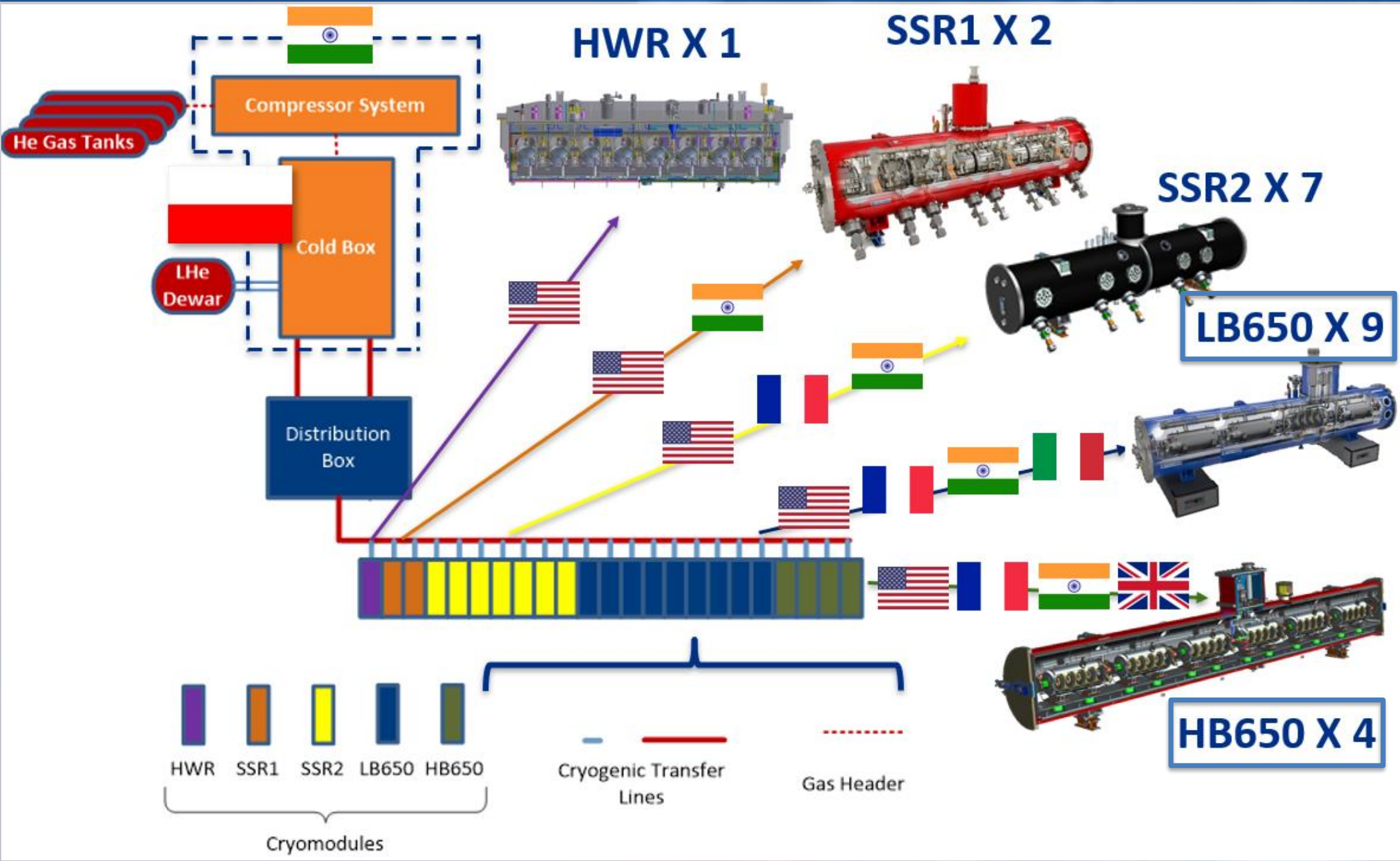


Status of PIP-II 650 MHz Prototype Dressed Cavity Qualification

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Fermilab is upgrading its existing accelerator complex to support a world leading neutrino program and future high intensity frontier particle physics experiments. At PIP-II core is the design and construction of a Continuous Wave (CW) superconducting radio frequency (SRF) linear accelerator that would accelerate an average beam current of 2 mA up to 800 MeV. PIP-II beam acceleration occurs mainly in SRF CW linac that will employ five different types of superconducting cavities.

Low-beta and high-beta sections of PIP-II linac will use nine low-beta cryomodules with four cavities each and four high-beta cryomodules with six cavities each. These cavities will be produced and qualified in collaboration between Fermilab and the international partners. After qualification of 0.9 HB650 cavities at Fermilab, several pre-production 0.92 and 0.61 cavities have been and are being fabricated and qualified. We discuss the current status of cavities and subsystem qualification for PIP-II.

650 Cavity Fabrication

HB650 proto cavity (B92D-RRCAT-502) received from RRCAT, India

LB650 proto cavity (B61-EZ-001) received from INFN, Italy

Jacketing of the last $\beta = 0.9$ cavity

$\beta = 0.9$ cavity pressure testing

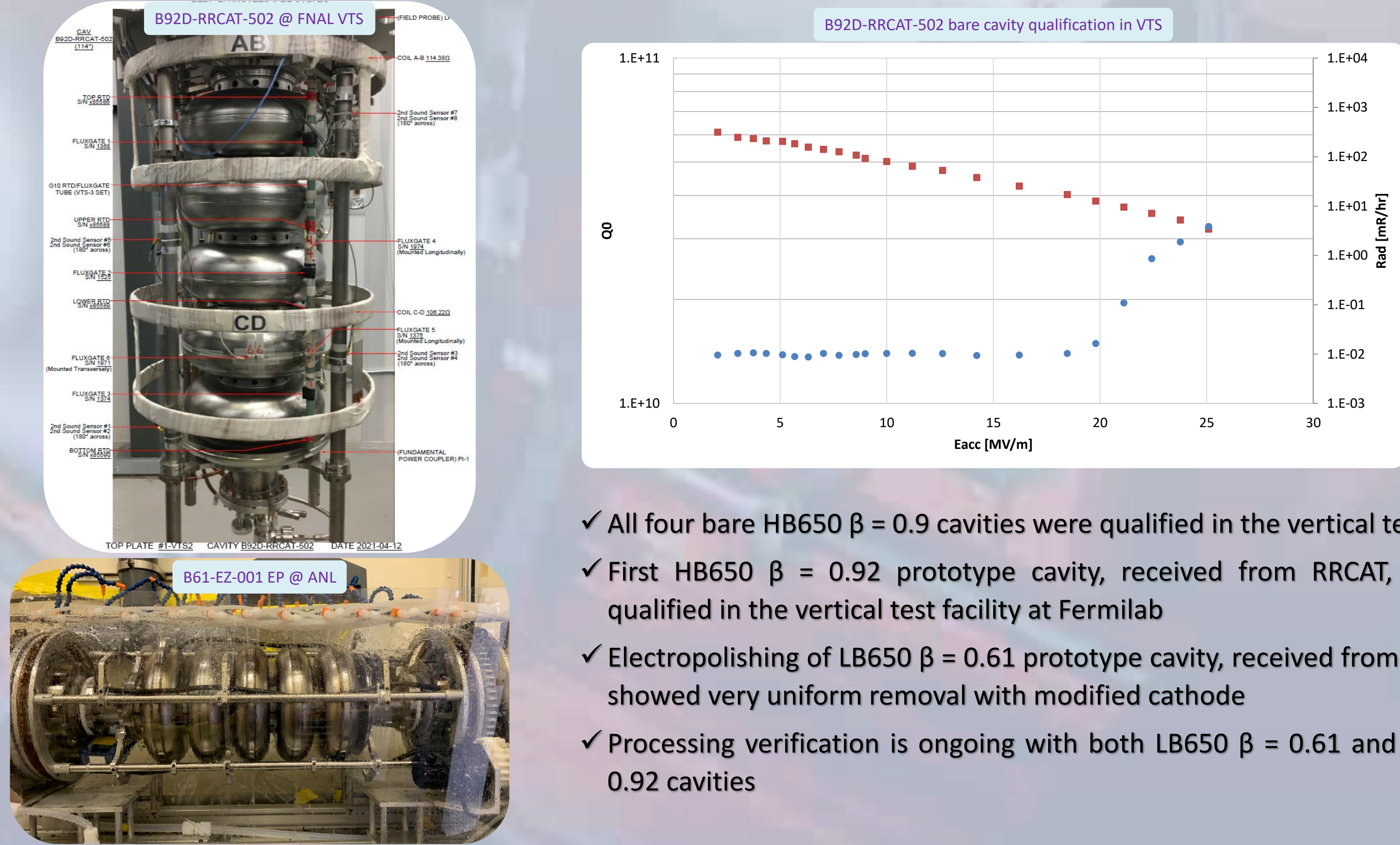
B90 5-cells at FNAL	status	Instrumentation	VTS as jacketed	STC test
B9A-AES-007	Jacketed	No	In progress	No
B9A-AES-008	Jacketed	Yes	In progress	planned
B9A-AES-009	Jacketed	No	In preparation	No
B9A-AES-010	Jacketed	Yes	Completed	Completed

B92 5-cell at FNAL	status	VTS as bare	Jacketing	STC test
B92D-RRCAT-502	Bare	Completed	In preparation	Planned
B92D-RRCAT-504	Bare	In progress	Planned	TBD
B92E-RRCAT-506	Bare	In preparation	Planned	TBD

B61 5-cell at FNAL	status	VTS as bare	Jacketing	STC test
B61-EZ-001	Bare	In progress	Planned at INFN (?)	No

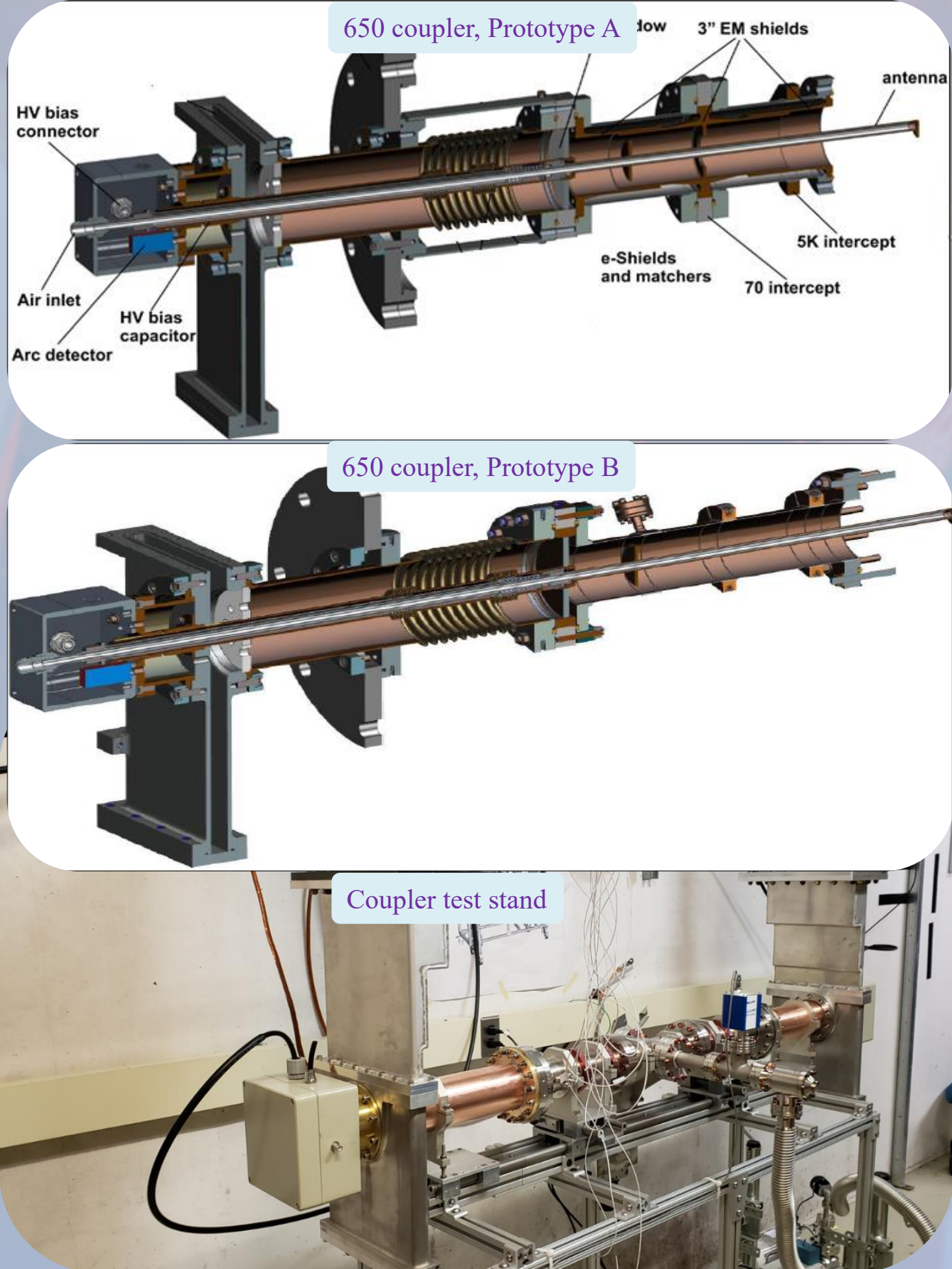
- ✓ Four bare HB650 $\beta = 0.9$ cavities were jacketed after qualification in the vertical test and pressure tested
- ✓ First LB650 $\beta = 0.61$ prototype cavity was received from INFN, Italy
- ✓ First three HB650 $\beta = 0.92$ prototype cavities received from RRCAT, India
- ✓ Four prototype LB650 $\beta = 0.61$ and three prototype HB650 $\beta = 0.92$ cavities with jacketing components are in procurement from industry
- ✓ The prototype HB650 $\beta = 0.92$ cavity is being jacketed at FNAL
- ✓ Specifications and requirement are in preparation for the procurement of production niobium and cavities

Cavity processing



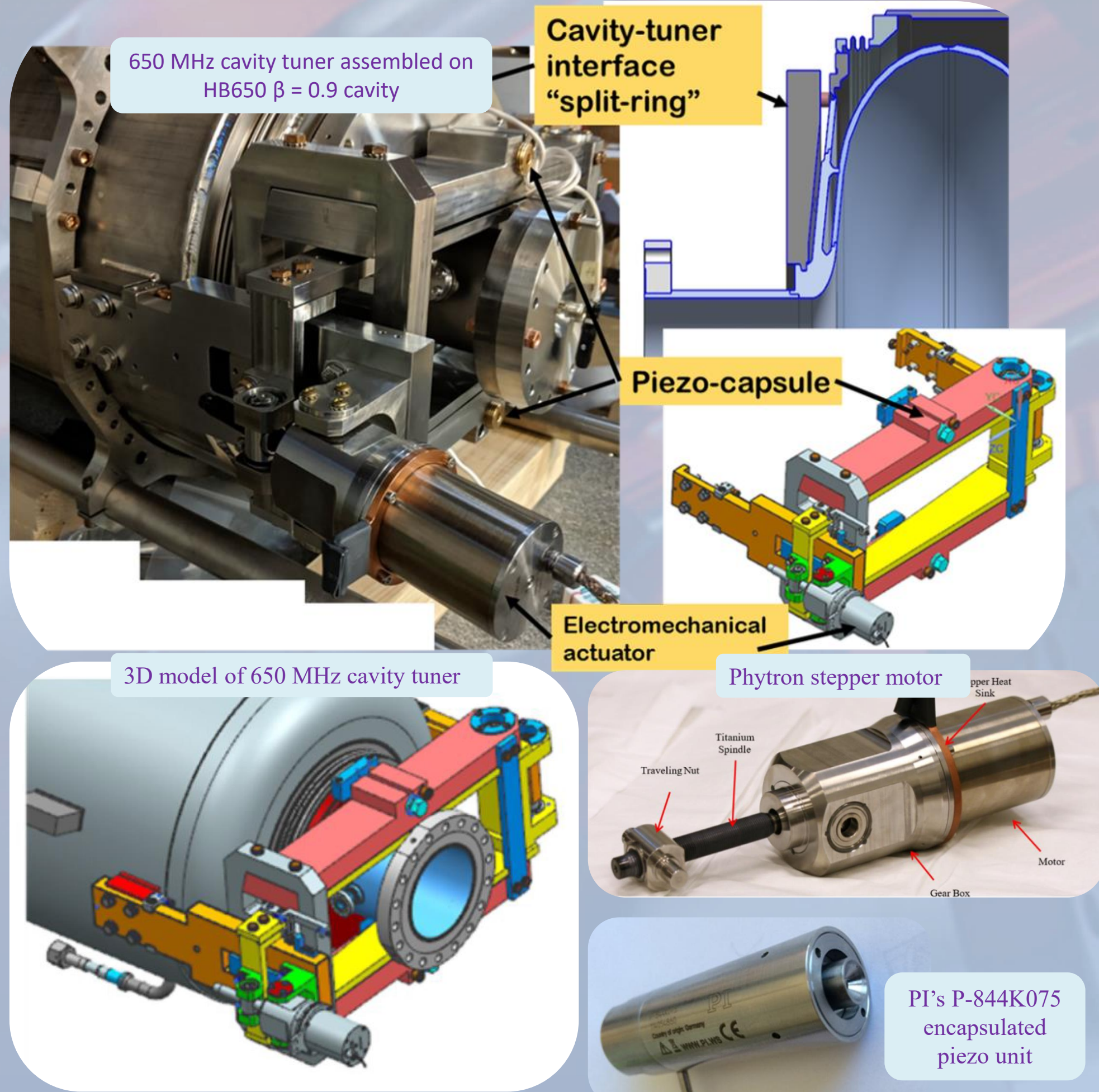
- ✓ All four bare HB650 $\beta = 0.9$ cavities were qualified in the vertical test
- ✓ First HB650 $\beta = 0.92$ prototype cavity, received from RRCAT, India, was qualified in the vertical test facility at Fermilab
- ✓ Electropolishing of LB650 $\beta = 0.61$ prototype cavity, received from INFN, Italy, showed very uniform removal with modified cathode
- ✓ Processing verification is ongoing with both LB650 $\beta = 0.61$ and HB650 $\beta = 0.92$ cavities

Coupler Design and Fabrication



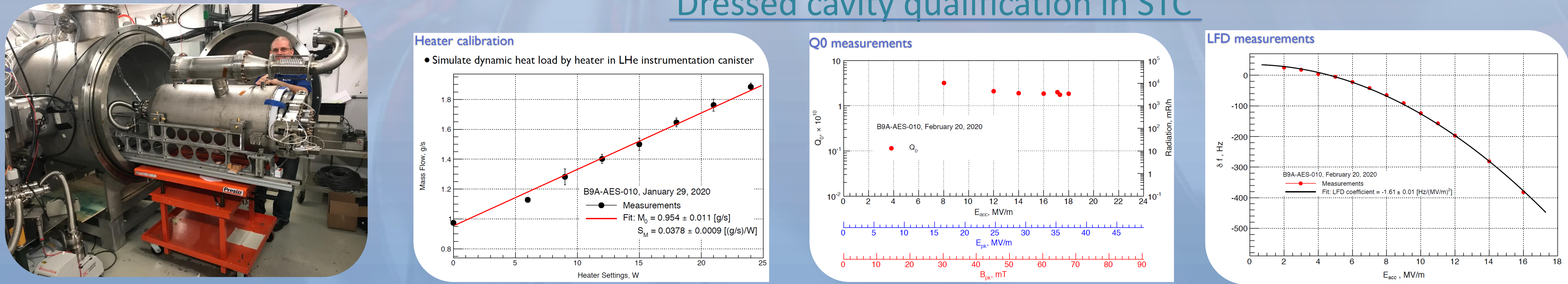
- ✓ 650 MHz power coupler was designed for both $\beta = 0.61$ and $\beta = 0.92$ cavities
- ✓ Coupler consists of two parts: cold vacuum part with flat ceramic window and antenna and warm part with bellows in inner and outer conductors and transition to standard WR1150 waveguide
- ✓ DC bias up to 5kV to damp multipactoring activity in the coupler
- ✓ Orientation of the flag at the end of antenna allows to change coupling during coupler-to-cavity installation in the clean room
- ✓ Proposed, built and tested two designs of the 650 MHz power coupler at the prototyping stage: in prototype A stainless steel outer conductor is shielded by copper screen from electromagnetic fields, in prototype B, all stainless-steel tubes and bellows are copper plated, antenna is made of solid copper, polished to reduce thermal radiation
- ✓ Current design is modified version of prototype B coupler, built and successfully tested at full parameters
- ✓ For pre-production $\beta = 0.61$ and $\beta = 0.92$ cryomodules Fermilab started the procurement of eight couplers and three cold antenna-window assembly
- ✓ PIP-II partners are planning to start procurement of 650 couplers soon

Tuner Design and Fabrication



- ✓ SRF cavity tuner designed to be able to serve three type of 650MHz cavities $\beta = 0.61, 0.9$, and 0.92
- ✓ Double-lever tuner with piezo-actuator installed between main tuner arm and conical flange of dressed cavity, benefiting from using the same highly reliable stepper motor and piezo actuators
- ✓ Incorporated lessons learned from the LCLS-II 1.3 GHz tuner
- ✓ Designed with high tuner stiffness to minimize Lornetz Force detuning of the 650 cavities
- ✓ First tuner prototype was installed on b=0.9 dressed cavity and performances of the cavity/tuner system have been evaluated on the warm and cold cavity
- ✓ Tuner's drawings and details of assembly procedure were shared with the partners

Dressed cavity qualification in STC



- ✓ Commissioned STC for 650 MHz testing: facility (mechanical, instrumentation, vacuum, cryogenic, RF, safety/interlocks), procedures, documentation)
- ✓ Tested and validated 650 MHz coupler and tuner designs
- ✓ Characterized B9A-AES-010 (HB650, 0.9) cavity (max E_{acc} , Q_0 , FE, MP, LFD, df/dP)

The high energy section of the SRF CW linac will comprise a section with nine LB650 cryomodules, hosting four LB650 dressed cavities each, and a section with four HB650 cryomodules, hosting six HB650 dressed cavities each. Fermilab is in the process of the design validation of both types of 650 cavities. Several prototype cavities and other components have been received from the international partners are being processed and tested at Fermilab. At the same time prototype procurement by Fermilab is ongoing along with refinement and finalization of the components requirements to initiate procurements by the partner labs. As a part of validation process, the first Hb650 $\beta = 0.9$ cavity has been successfully tested in the recently modified STC horizontal testing bed.

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