



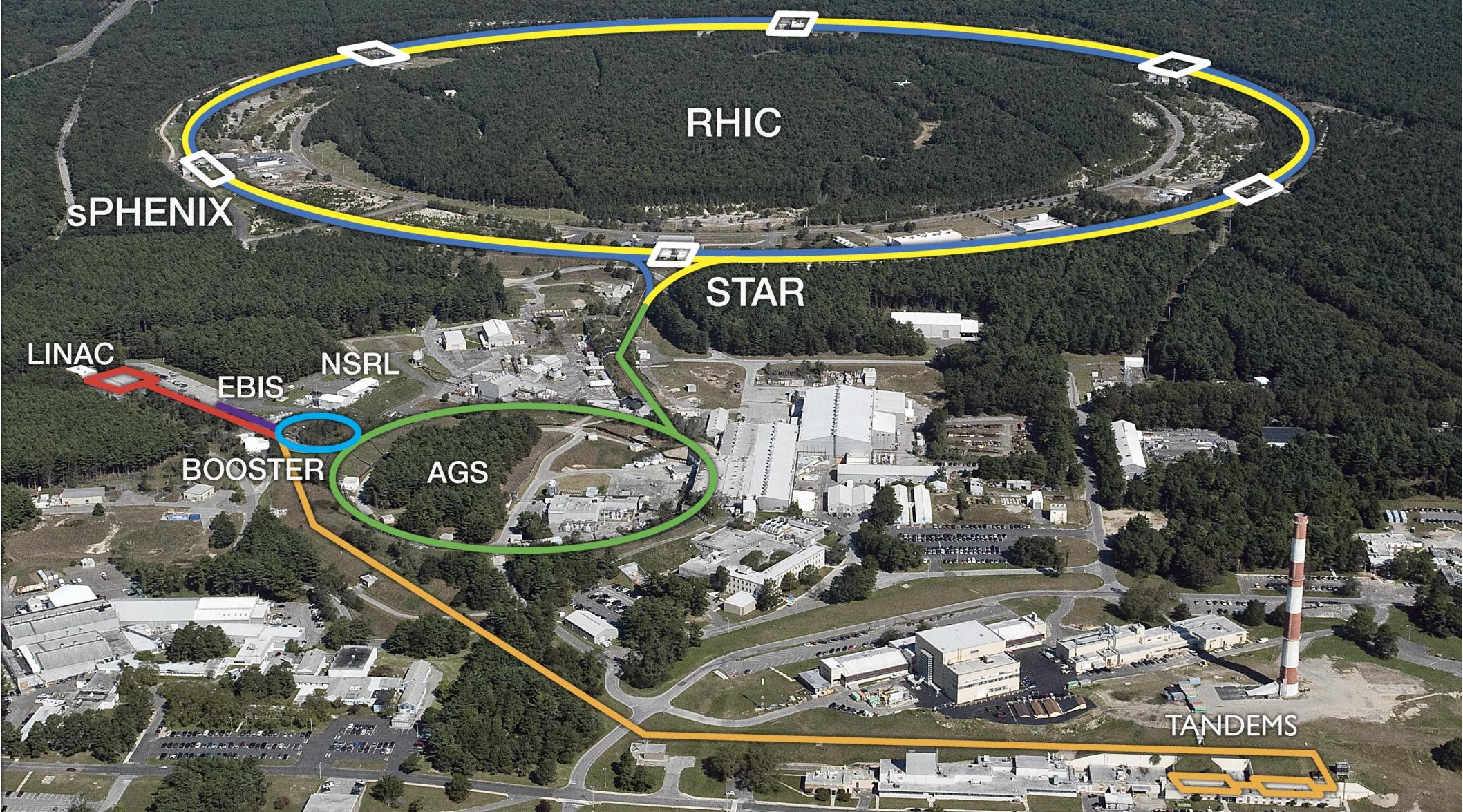
Status and Activities for LLRF at BNL C-AD and EIC

Kevin Mernick
for the BNL C-AD & EIC LLRF Groups

13 October 2025

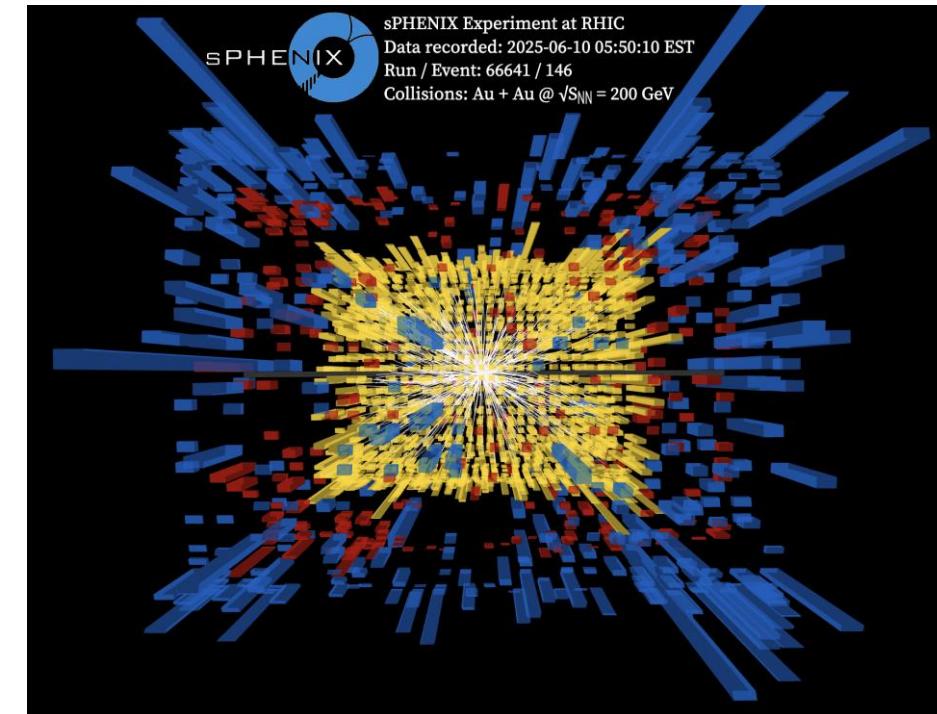
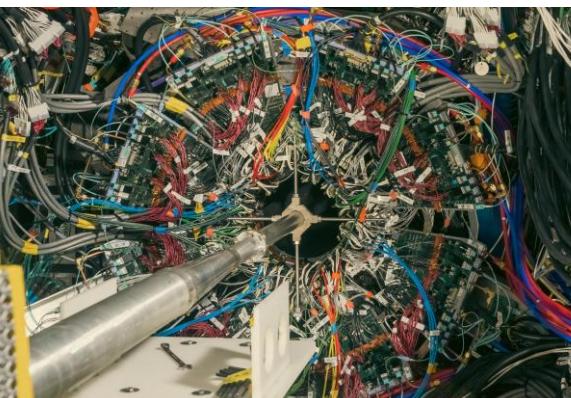
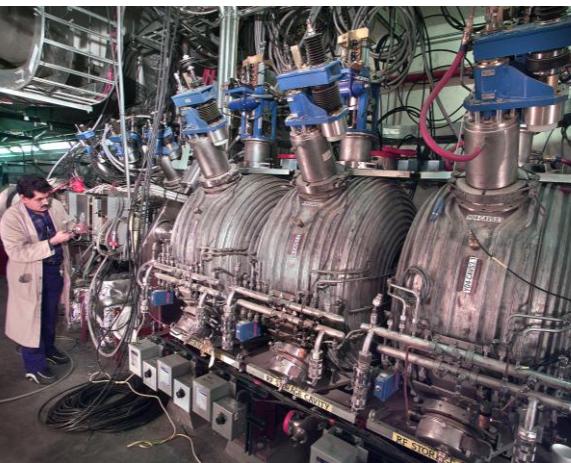
X @BrookhavenLab

Collider-Accelerator Complex

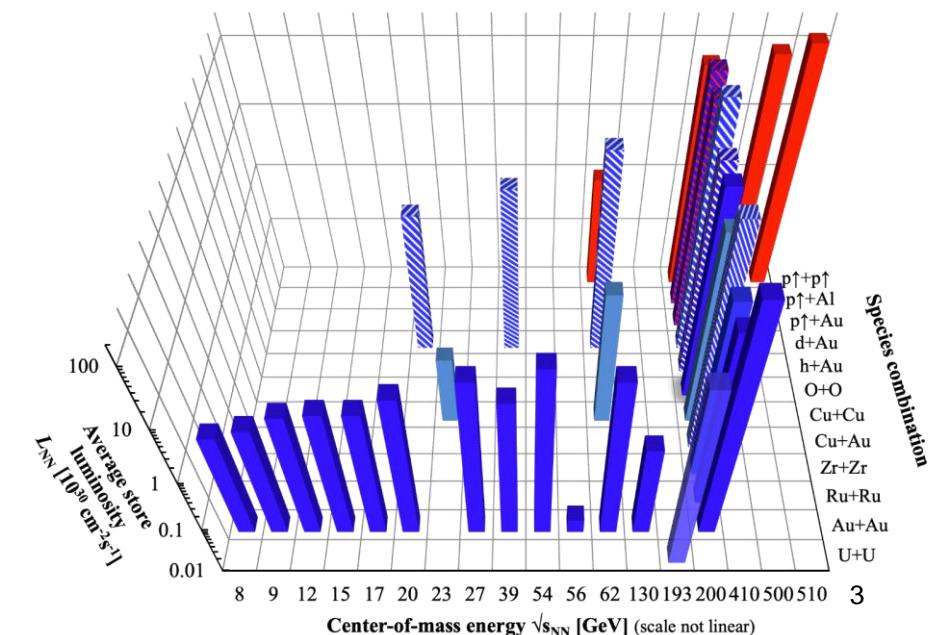


RHIC Operations

- We are in the 25th and final year of RHIC operations
- Since the last time we presented about RHIC (LLRF 2019)
 - 2020 – 2021: completed Beam Energy Scan II (15 different energies, <1 day to 117 days run time for each) plus O-O and d-Au
 - 2022: 255 GeV polarized protons
 - 2022: complete sPHENIX installation
 - 2023: 100 GeV Au
 - 2024: 100 GeV polarized protons
 - 2025: 100 GeV Au
- Injector operations outside of RHIC running periods to support the NASA Space Radiation Laboratory (NSRL) and Brookhaven Linac Isotope Producer (BLIP)



RHIC energies, species combinations and luminosities (Run-1 to 24)

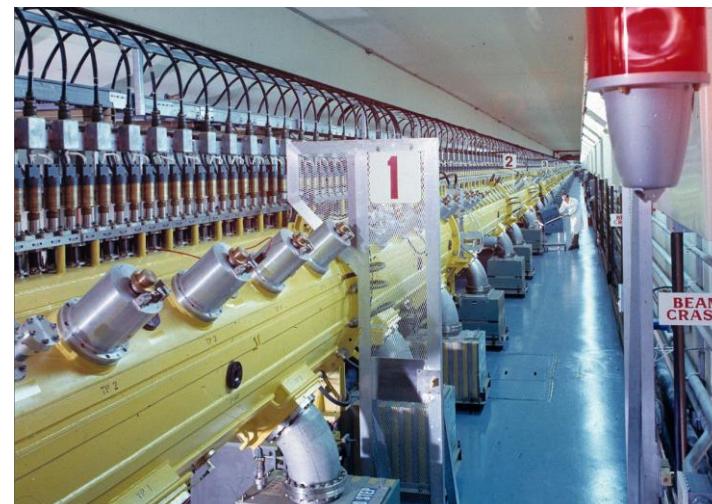
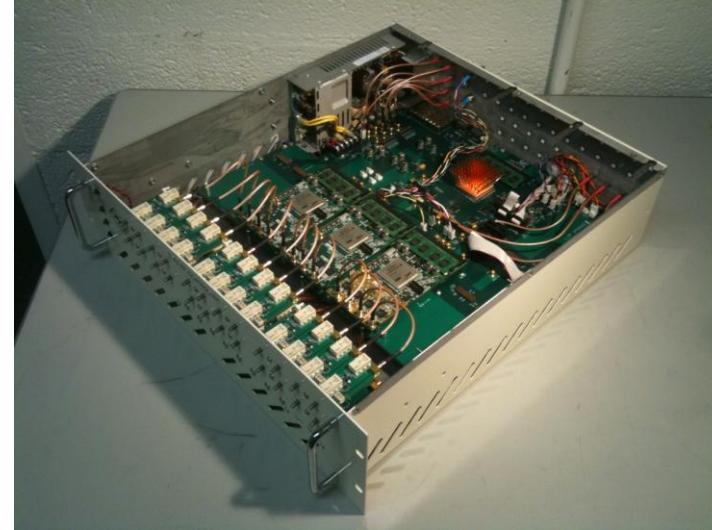


LLRF Operations

Our aging, but still capable, C-AD LLRF Platform is used in all operational accelerators and RF test facilities

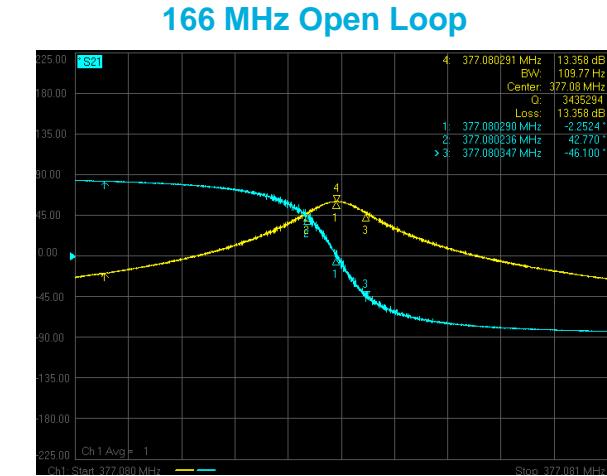
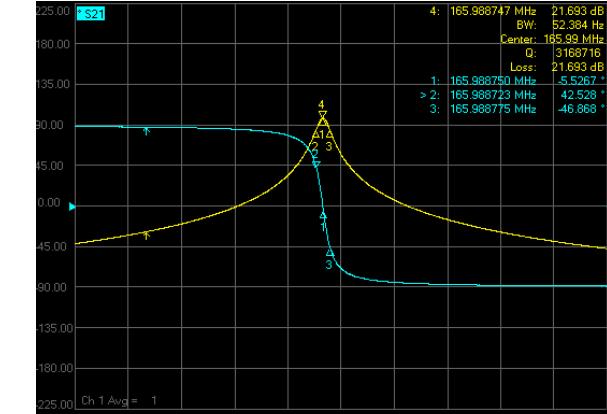
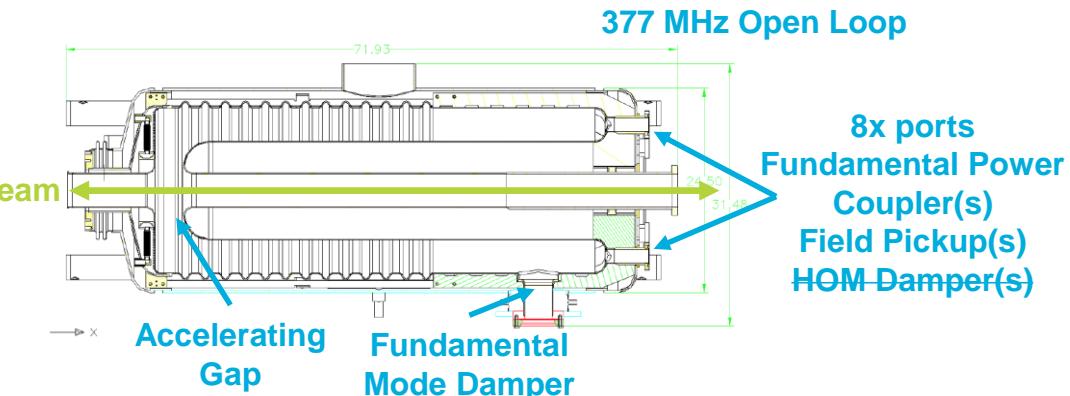
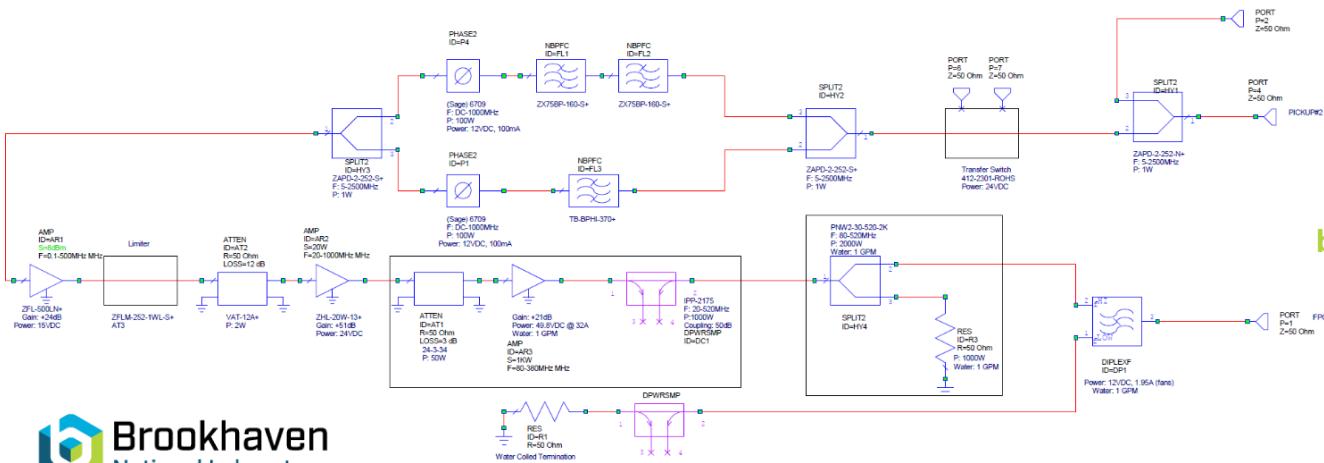
- Conceptual design first presented at LLRF05
 - Prototyping 2007-2009, first operation 2009
 - Roll out to all machines 2010 – 2015
 - Feature enhancements, new applications (electron cooling), operational efficiency, etc.
- 2015+

Nearly 100 chassis installed in operational systems. Retirement of RHIC systems will provide spares for the injector complex for the foreseeable future.

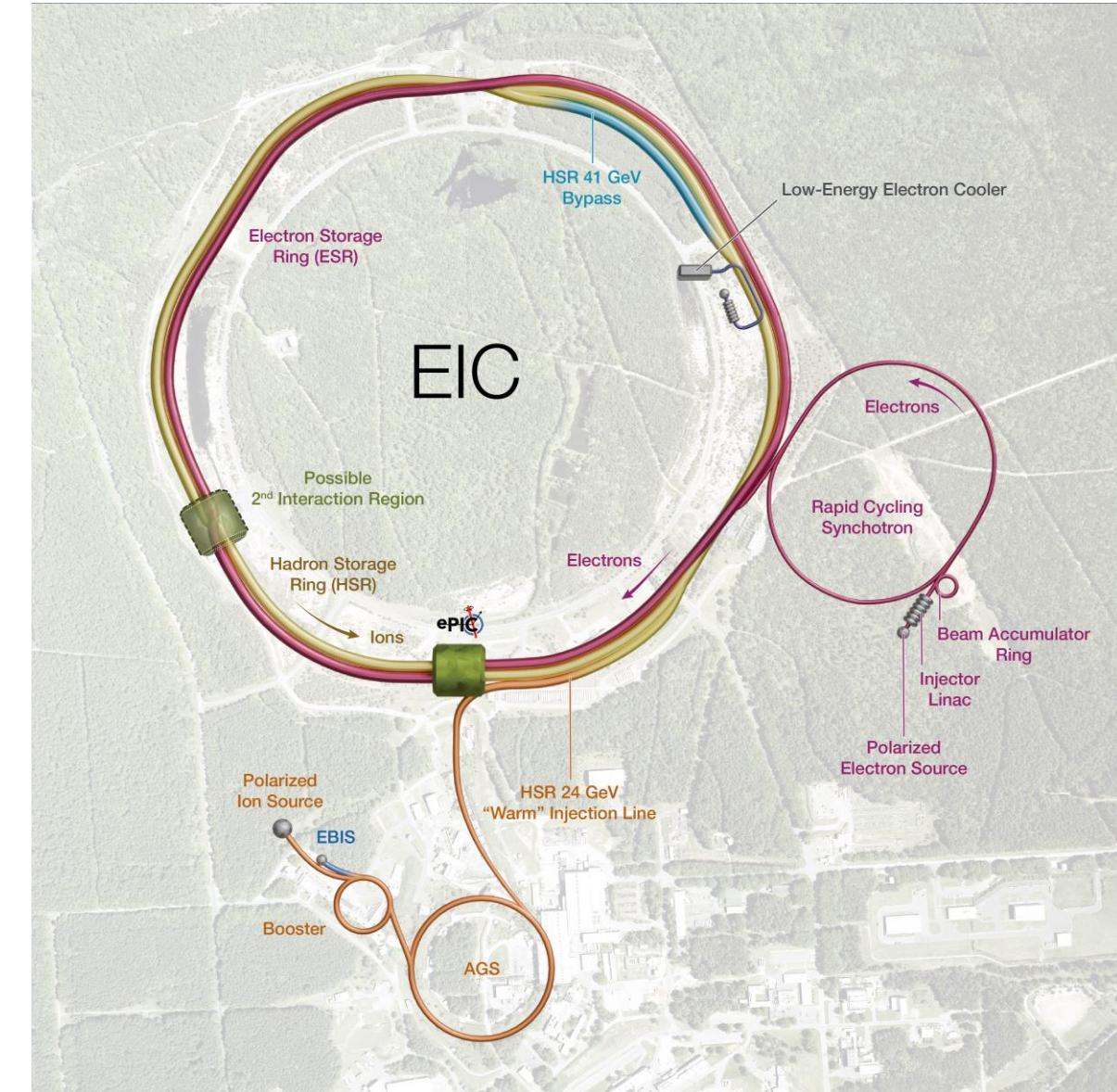
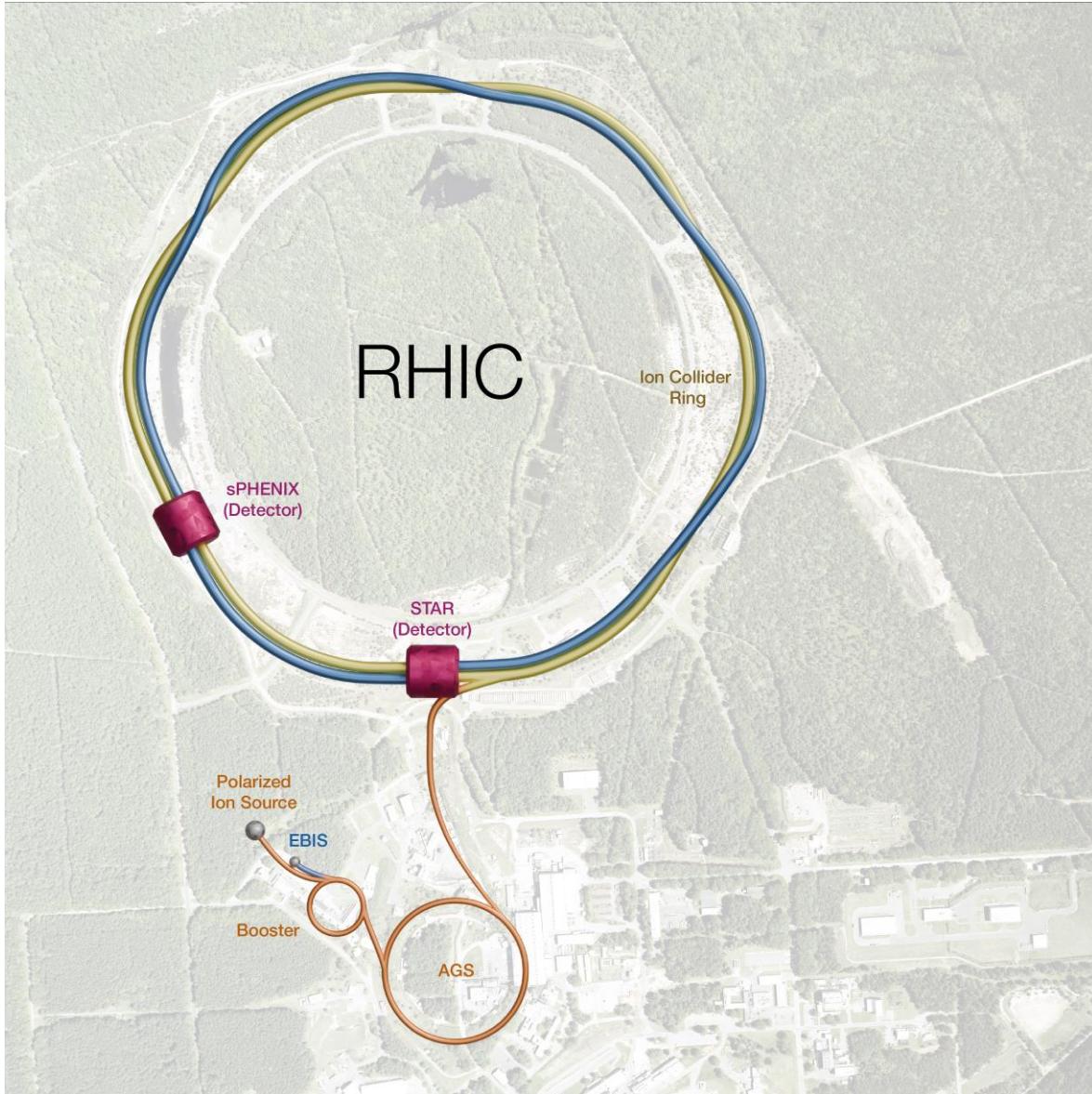


56 MHz QWR SRF HOM Active Damping

- Cavity HOM dampers never worked. Combination of FMD and FPC were used to lower Q_{ext} of HOMs, at the expense of high power dissipation at the fundamental frequency.
- For 2025, developed direct RF feedback to reduce impedance of 166 MHz and 377 MHz HOM modes.
- Also developed ‘multi-harmonic’ processing in 4 channel ADC board to monitor 4 different HOM frequencies per RF channel.



Electron Ion Collider

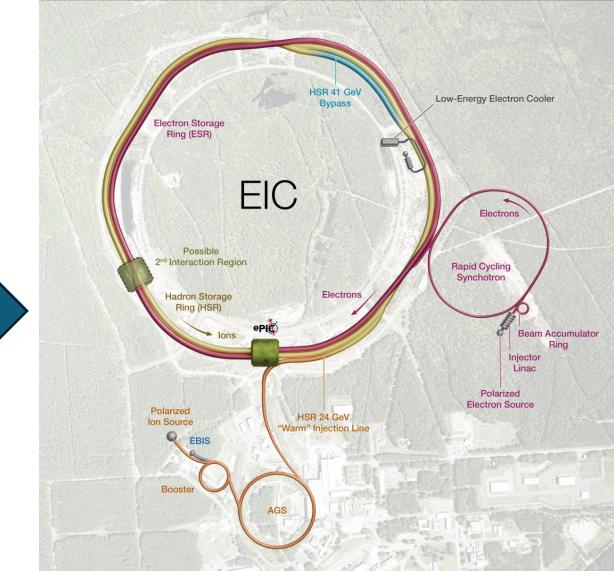
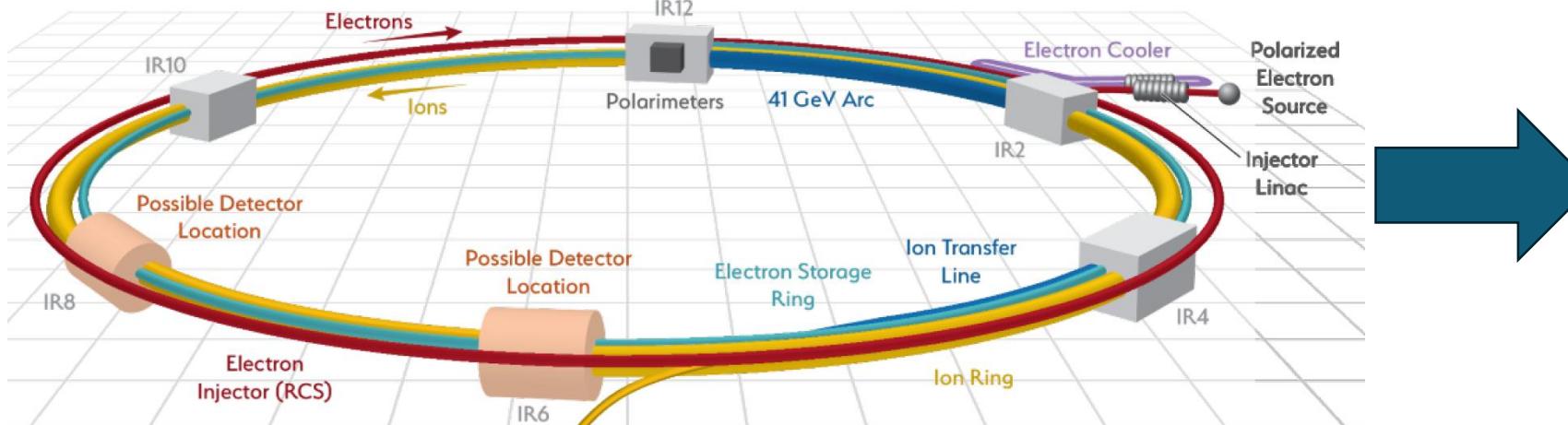


EIC Accelerator (RF) Design



Geetha Narayan, "Overview of Electron Ion Collider RF Systems,"
this afternoon @ 3:15

- Updates since we last presented at LLRF2022
 - Machine design (electron injector, hadron cooling, ...)
 - LLRF design progress



EIC Crab Cavities



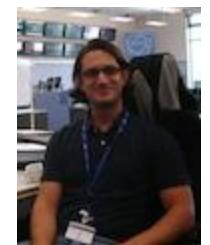
Freddy Severino, “Low-Level RF System Development for EIC Crab Cavities,” Wednesday morning

- LLRF system architecture and control scheme
- Hardware development status and roadmap to implementation

Also

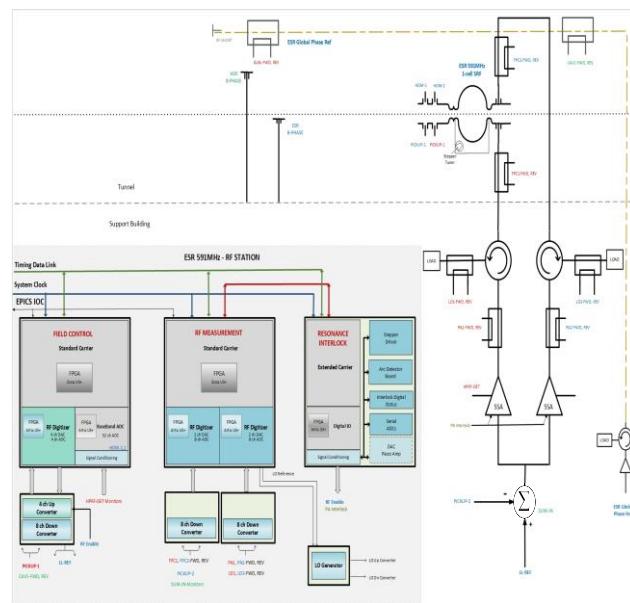
Themis Mastoridis, “Crab Cavity Low-Level RF in hadron machines,” today, after lunch

- Themis has contributed enormously to our effort
- Presenting about crab systems in HL-LHC and EIC



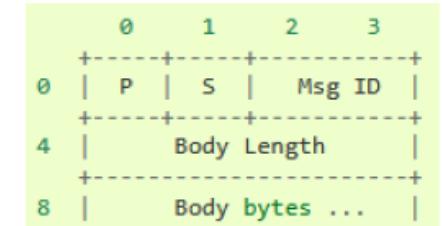
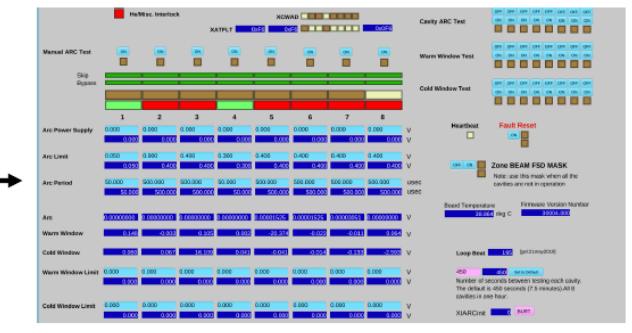
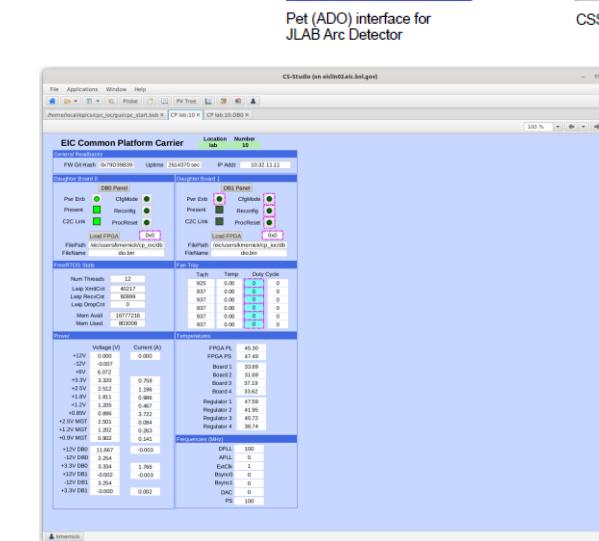
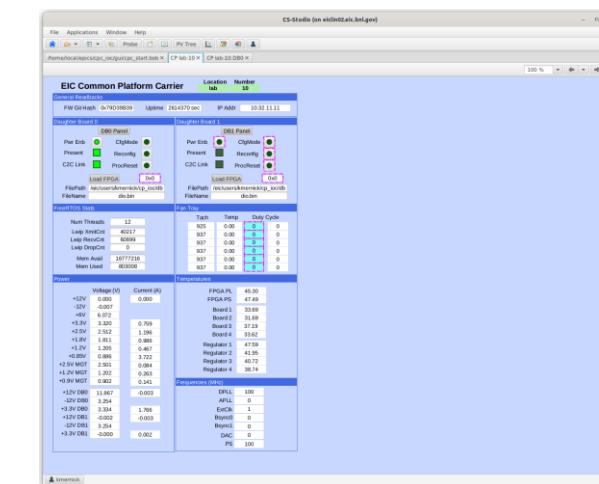
EIC LLRF Design: Controls HW/SW

Kevin Mernick, “Design of the EIC Common Platform and Applications for RF Controls,” poster, Tuesday



Common Platform Carrier Chassis

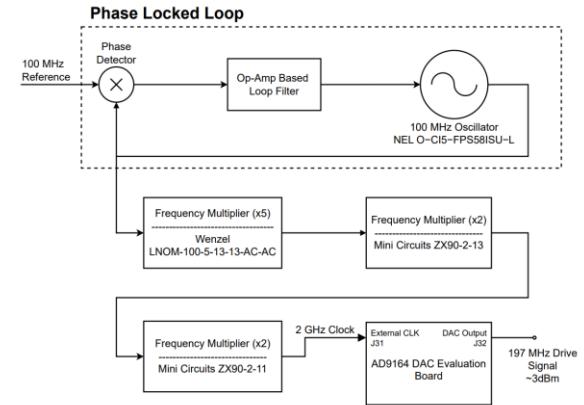
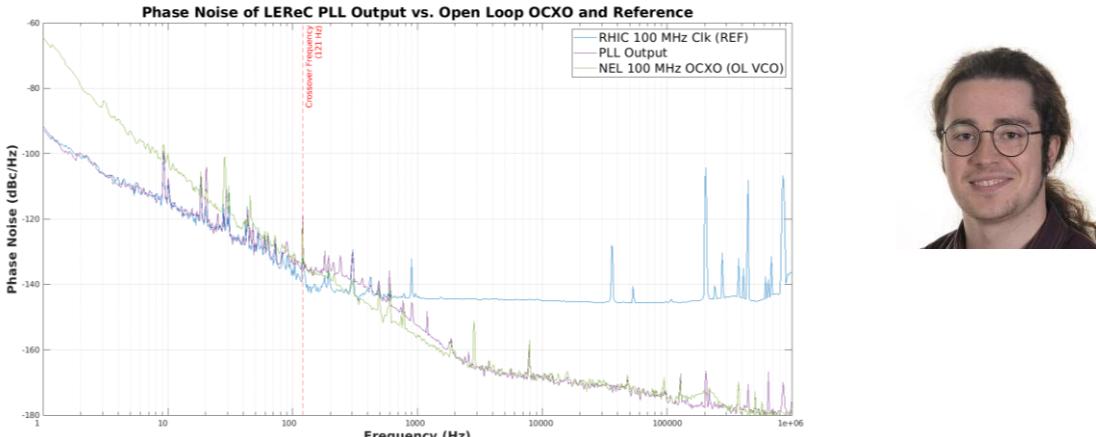
Kyle Fahey, “Transitioning to EPICS at EIC: PSCDrv,” poster, Wednesday



Standard PSC Protocol

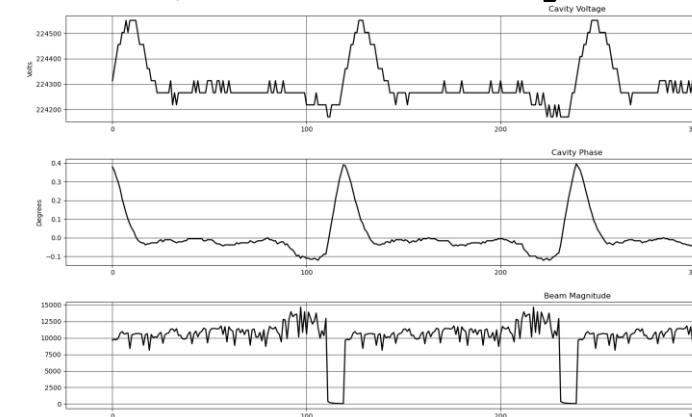
EIC LLRF Design: Cavity Control

Michael McCoey, "The Development of an Ultra-Low Phase Noise Source for EIC Crab Cavities," poster, Tuesday

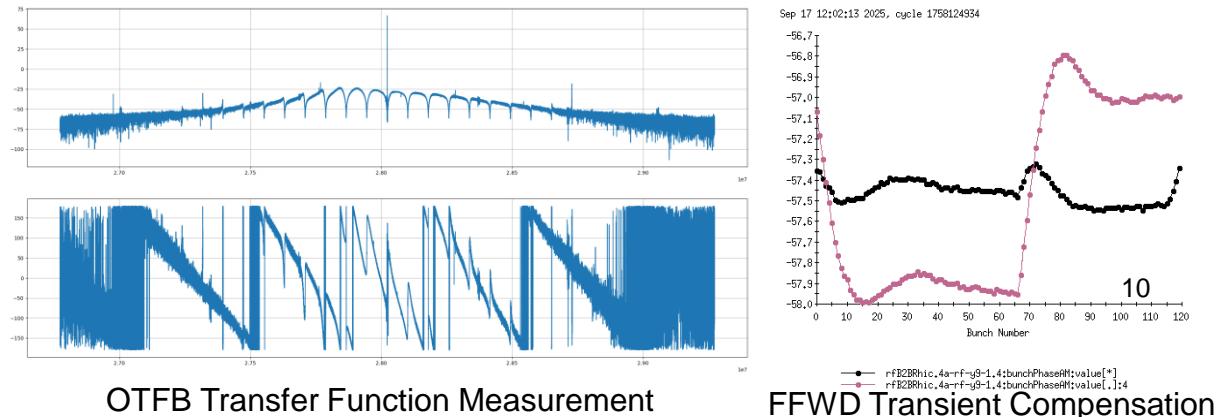


Developmental Clock Receiver Chassis

Arshdeep Singh, "LLRF Upgrades for Studying Transient Beam-Loading in RHIC 28 MHz Accelerator Cavity for the EIC," poster, Wednesday

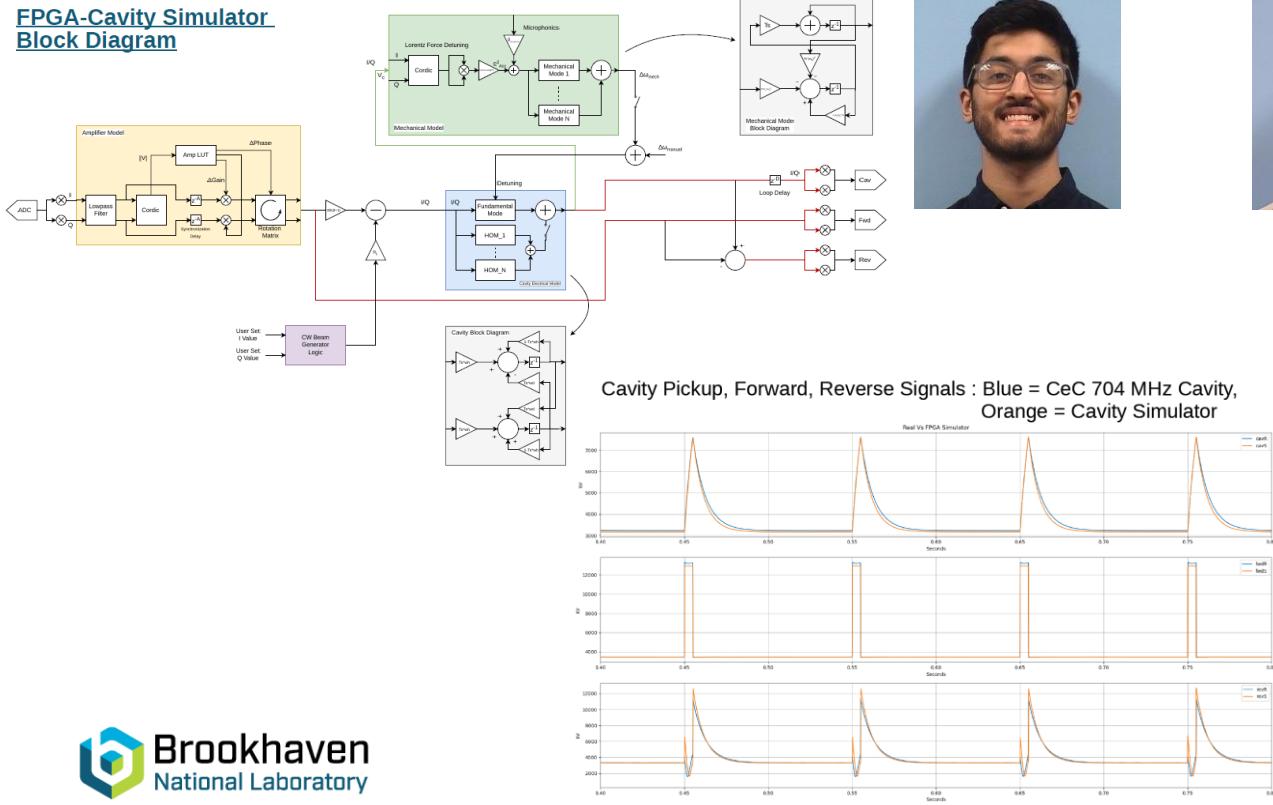


Periodic Transient Beam Loading from Beam Abort Gap



EIC LLRF Tools for Design & Test

Arshdeep Singh, "Development of an FPGA-based Cavity Simulator for Testing RF Controls," poster, Wednesday



Samson Mai, "Baseband Digital Network Analyzer Upgrade for LLRF Controllers," poster, Wednesday

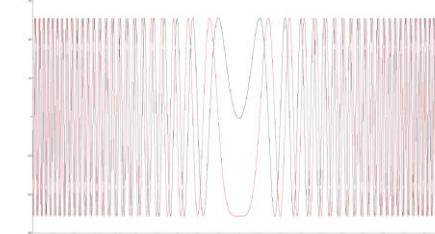
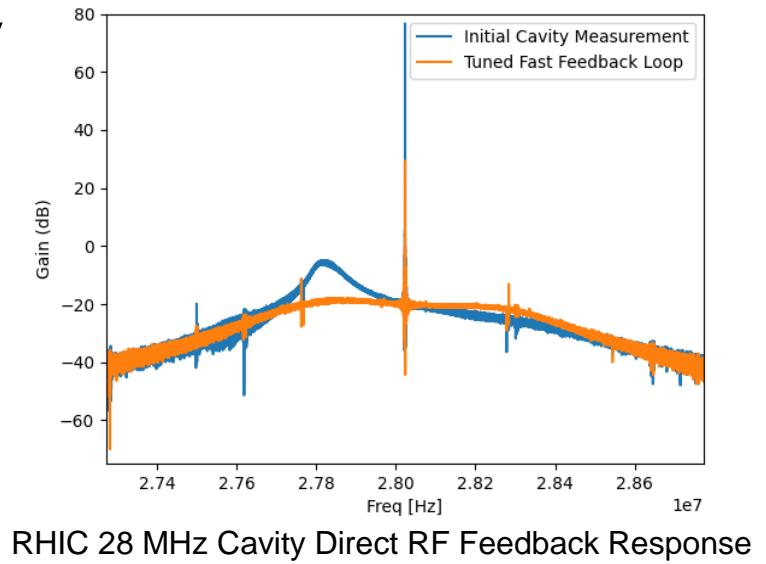
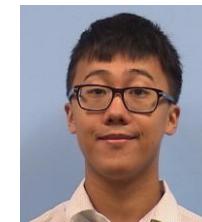
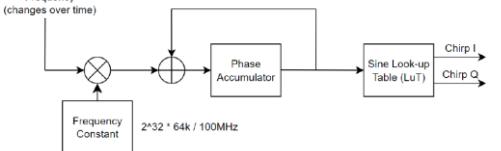


Figure 3: Baseband IQ chirp sweeping from negative frequency to positive frequency. In-phase components (black) and quadrature components (red).

Figure 4: Simplified block diagram of chirp. The frequency is linearly swept and added to the phase accumulator every clock cycle. The BRAM Lut uses the phase index to create the IQ sweep.



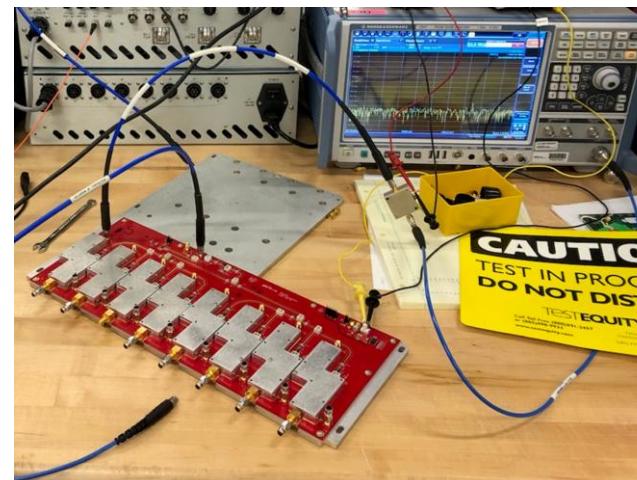
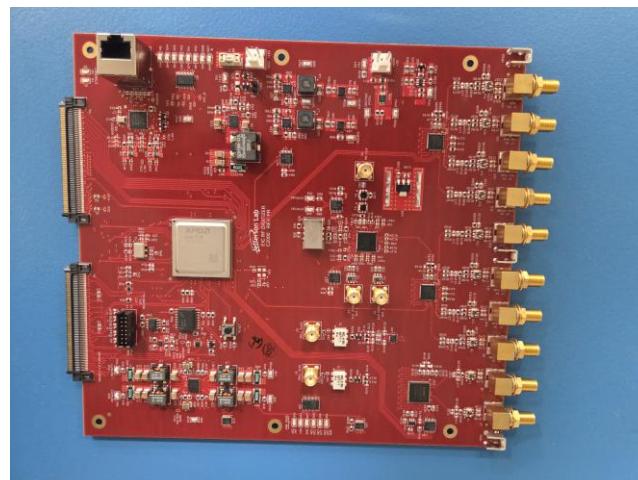
EIC LLRF Collaboration Team

Our JLab colleagues are an integral part of the EIC LLRF team – even though this is the BNL Lab talk, I couldn't leave them out.

- J. Latshaw, “EIC Resonance and Interlocks Control”
- J. Settle, “Local Oscillator Conditioner for the EIC”
- R. Bachimanchi, no EIC poster, but the digitizer board he designed was delivered last week

Jefferson Lab

Brookhaven
National Laboratory



From Left: Tomasz Plawski, Joshua Settle,
Rama Bachimanchi, James Latshaw

Summary and Outlook

- This has been a period of transition for our team and Brookhaven
 - Last RHIC run is bittersweet, but EIC is an exciting future
 - Lots of new faces in our group for both low-level and high-power systems
 - Glad that our new LLRF engineers could attend and meet others in the community
 - Familiar faces in new (or additional) roles:
 - Kevin Smith – EIC Deputy Technical Director
 - Alex Zaltsman – former C-AD & EIC RF Group Leader, now in senior advisor role
 - Freddy Severino – C-AD Department RF Group Leader
 - Silvia Verdu Andres – EIC Department RF Group Leader
 - Geetha Narayan – EIC RF Controls L3 manager
 - Tom Hayes & Kayla Hernandez moved on to other departments at BNL