# LANSCE Beam Instrumentation and the LANSCE Refurbishment Project

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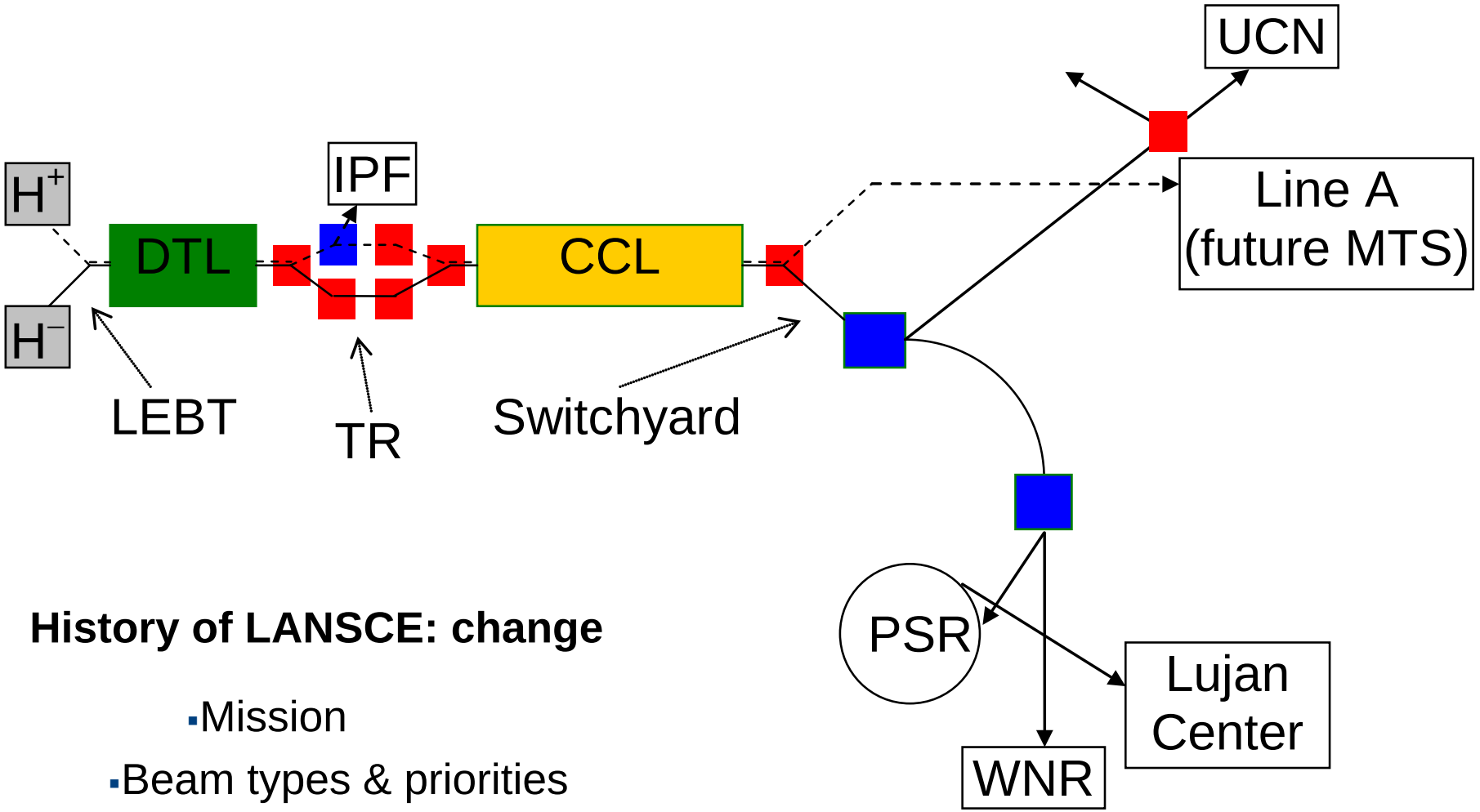
# Outline

- LANSCE facility and experimental areas
- LANSCE refurbishment
- Uses of beam diagnostics
- Characteristics of the various beams
- Diagnostics systems and requirements
- Summary

# LANSCE




**History of LANSCE: change**

- Mission
- Beam types & priorities
- Need flexibility in the diagnostics

# LANSCE-R (Refurbishment)

- **Purpose: To ensure the on-going reliable operation of the LANSCE accelerator**
- **Scope is limited to the core accelerator infrastructure**

**Radio-Frequency systems**

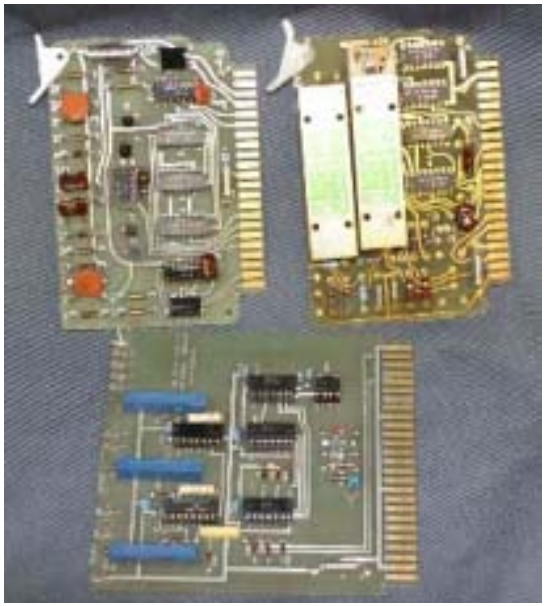
**(Power amplifiers, HV & Modulators, LLRF, support systems)**

# LANSCE-R scope

- **Control and Timing Systems**

RICE

Remote Instrumentation and Control Equipment



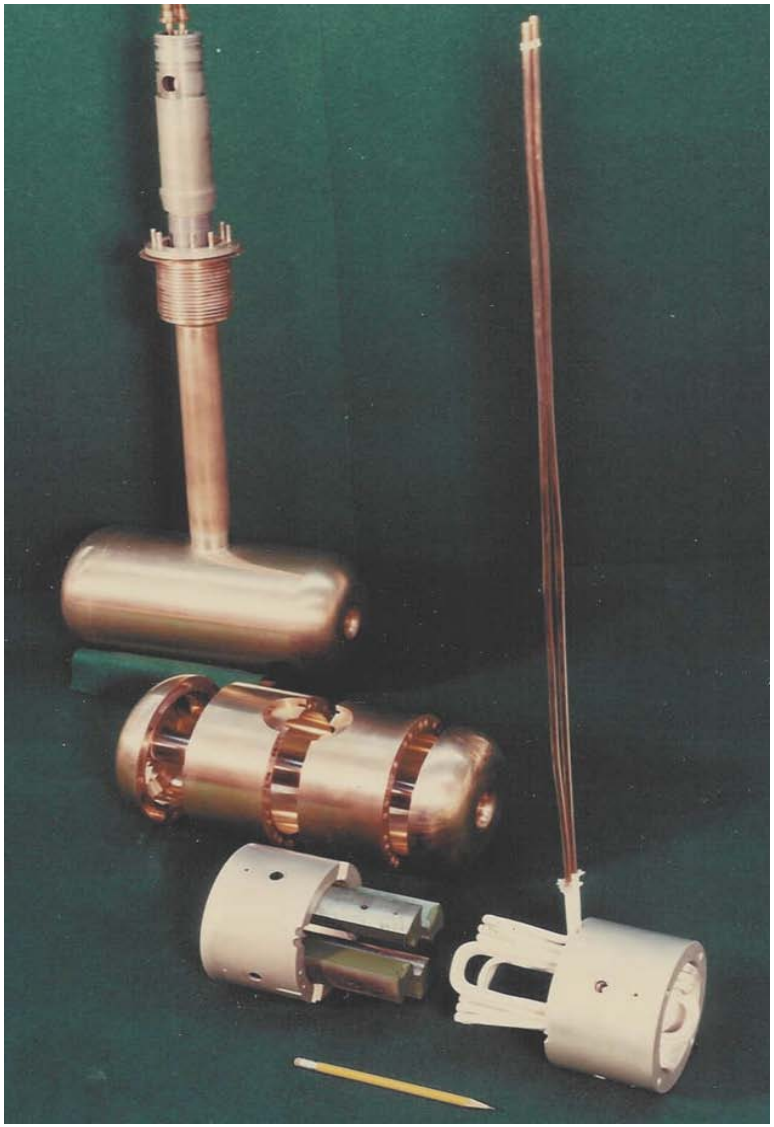
Diode-Transistor Logic

# LANSCE-R scope

- DC magnet power supplies
- Vacuum systems

# LANSCE-R scope

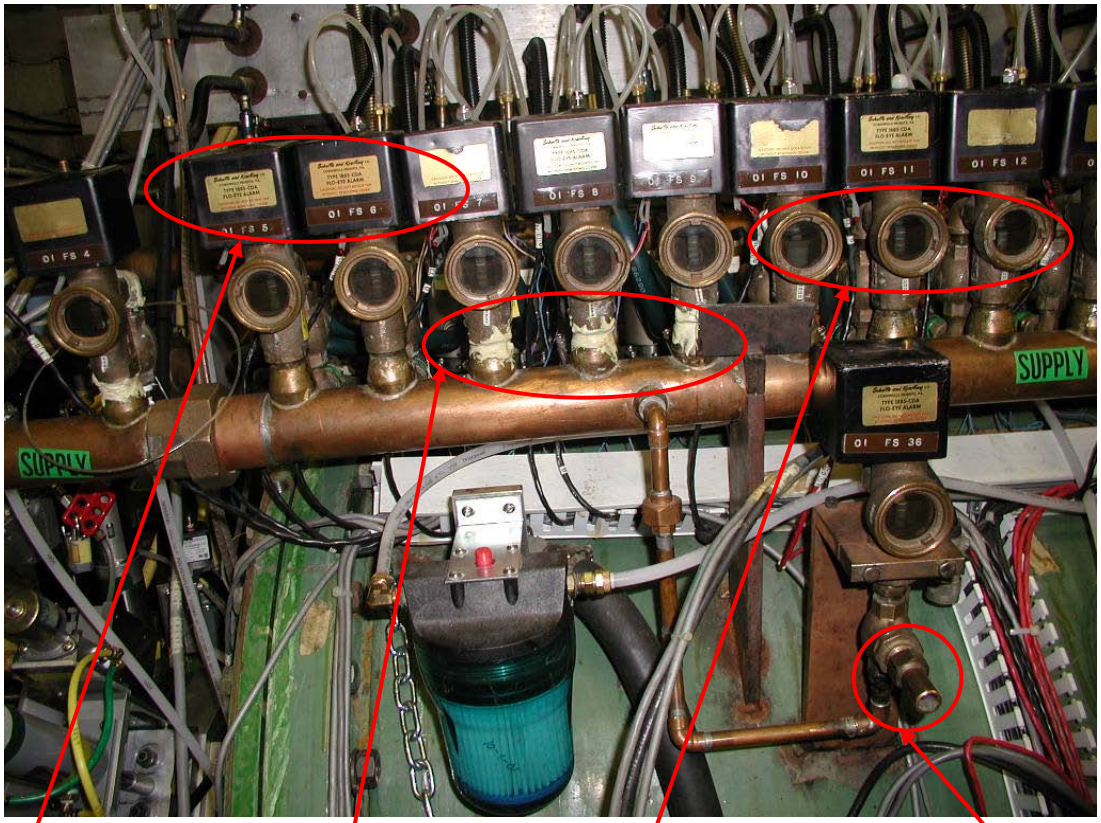
## Spare drift tubes for the DTL



# LANSCE-R scope

## Water systems

**Drift Tube Linac Tank 1 water manifold**




**Flow sensors rely on archaic magnetic switches**

**Epoxy repairs have been made to mitigate braze joint leaks**

**"Float" type flow switches are difficult to calibrate and set accurately**

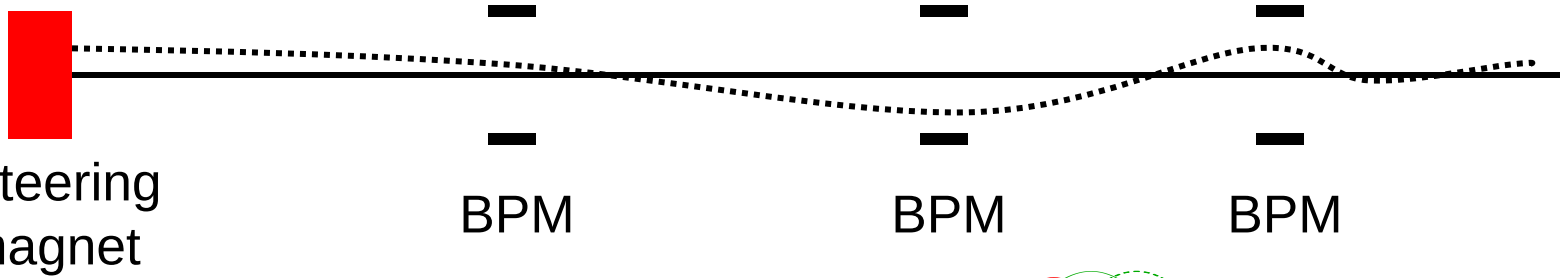
**Manual key adjustment required to set flows**

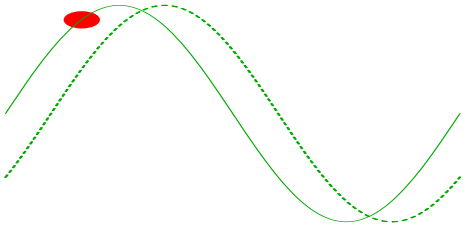
# LANSCE-R scope

- **Diagnostics systems – systems-wide replacement:**
  - Wire-scanners
  - Beam position and phase monitors
- **NOT in the LANSCE-R scope:**
  - Beam current monitors
  - Slit / Collector beam phase space measurement system
  - Absorber / collectors
  - Collimator currents
  - Beam loss monitors

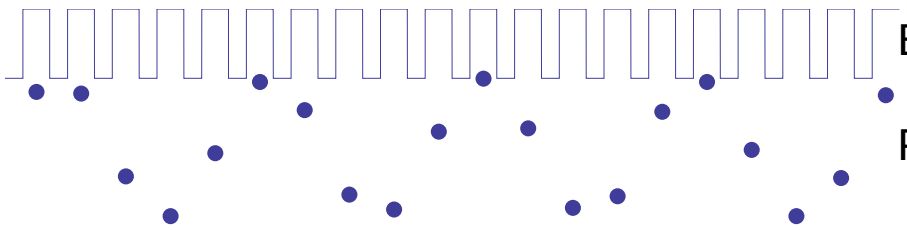
# Purposes of Beam Diagnostics

## 1. Setpoints of accelerator equipment



## 2. Diagnosing problems with accelerator equipment

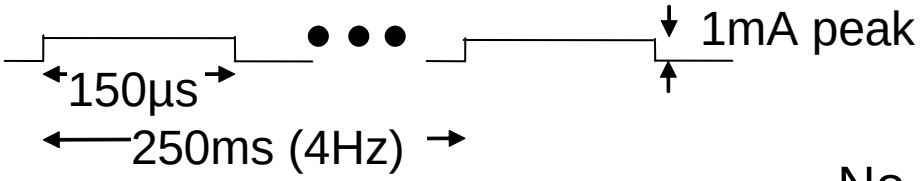



| Minipulses | Macropulses |
|---|---|
| RF control oscillation | Water system vibration |

Requirements: Bandwidth, Data rates, Synchronization, Flexibility

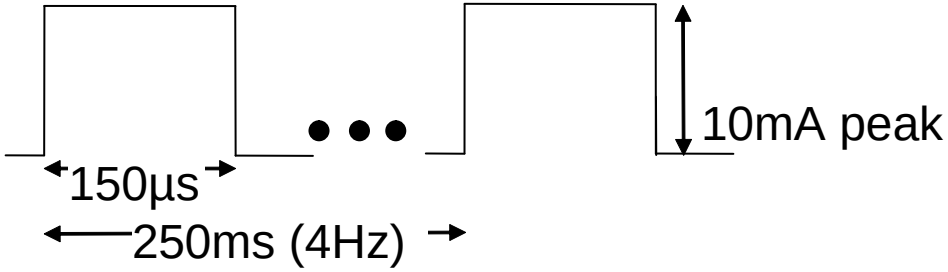
# Diagnostics: Initial tune-up vs. production operations

Initial Tune-up:




No additional time-structure

Full-peak current:




10μA limit on intercepting diagnostics and beamstops

Production-like beams

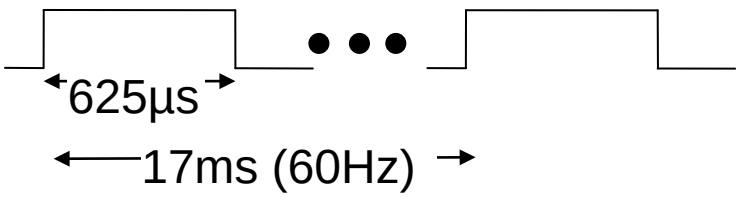
(more on this later)

Requirements:

Precision

Long-term stability ↔ accuracy

# Beams' time structures: Macropulses




Linac macro pulses

@ 60Hz (formerly 120Hz)

LANSCE-R objective

During the macropulse:

RF accelerating fields are on and stable

Pulsed magnets are in the proper states

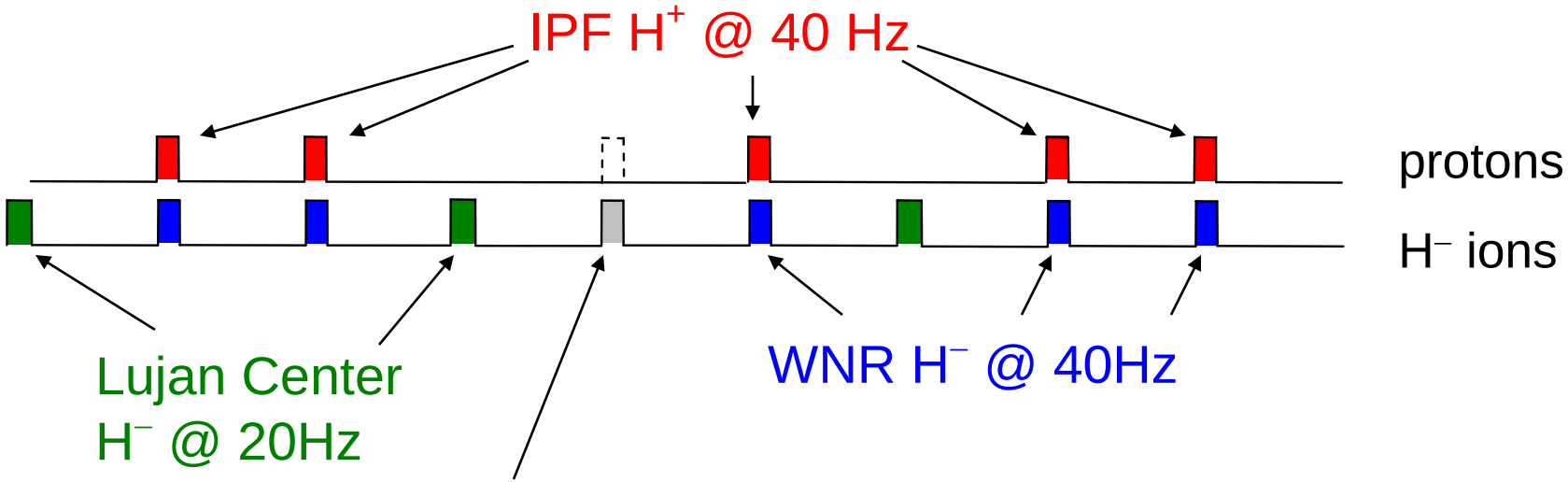
Ion sources are on

Effect on diagnostics:

Current monitors' time constants

AC-coupled amplifiers' time constants

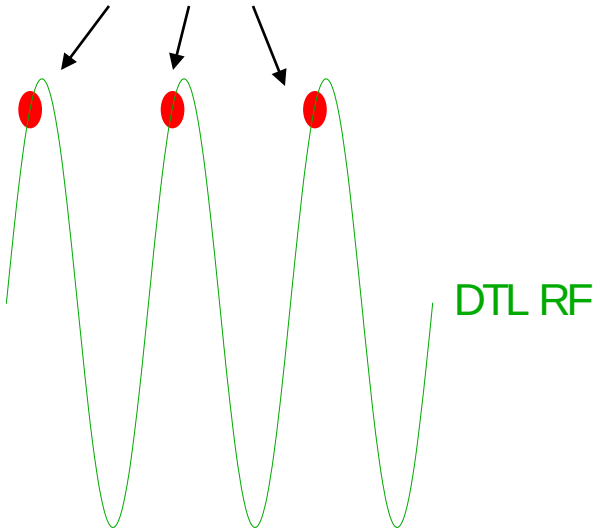
# Beams' time structures: Macropulses & beam "flavors"

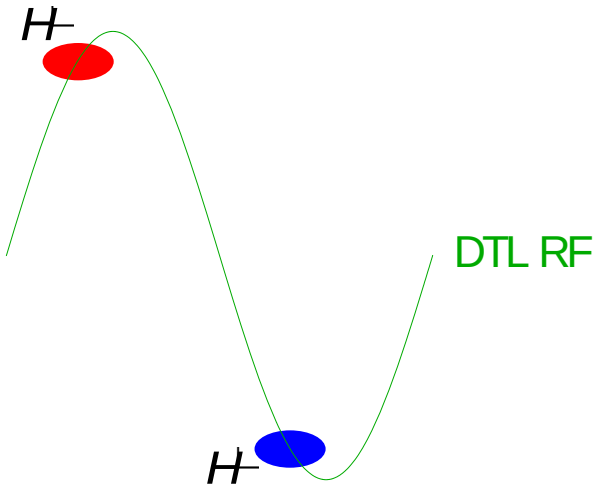



We need to associate measurements with the beam flavor

# Beams' time structures: Micropulses

Beam micropulses *f* = 201.25MHz ~100ps long

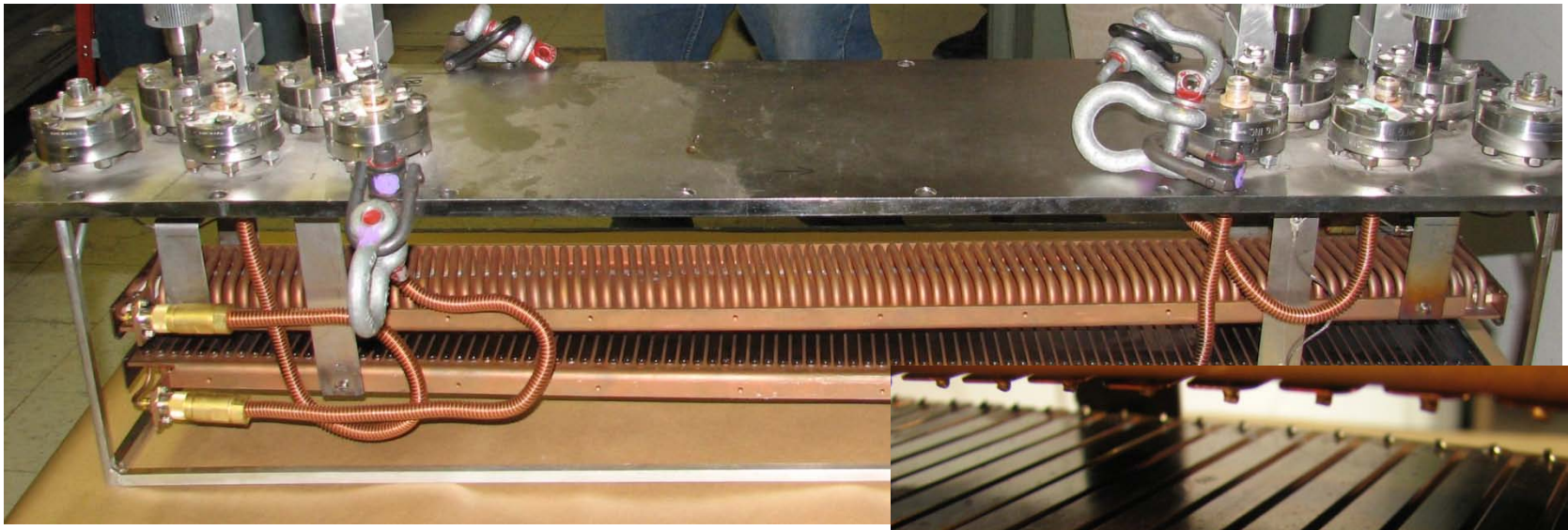



Provides a 201.25MHz signal for diagnostics

# Beams' time Structures: Minipulses

- $H^-$ chopper: Structures at medium timescale (10s of nanoseconds)
- Extraction gap for PSR beam
- Selects micropulses for WNR beam
- Pulse pattern for pRad



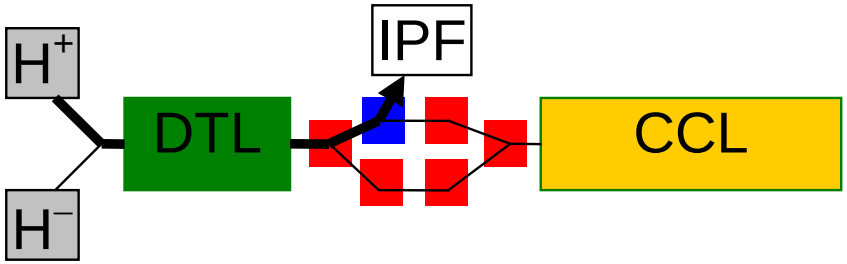

In the 750keV beam transport
(between injector and DTL)

# Beam flavors: Isotope Production Facility

Proton beam to Isotope Production Facility (IPF)

In the DTL only

Presently, no chopper for protons



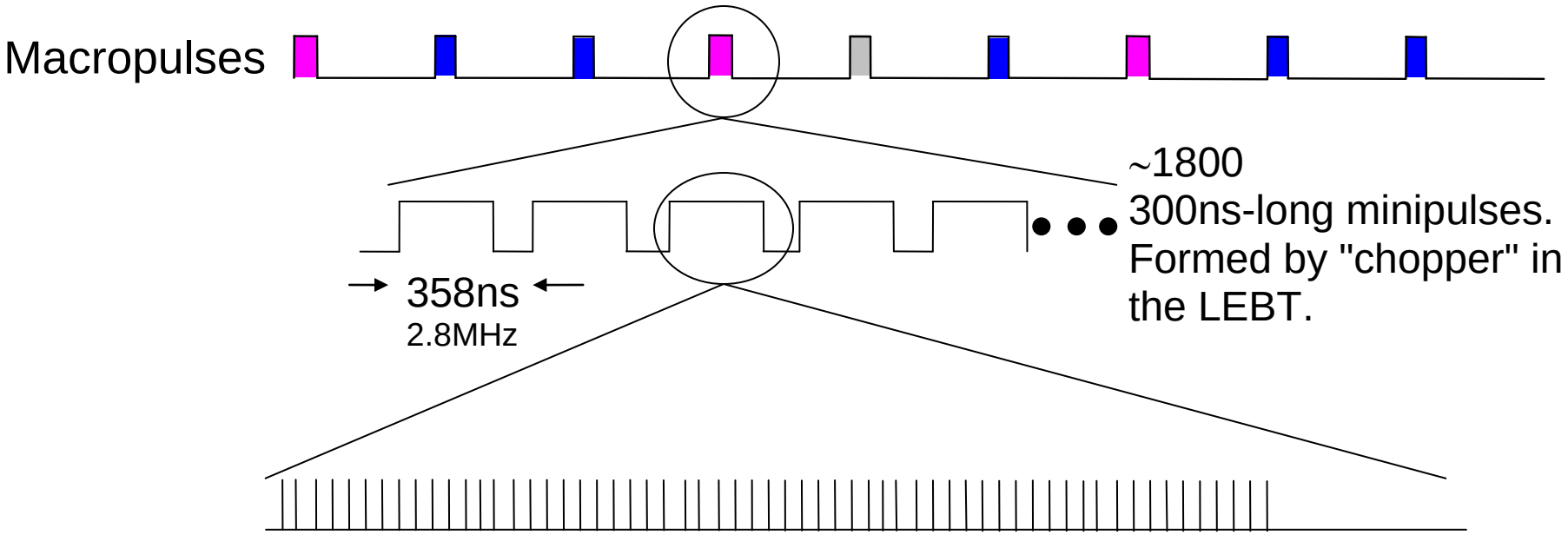

→625μs-long burst of micropulses

About 12mA peak current (a few $\times 10^8$ protons / micropulse)

Possibly in the future: Proton beam to Materials Test Station

800MeV → use DTL *and* CCL

# Beam flavors: Long-Bunch H⁻ Beam to the PSR and Lujan Center

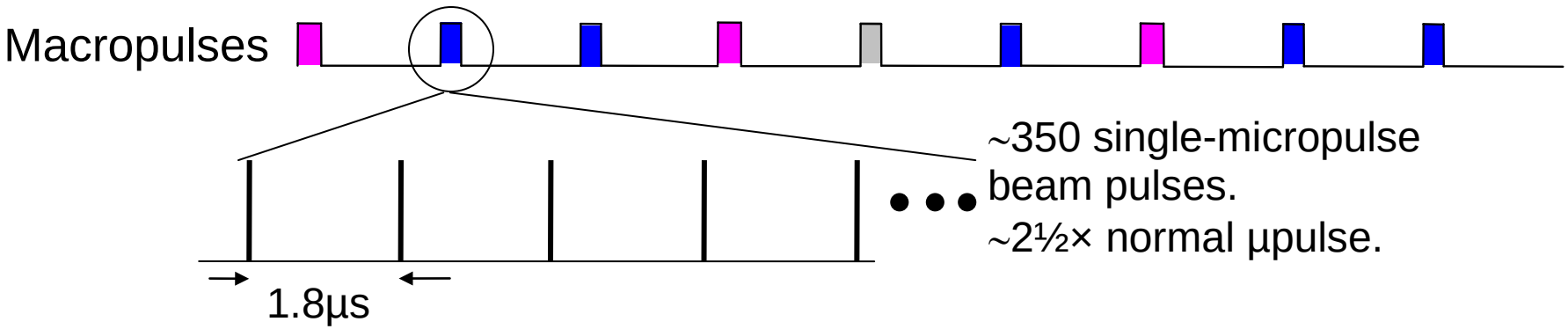



Measurements synchronized with minipulses

Strong 201.25MHz component

CD and PW often modified for minor tune-up.

# Beam Flavors: Single-Micropulse Beam to WNR




Small 201.25MHz component

Protons also present during this macropulse
(in DTL only now, but later…?)

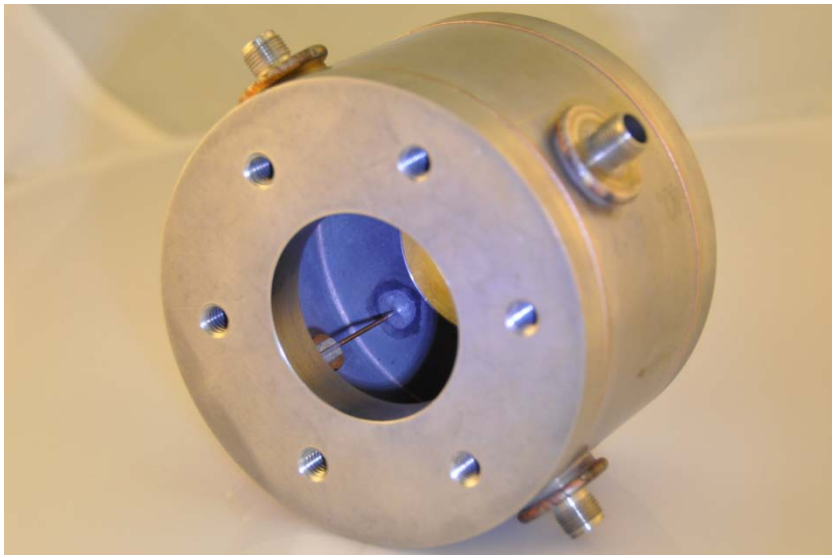
# Diagnostic systems

- **System-wide refurbishments**
  - Beam Position and Phase Monitors
  - Wire Scanners

# Present transducers for beam phase and position

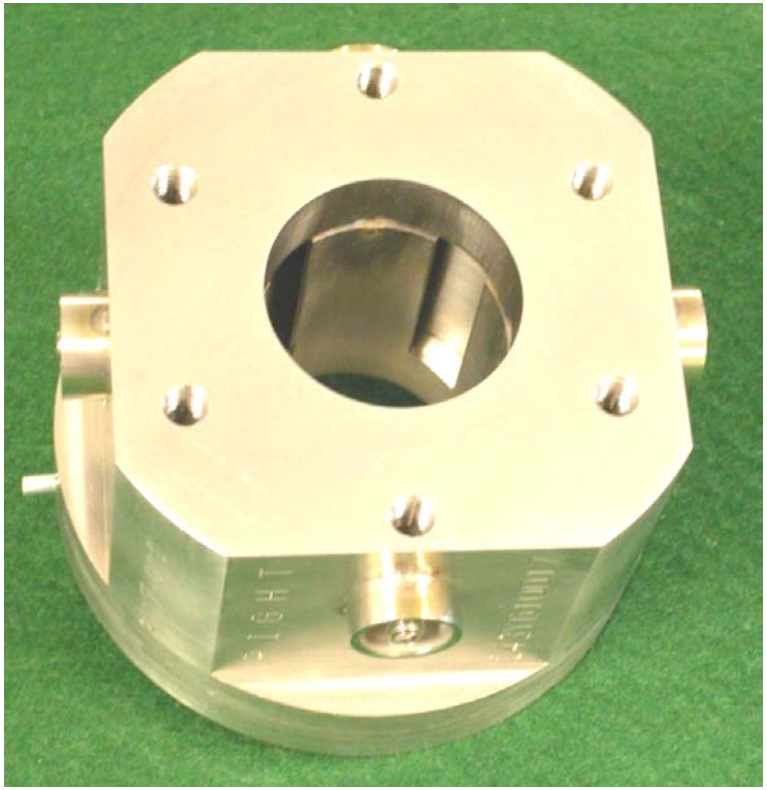
- **Δt loops**
  - Phase measurement
  - Δt procedure does not require absolute phase
  - Presently not useful for chopped beams
  - Sensitivity to beam position

- **B-dot loops**
  - Bad TNC connectors
  - No present system for data



# BPPM – beam position and phase measurement

- **Beam position and phase from one transducer**
- **Reduced sensitivity to beam position for phase measurement**
- **Shorted striplines**
- **Fits in where present BPMs / Δt loops are located**
  - About 7.5cm long
  - Not optimum for 201.25MHz striplines
- **Replace all present Δt loops**
- **Where to put extras**
  - To measure CCL injection position and angle



# Production vs. Tune-up use of BPPMs

- **Tune up:**
  - Measure CCL injection position and angle
    - Is it the same as last year? Long term stability. (Accuracy)
  - RF phase scans
  - Drives requirements on precision & accuracy
- **Production:**
  - Important for tracking problems in other systems.
  - Important for beam optimization
  - Is beam changing during the macropulse?
  - Is MP beam different from LB beam?
  - Is beam changing over the course of seconds or minutes?
  - Where along the machine does a problem start?
  - Drives requirements on bandwidth, synchronizations, flexibility

# Requirements for new BPPM system

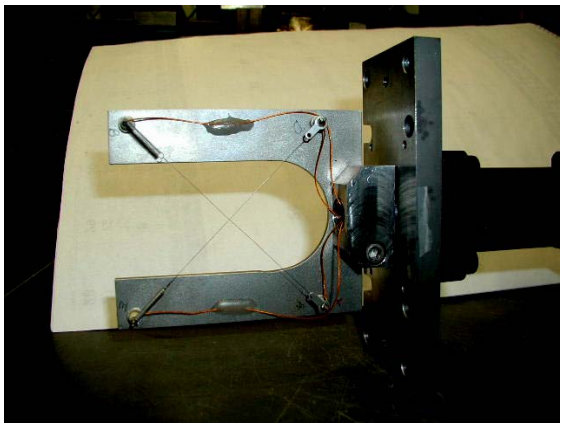
- **Modest requirements on absolute position and phase**
- **Good repeatability**
- **High bandwidth**
- **Long-term stability**
  - Allow steering parameters year-to-year
  - Monitor changes in other systems
- **Measurement of chopped and unchopped beams**
  - Initial tune-up AND operations
- **Measurement per-minipulse, per-macropulse, etc.**
- **Easily upgradable to single-micropulse measurement**
  - E.g. by adding transversal filters
- **Data rates**
  - Per-minpulse vs. per-macropulse or time-vector
- **Analog monitor signals**

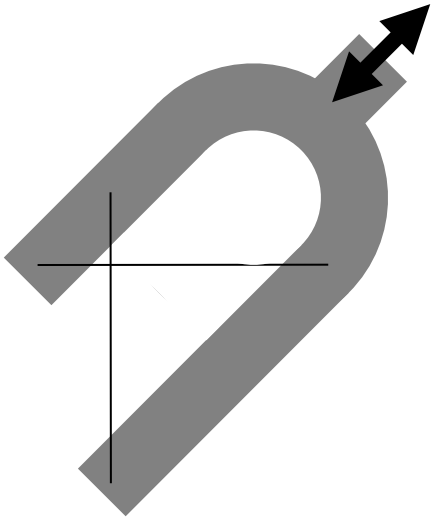
# BPPM requirements

| Parameter | Value |
|---|---|
| Frequency of Measurement | 201.25 MHz |
| System Response Time | 50 ns |
| Averaging Window for System Resolution Specifications | 100 μs |
| Position Resolution (% of radius, RMS) | 0.46 (0.1mm) |
| Position Accuracy (% of radius) | ±4.6 |
| Position Range (% of inner electrode radius) | ±60 |
| Phase Resolution (RMS) | 0.25° |
| Phase Linearity | ±2° |
| Beam Current Resolution (RMS) | 0.05 mA |
| Beam Current Accuracy | N/A |
| Beam Current Range | 0.9 to 21 mA |
| Timing Uncertainty | ±50 ns |

# Wire Scanners – beam profile measurement

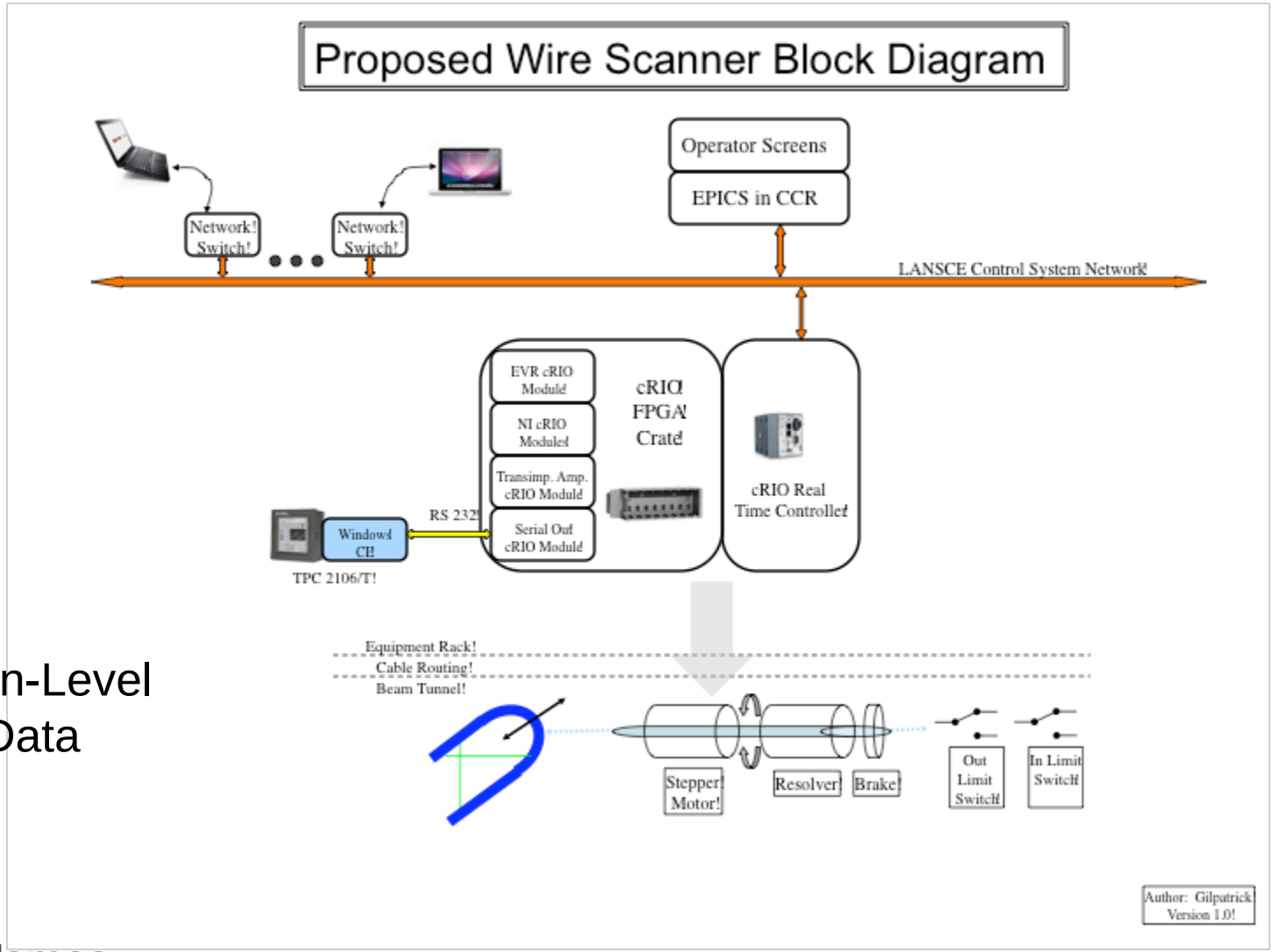
- **Linac and Switchyard**
- **Linac: 125μm Tungsten wires – beam spill (0.002 nuclear collision length)**
  - Presently not useful during production
- **Switchyard: 100μm SiC fibers**
  - Mostly useful in production
- **Also affecting beam spill per scan: speed**
- **Many in the linac will be removed**
- **Provide beam phase space reconstruction and matching (show examples)**
- **RMS beam spot size: a few mm**
- **Scans are run from a centralized computer**
  - Lots of slow communication
- **Crossed wires : H ↔ V crosstalk**





# Wire-scanners

- **Complete system replacement**




Scan-Level Data

# Wire Scanners Requirements

- **Beam spill is the major factor in production**
  - Thin, Low-Z wires
  - Fast scans
    - Local device-level computer runs a scan
    - Actuator velocity profile
- **Data collected at particular time in macropulse**
  - Will probably provide waveform data
  - 10μs steps
- **No other synchronization needed**

# Wire-Scanner Requirements

| Parameter | Value |
|---|---|
| Sensing Wire or Fiber Materials | SiC, W, or C |
| Sensing Wire or Fiber Diameters (mm) | <0.15 |
| Minimum Distribution Horizontal or Vertical Width, rms (mm) | 1.0 |
| Minimum Projected Distribution Bin Width (mm) | 0.1 |
| Typical Minimum Beam Macropulse Length (μs) | 150 |
| Typical Repetition Rate (Hz) | 4 |
| Minimum/Maximum Peak Secondary Electron Emission Current (μA) | -1/-2000 & +0.01/+500 |
| Distribution Minimum Peak-to-Edge Ratio | 100:1 |
| Amplifier Response Time Constant (μs) | ~10 |
| Maximum Sampling Rates within a Single Macropulse (MS/s) | 0.1 |
| Linear Peak Actuator Velocity, under Closed Loop Control (mm/s) | >8 |
| Wire Location Repeatability or Precision (% rms distribution width) | <10 |
| Absolute Wire Location Accuracy (mm) | 1 |
| Peak Beam Current Range (mA) | 21 to 0.9 |
| Timing System Resolution (ns) | ~ 100 |

# Other diagnostics – Not in the scope of LANSCE-R

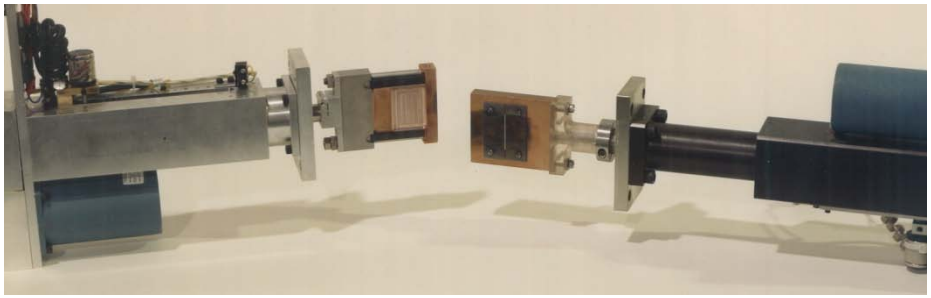
New interfaces to the control system are need for

- Slit / Collector Beam Phase Space Measurement
- Harps (Multi-wire profile monitors)
- Absorber / Collectors
- Beam Current Monitors
- Beam Loss Monitors
- Collimator Currents

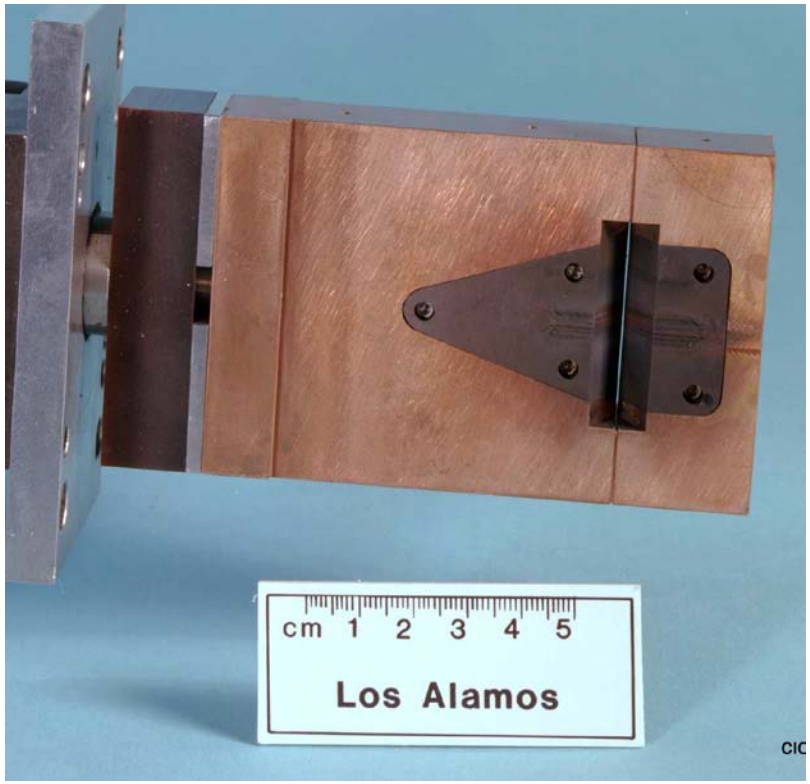
Turn “signals” into “data”

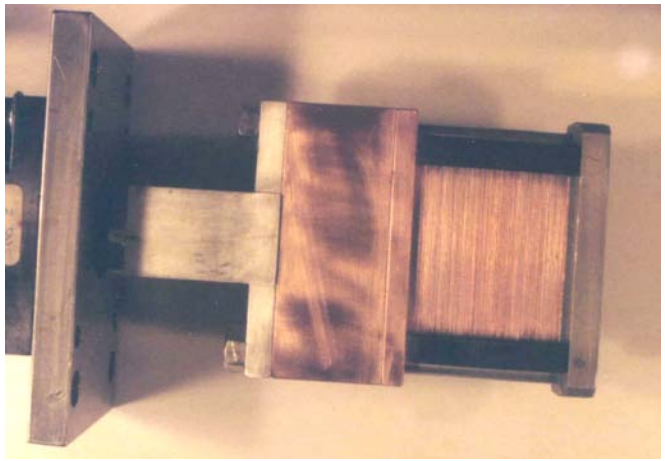
# Slit-Collector emittance stations and harps

- **No replacement of this "system" but replacement of RICE requires new A-D and data systems.**
- **High bandwidth**
- **Timed data**
- **"Multiplexed"**
- **Many wires; each will need amplifier and digitizer**
  - 10 devices
  - 76x2 wires each
  - 4 motors each



# Slit / Collector Beam Phase-Space System

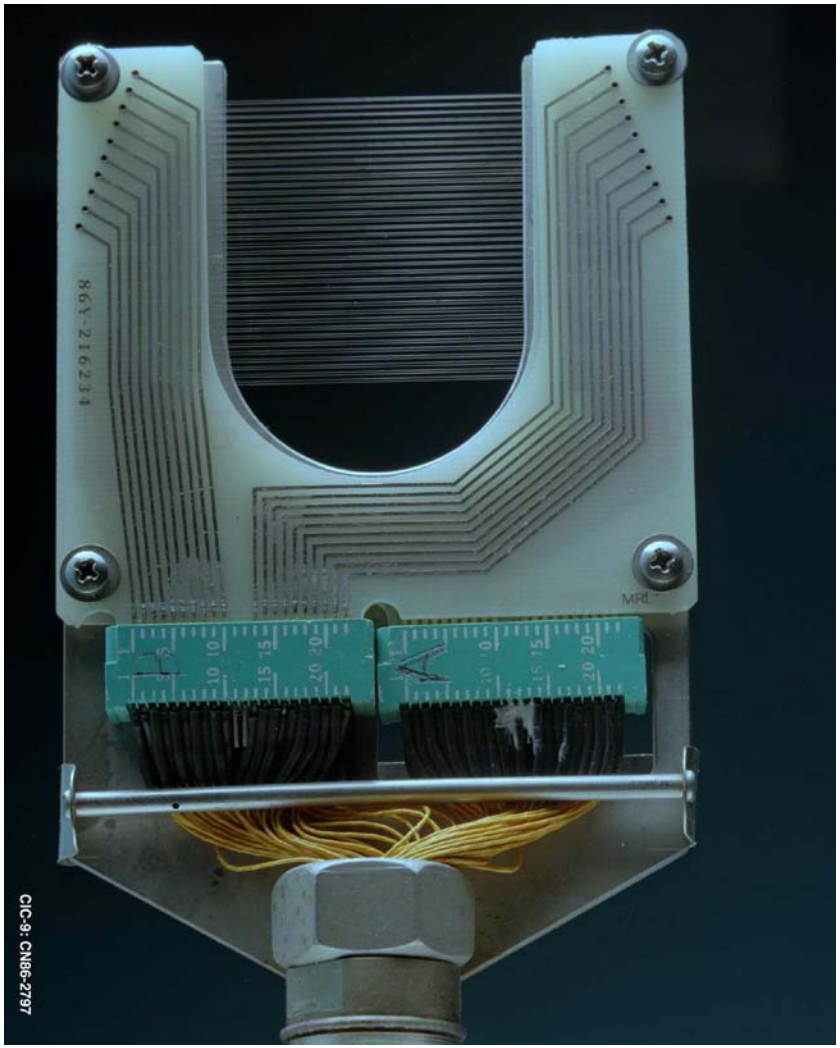


- New system:
- ADCs, Motor driver controls, Timing
- Scan-Level Data
- Still multiplexed (at first…)

# Harps

- **17 of these systems**
- **Same multiplexed electronics as the Slit/Collector system**
  - 76 x 2 wires each

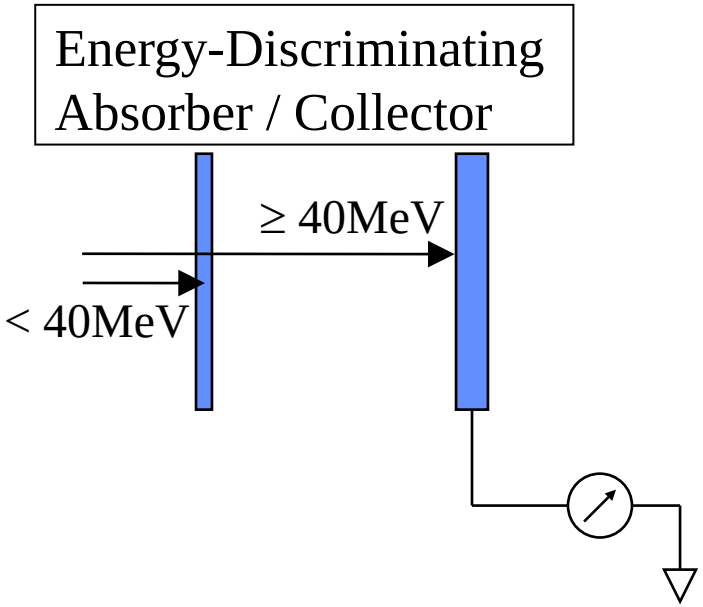



Eventually, move toward non-multiplexed system for slit/collectors and harps

4100 signal channels

74 motors

# Absorber / Collector systems




**For setup of 201MHz RF**

**Systems at: 40, 72, 100, 121 MeV**

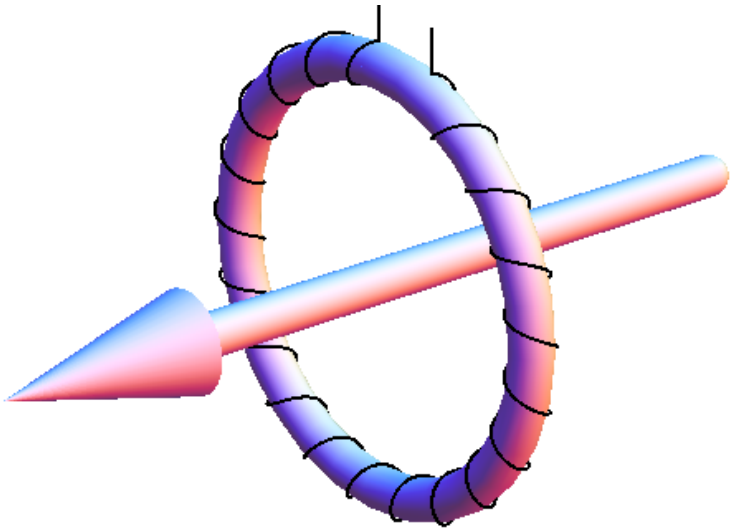
**New System:**

**Insert / Retract control**

**ADC for 2 currents**

**No scan-level data**

# Other Diagnostics



- **Beam Current Monitors**
  - New A-D system
  - High-gain / low-gain signals from amplifie
  - Timing signals (get a schematic)
  - Inter-device synchronization
- **Beam Loss Monitors**
  - Slow signals
    - Beam optimization
    - Beam flavor specific
    - ADCs, timing, HV controls
  - Fast signals
    - Troubleshooting
    - Waveform-type data
    - Inter-device synchronization

# Summary

- **LANSCE refurbishment project requires a close look at how we use diagnostics**
  - Tune-up vs. production ops
  - Beam optimization vs. trouble-shooting
- **Three systems will be replaced**
  - Beam Phase
  - Beam Position
  - Beam Profile (Wire-scanners)
- **Control system will be replaced**
  - Other diagnostics' interfaces need replacing
- **LANSE-R is large and complex**
  - Many Managers, Administrators, Engineers, Scientists, Technicians
  - Thank you to them

Thank you for listening