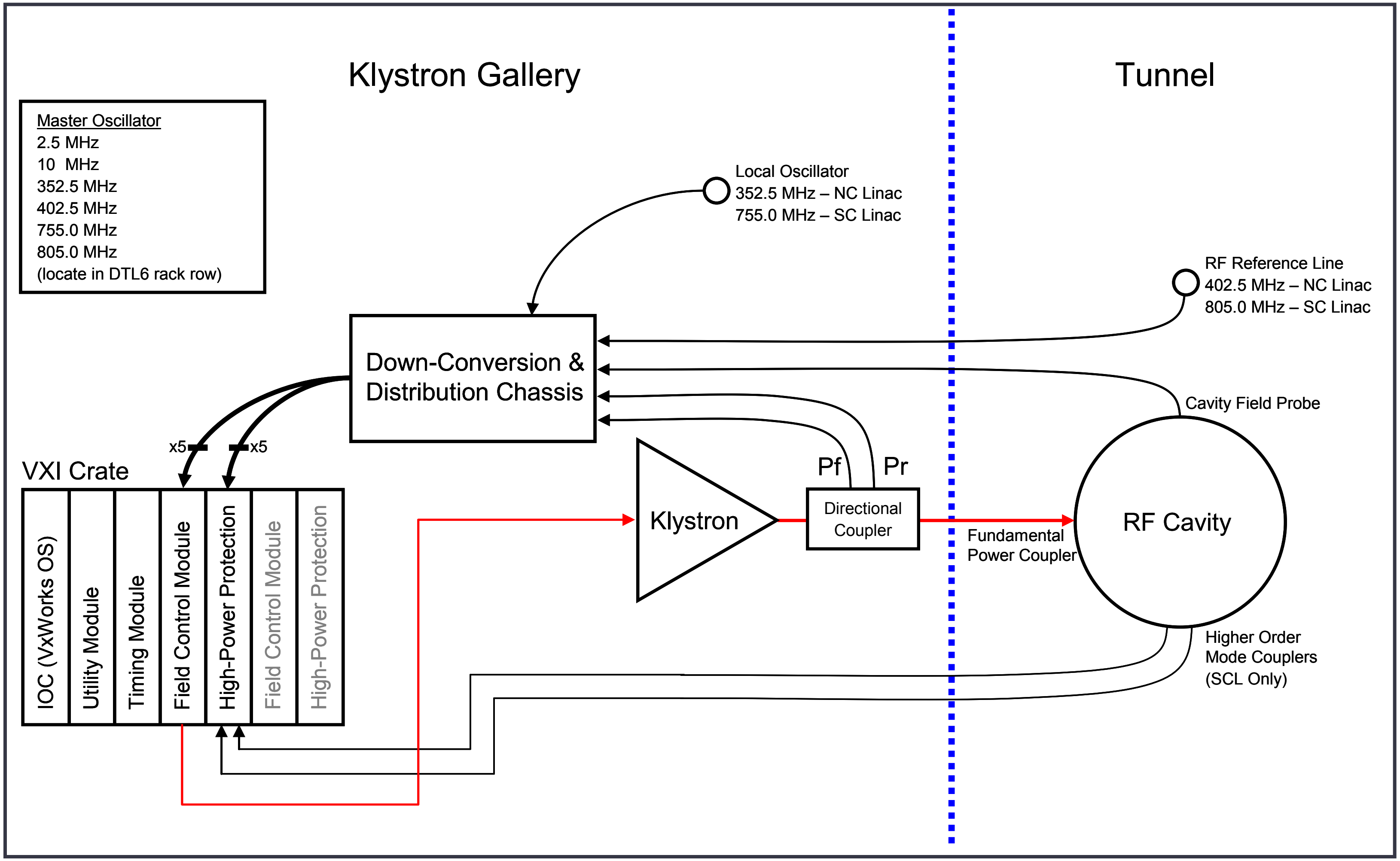
Typical LLRF Control Rack

Typical LLRF control rack installation in the superconducting linac.

The VXI crate contains:

- Input/Output Controller: PowerPC running VxWorks
- Utility Module: Decodes events from Real Time Data Link (Global Timing System)
- Timing Module: Generates RF Gate timing signal
- Two FCM/HPM pairs – generates the patterns for the high power RF, includes feedback, feed-forward, interfaces to the control system, etc.

Block Diagram of the SNS Linac LLRF Control System



Field Control Module (FCM)

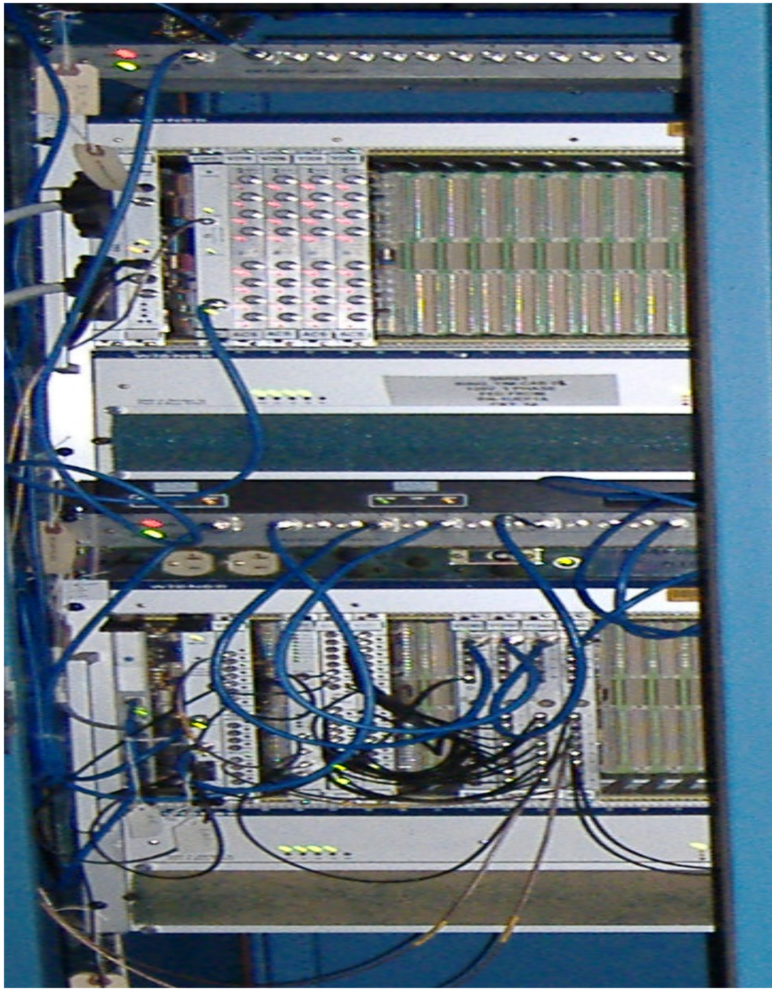
- **Regulates frequency control , field amplitude and phase regulation**
- **Corrects for correlated and uncorrelated errors**
- **Adaptive feed-forward control used for correction of repetitive field errors caused by beam loading and Lorentz force detuning**
- **RF Sequencer is used for normal operations – startup, warming up cavities, tuning cavities, etc.**
- **Primary interface to the Control system, e.g. what phase and ampltiude does the user want the cavity to run at.**

High-power Protection Module (HPM)

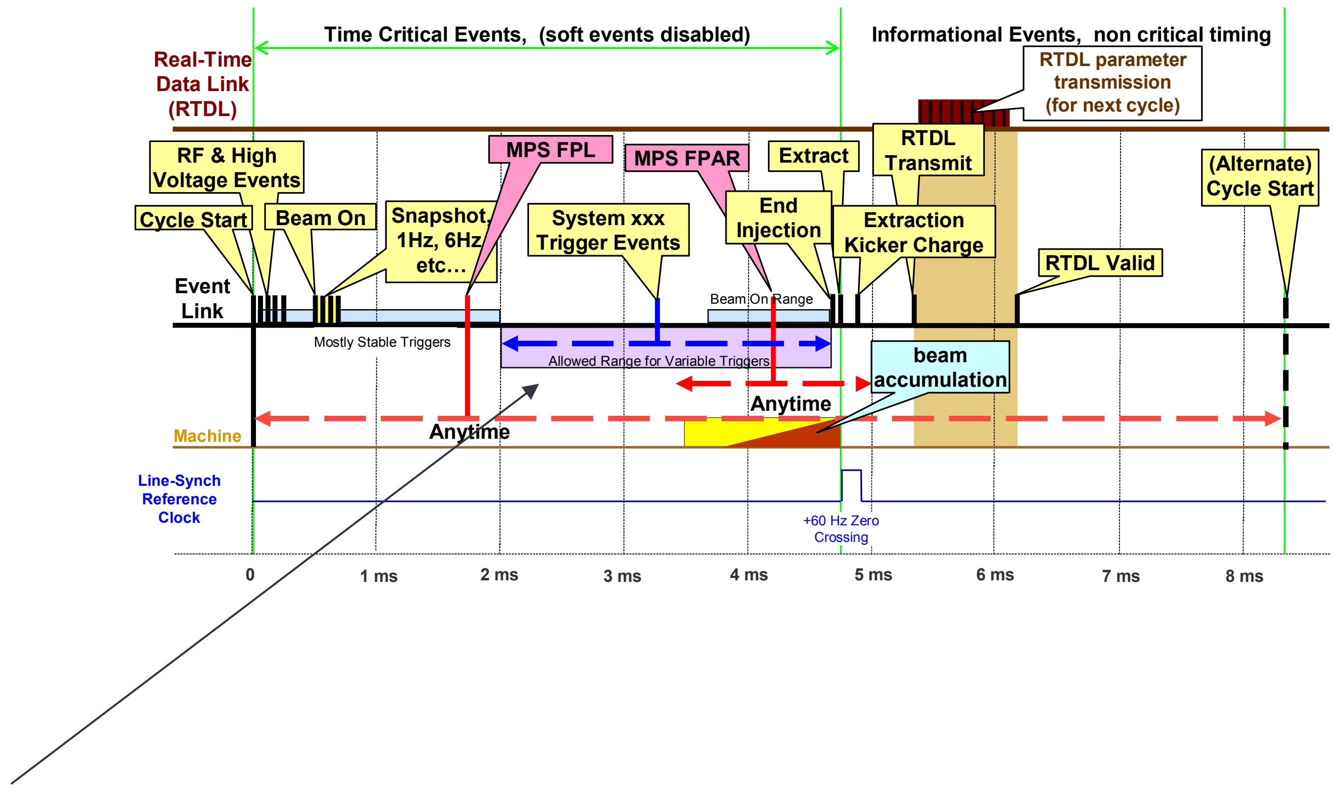
- Responsible for protection of the RF systems
  - Monitors up to 7 RF inputs
- Detects cavity and klystron arc faults utilizing the AFT FOARC chassis
- Vacuum interface is connected to LLRF via HPM
- Soft interlocks from Cryo, Water, HPRF and Coupler Cooling
- Chatter faults are expert settable to fine tune individual channels
- History plots are available to monitor any two input channels

Timing Systems (Master)

- Master Timing system generates event signals and propagates these throughout the accelerator to be used as triggers for systems
  - Pulsed magnets
  - Diagnostics
  - RF
  - …

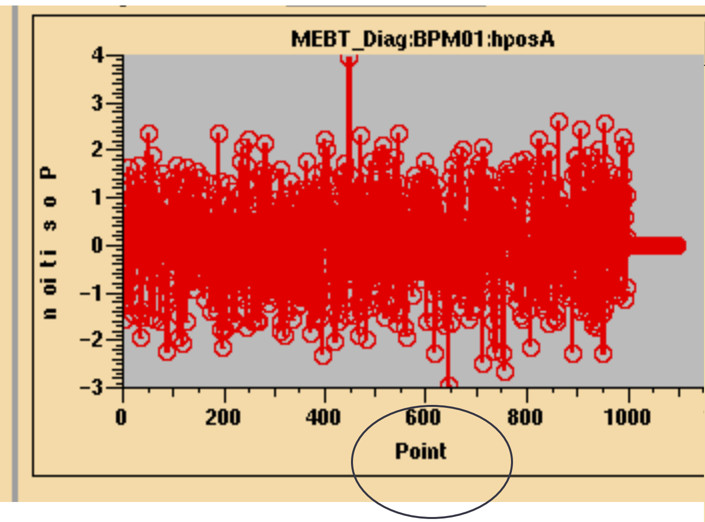


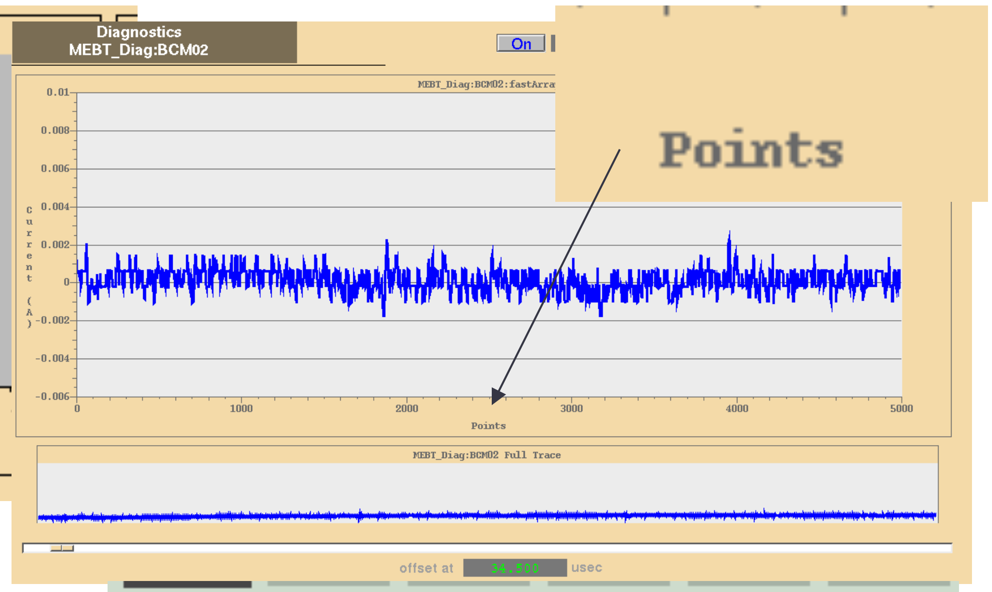
Timing Systems (Clients)



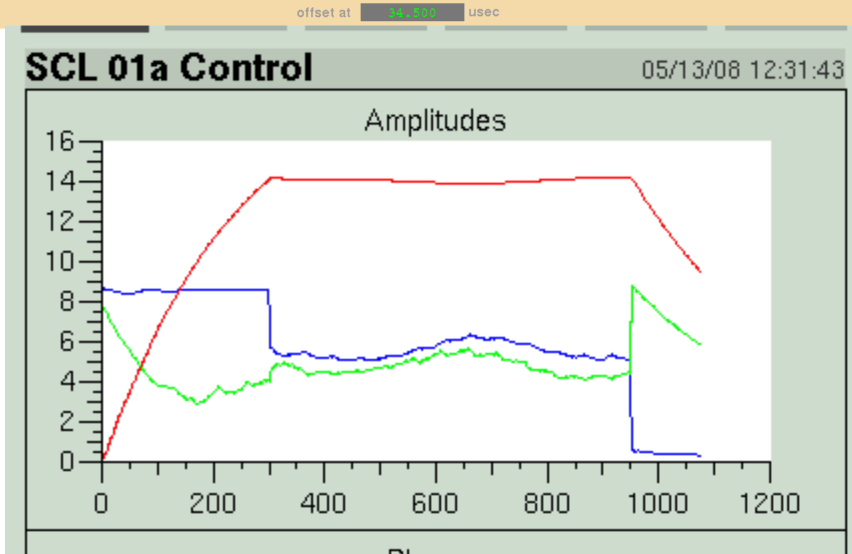
- A difficulty is that different systems receive separate triggers and handle the triggers differently

Timing Signals from Multiple Sources





- Providing common units and ways of providing information amongst disparate groups is important



Putting it All Together – The Big Picture

- We want to know what the beam is doing where and when (the beam state)
- We want to control the magnets, RF, hardware, etc. with "physically meaningful units" relative to the beam
- We want to adjust the controllable parameters in a predictable manner
- Lots of things can go wrong: "trust but verify" all information that you use.