Los Alamos NATIONAL LABORATORY

LANSCE Digital Low Level RF Upgrade Overview

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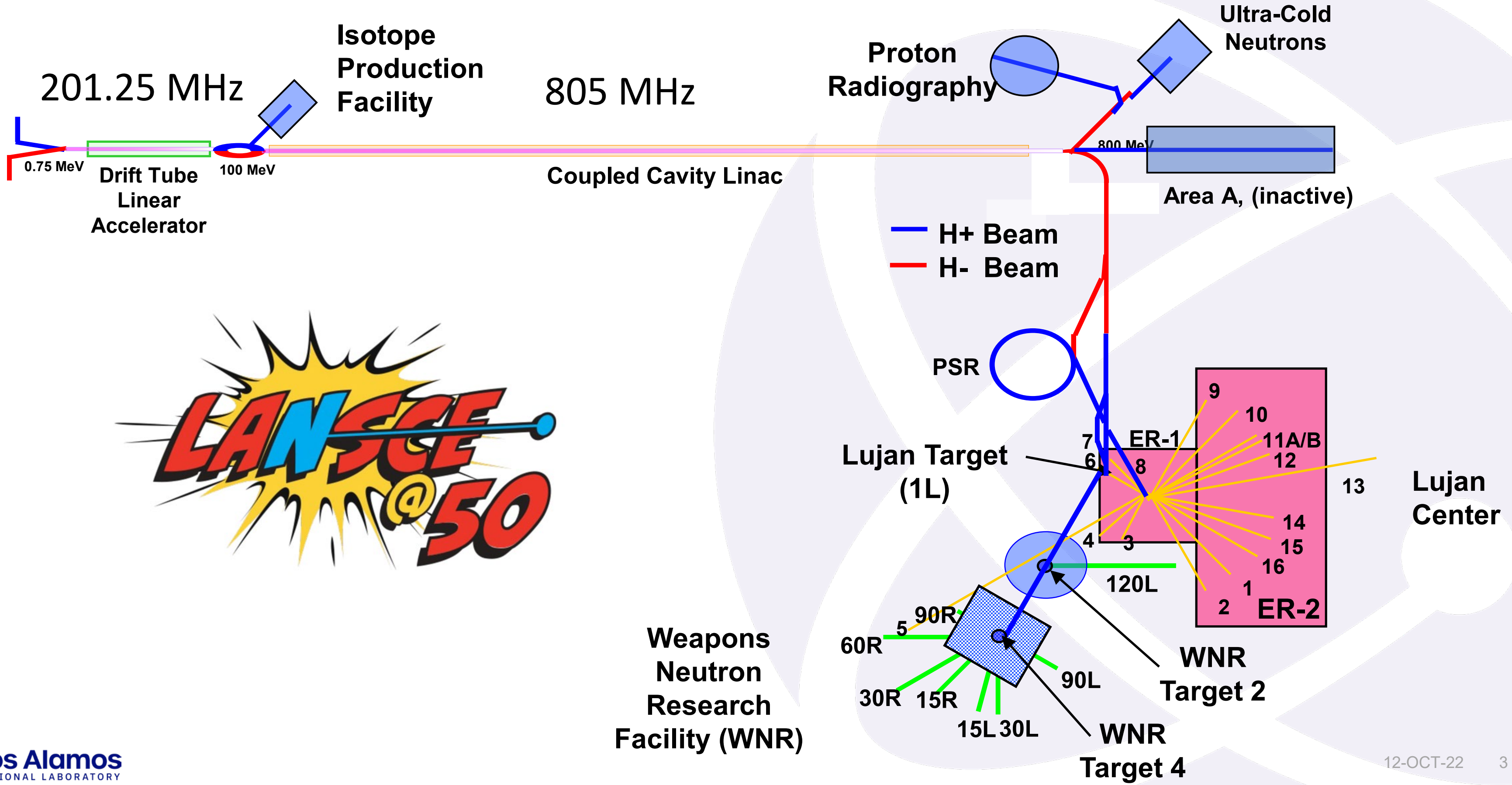
Overview

- Overview of LANSCE
- Analog LLRF
- Digital LLRF

LANSCE


201.25 MHz
Isotope Production Facility
805 MHz
Proton Radiography
Ultra-Cold Neutrons
0.75 MeV
Drift Tube Linear Accelerator
100 MeV
Coupled Cavity Linac
800 MeV
Area A, (inactive)
H+ Beam
H- Beam
PSR
Lujan Target (1L)
ER-1
ER-2
Lujan Center
120L
WNR Target 2
WNR Target 4
Weapons Neutron Research Facility (WNR)
90R
60R
30R
15R
15L
30L
90L
1
2
3
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11A/B
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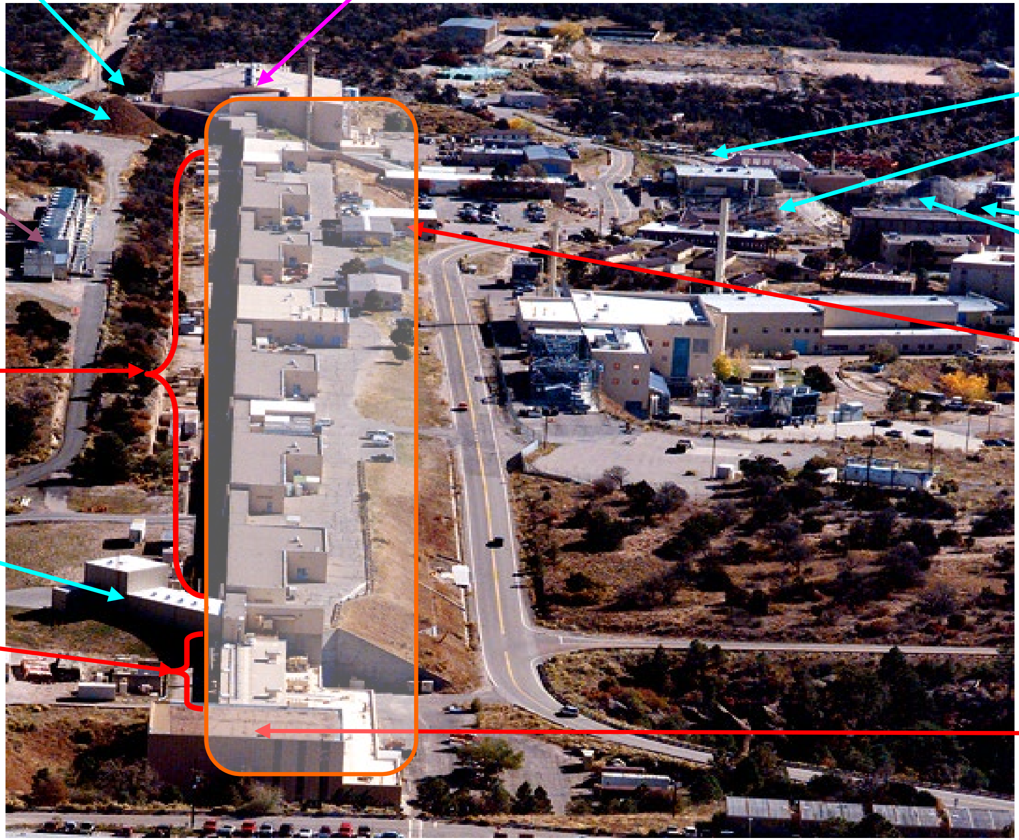
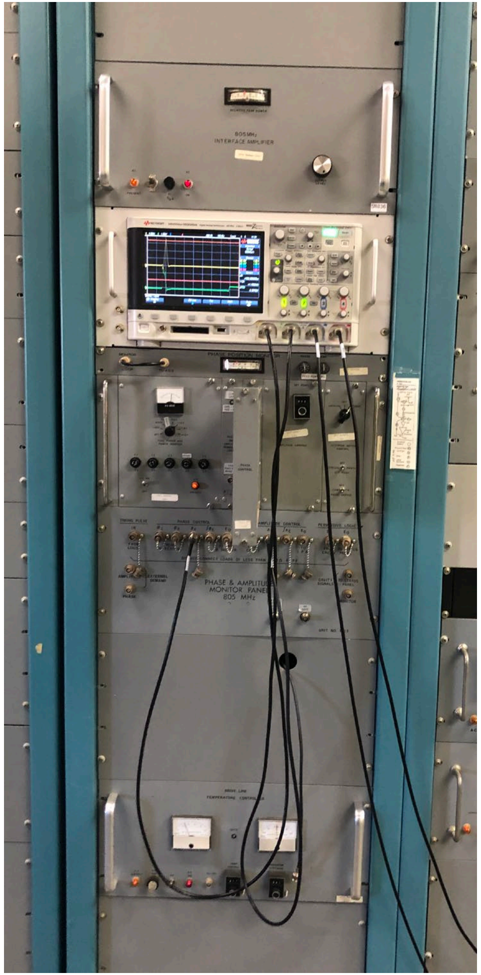
LANSCE
@50

Los Alamos Neutron Science Center Facility



Analog LLRF System

- Originally designed in the late 1960s and early 1970s
  - Production started in1972
- No major upgrades for LLRF until the digital LLRF upgrade began in 2015
- Becoming increasingly difficult to source parts and maintain the systems
- A lack of flexibility and adaptability for new high-power systems
- Lack of remote data about system status

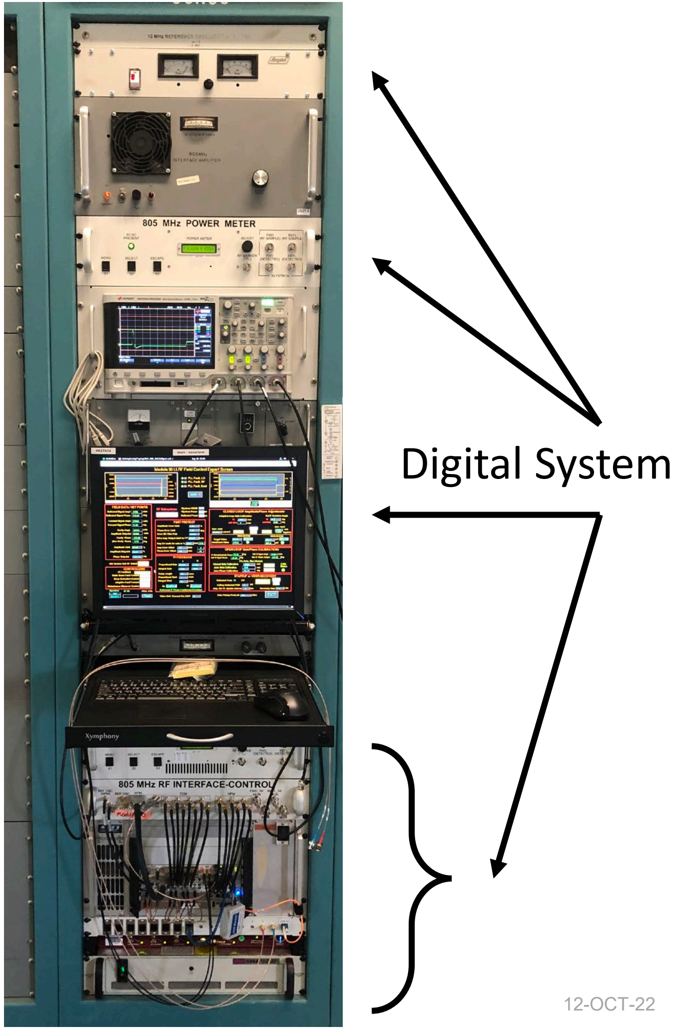


Status of digital LLRF systems at LANSCE

- Upgrade from original analog systems to modern digital LLRF systems
- First systems were operational in 2015
- As of 2022, 30 of the 53 systems have been upgraded
- Scheduled to finish upgrade by end of 2024
  - Proton Storage Ring
  - Low Energy Beam Transport
  - Remaining 805 MHz Systems

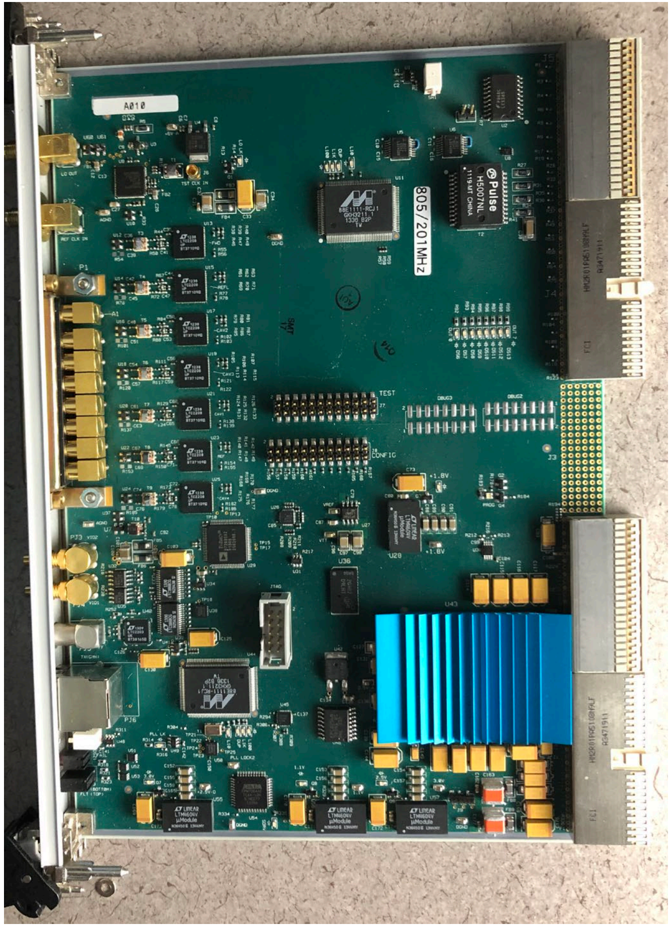
Digital LLRF System

- Greater flexibility
- Data available over EPICS
- Integrated with legacy analog systems
- Ability to adapt to one-off systems
  - Module 1
  - Low Energy Beam Transport (LEBT) Bunchers
  - Proton Storage Ring Harmonic Buncher
  - Low Frequency Buncher

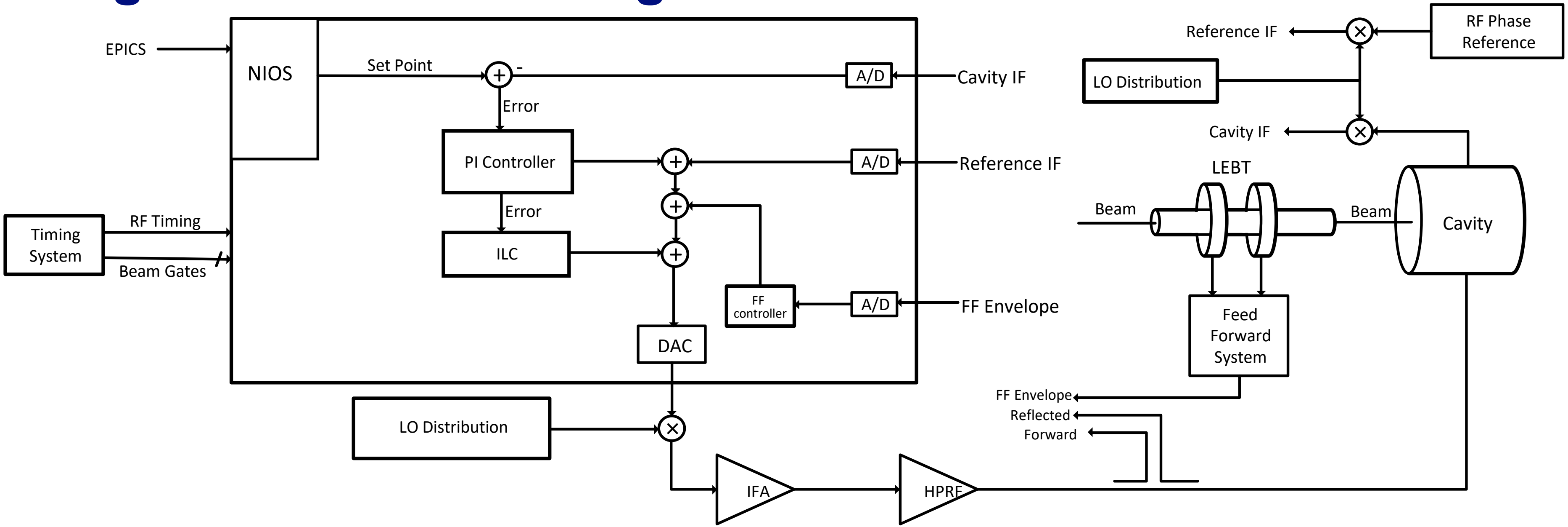


Digital LLRF System

- Version One
  - Altera Stratix 3 using NIOS 2
  - IF based 100.625 MHz sample rate I/Q
- Version Two
  - Intel Arria 10 using NIOS 2
  - IF or RF based, variable sample rate I/Q
- Platform: cPCI and direct network
- Uses RTEMS

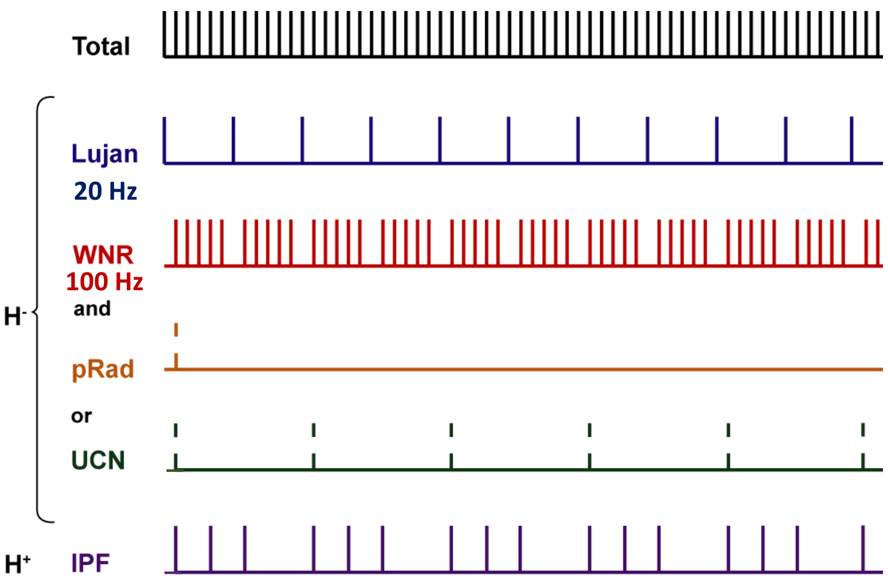


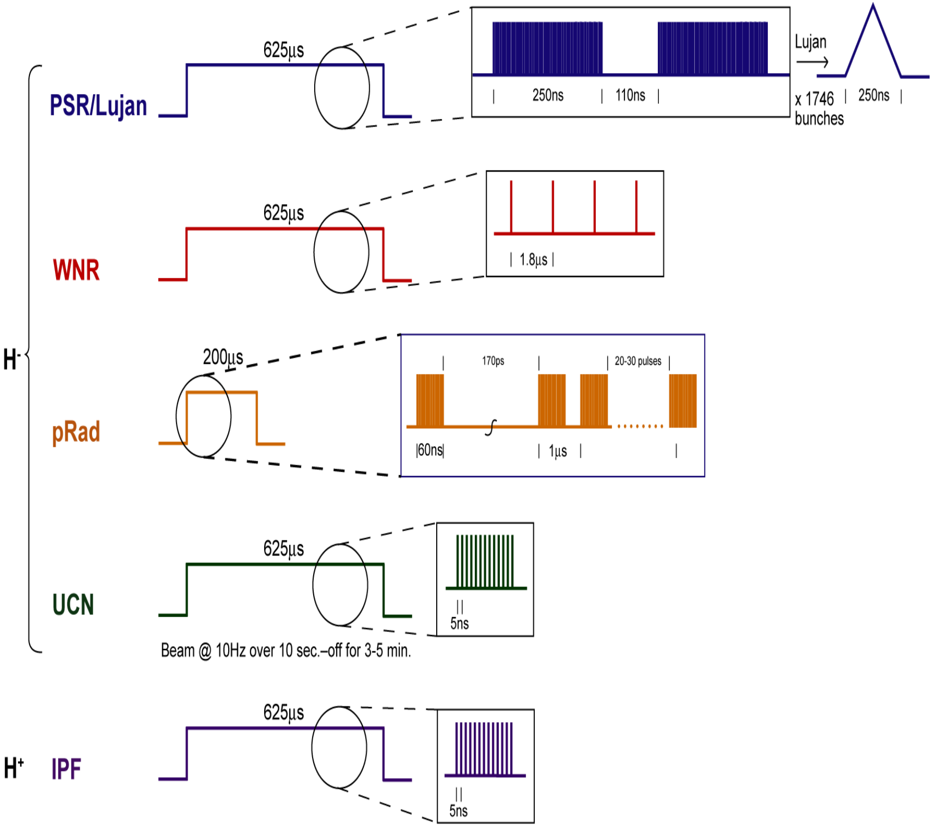
Digital LLRF Block Diagram



Simultaneous Multi-Energy Beam Operations

- LANSCE has multiple user facilities that require differing rates of beam delivery
- Requires multiplexing individual beams into the 120 Hz timing structure
- Have the capability to operate at different energies on a pulse-to-pulse basis by delaying individual RF stations
  - delivered beams from 256 MeV up to 800 MeV with gradation of approximately 10 MeV
- RF modules are able to also perform a bunching capability for the low energy beams to maintain beam integrity throughout the long drift spaces of the LINAC





LANSCE delivers:

- Up to 120 beam cycles per second each of length of 625-825 microseconds, with single pulse capability of 1225 microseconds
- Within each cycle 1 nanosecond beam micro-pulses with a minimum separation of 5 nanoseconds
- 20 Hz are dedicated for the Lujan Center
- 40-100 Hz are available for multiplexed use by pRad, WNR, IPF, UCN
- IPF (H+) and WNR (H-) share machine cycles
- pRad and UCN “steal” on-demand machine cycles from WNR

Digital LLRF System Adaptability

- Was demonstrated with 201.25 MHz DTL Tank 1 upgrade in 2021
  - Need for the Disturbance Observer Controller added as an after-thought
  - Completely different performance of the cavity from the circulator
  - Different timing
- All RF front end circuit boards are located within one chassis, the RF Interface Control chassis (RFIC)
  - See poster #29 this afternoon
- Future upgrade: direct RF conversion at 201.25 MHz and 805 MHz
- The LEBT will now have phase and amplitude set points for each beam type
  - Improves beam capture especially when running H- and H+

Adaptive Feed Forward System

- Individual feed forward settings for each beam type
- Offers flexibility that the analog system could not
- Uses an iterative learning technique to accurately adapt to the particular transient response of the RF cavity for each beam

Digital LLRF System Controls

- Disturbance Observer Controller
  - Used at Module 1 to compensate for of the Phase Drift of the Solid State Power Amplifier
  - See poster with ID #71
- Under development and test
  - Frequency Agile Controller
  - Automatic Digital LLRF Turn On
- Also see poster with ID #73

Future

- Los Alamos Modernization Project (LAMP)
  - New RF driven beam source
  - RFQs for beam bunching
  - New DTL, reuses HPRF systems
  - For LLRF: RFQ controls, increasing the number of DTL controls, control system for RF Source
  - Current status is CD-0 by the end of 2022
- 23 digital systems to be installed including the remaining systems:
  - 18 805 MHz modules
  - Proton Storage Ring Harmonic Buncher
  - Four Low Energy Beam Transport Bunchers

Thank you!

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Many thanks to my colleagues and the LLRF team at LANL.