APS LINAC AND TEST AREAS

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ACKNOWLEDGEMENT

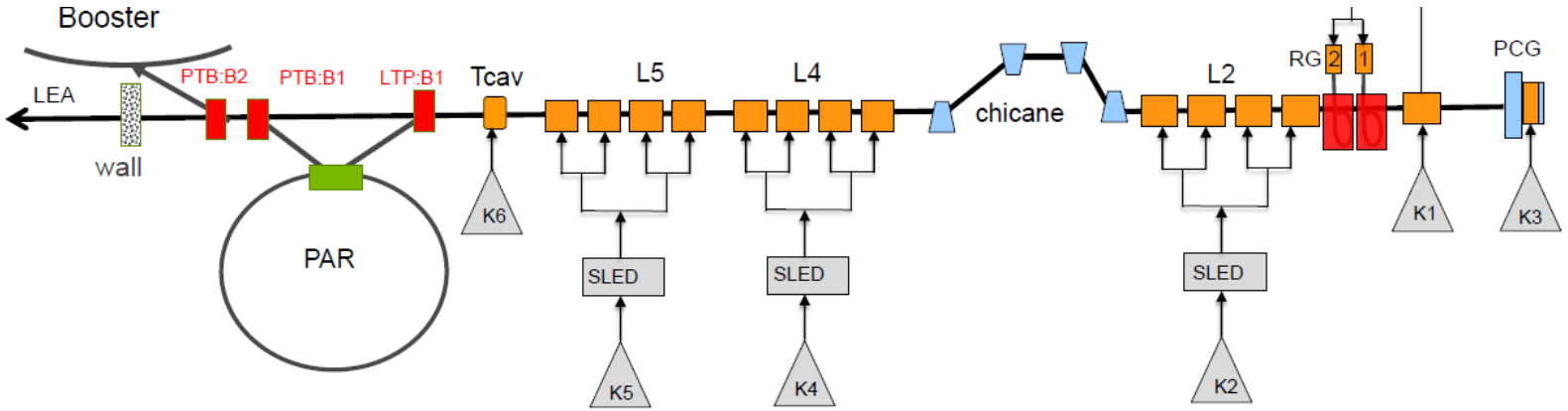
This presentation was put together with materials from:

1. K. W. Wootton, ”R&D: Linac Extension Development,” APS Machine Advisory Committee Review, ANL, October 11 – 13, 2022.
2. Y. Sun,” APS Linac Operation and Refurbishment,” APS Machine Advisory Committee Review, ANL, October 11 – 13, 2022.

OUTLINE

- APS Linac
- Linac Extension Area (LEA)
- Injector Test Stand (ITS)

APS Linac



- S-band rf guns and accelerating structures;
- Two thermionic rf guns (RG1 and RG2), and a Photo-Cathode Gun (PCG):
  - RG2 provides electrons for injection into PAR/Booster/SR;
  - RG1 is a backup;
  - PCG beam for LEA.

Courtesy Y. Sun

- Thirteen 3-meter long accelerating structures:
  - 12 structures downstream of RG1 and RG2.
- Six klystrons; three with SLED.
  - Max klystron power is limited to 38 MW due to the peak power the klystron window can handle.

Nominal APS Linac Parameters with thermionic rf gun beam

Parameter	Range	Unit
RF Frequency	2856	MHz
Beam Energy	**425**	**MeV**
Repetition Rate	≤ 30	Hz
Thermionic Gun Beam Energy	≤ 4	MeV
Microbunch charge	40 ~ 60	pC
Microbunch pulse length FWHM	200 ~ 1000	fs
No. of Microbunches per Macrobunch	17 ~ 34	
Macrobunch length	6 ~ 12	ns
Macrobunch charge	**1**	**nC**

Courtesy Y. Sun

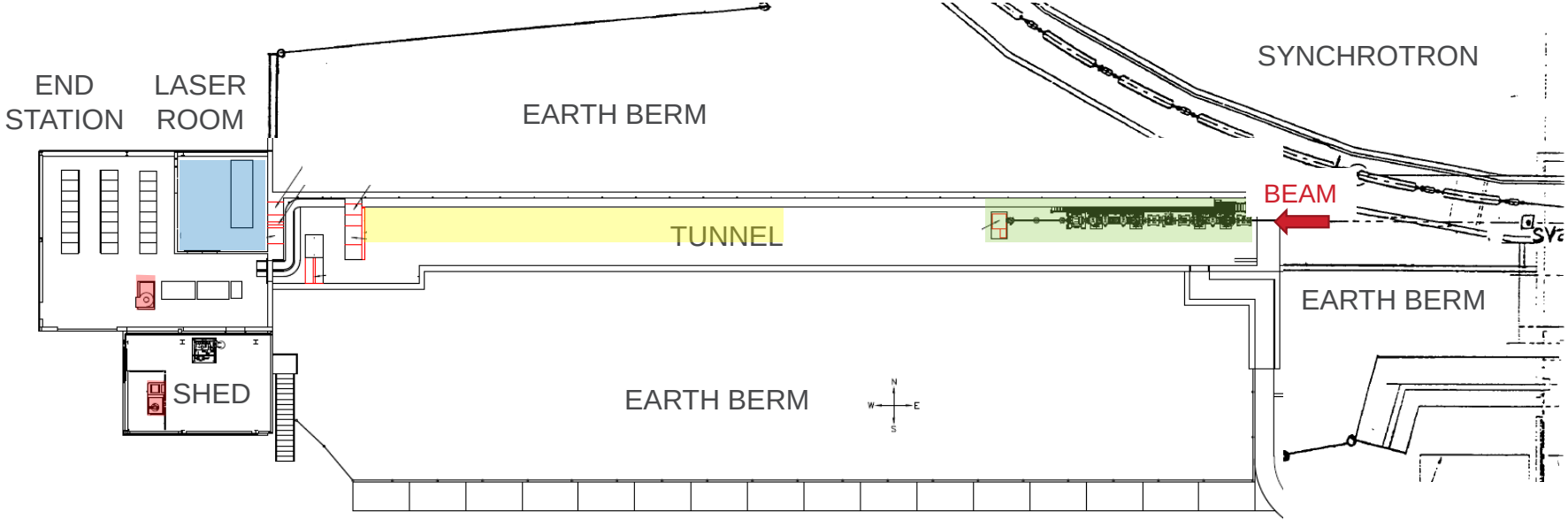
Linac beam with PC gun

Parameter	range	unit
Gun gradient	[100 ~ 130]	MV/m
Solenoid peak field	[0.2 ~ 0.315]	Tesla
Bunch charge	[50- 500]	pC
Drive laser pulse	[2 ~ 5]	ps
Drive laser size	[0.1 ~ 0.8]	mm
Energy gain in the first acc. structure	[10 ~ 30]	MeV
Energy gain per structure in the rest of the linac	[25 ~ 35]	MeV
Best normalized Beam emittance measured at 300pC	2	µm
Energy	[375~450]	MeV
Energy spread	[250~500]	keV
Beam repetition rate	[2~30]	Hz
Bunch length	[100~3000]	fs

Courtesy Y. Sun

LEA Layout

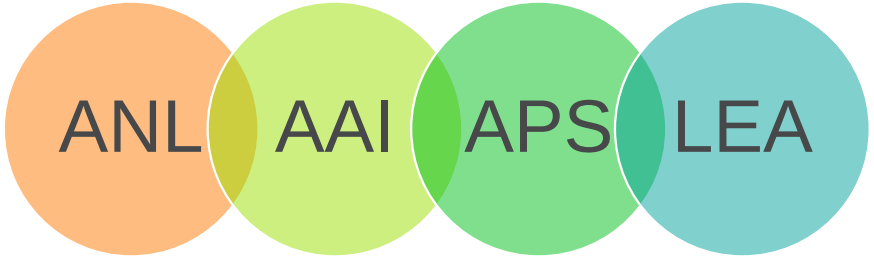
LEA Beamline
Future 2856 MHz structure, SLED conditioning
30 MW, 50 MW 2856 MHz test stands
LEA Laser Room

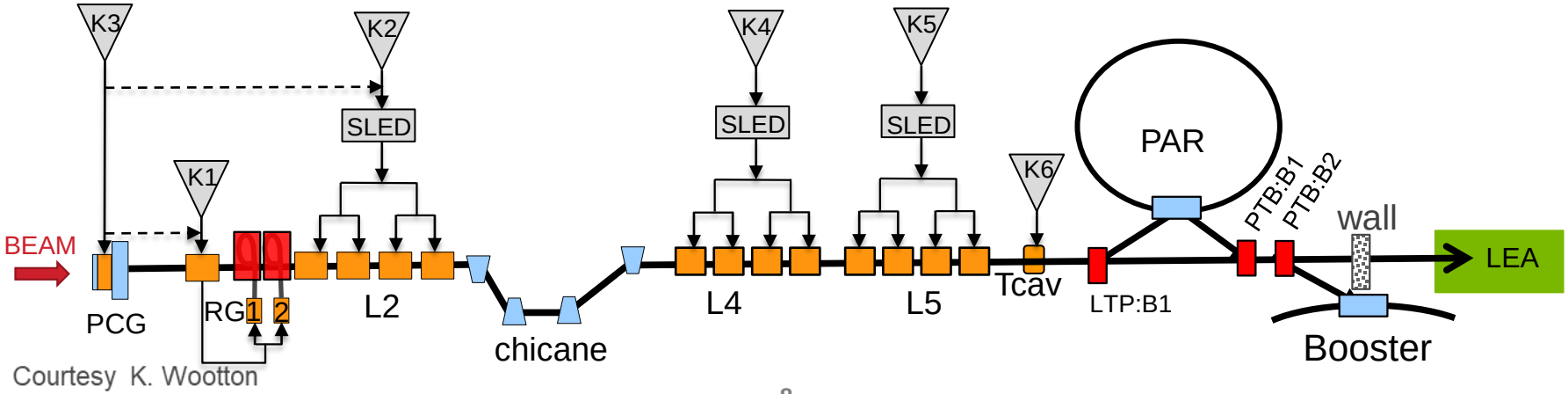


Courtesy K. Wootton

Mission & Location

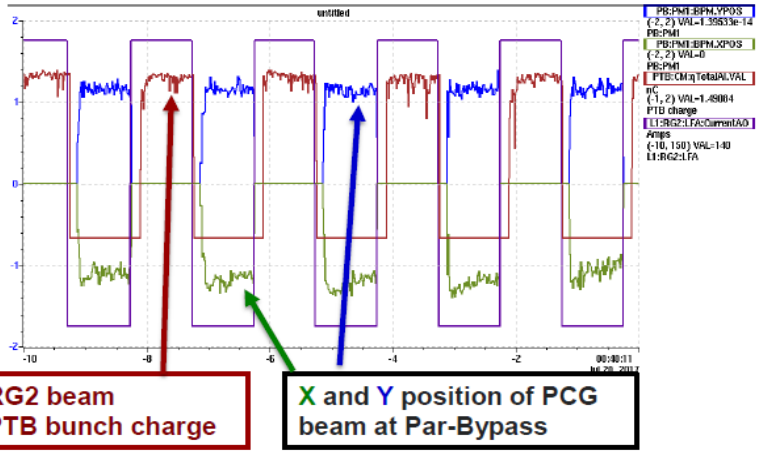
- LEA supports the mission of:
  - Argonne National Lab
  - Argonne Accelerator Institute
  - Advanced Photon Source
- Located downstream of APS injector

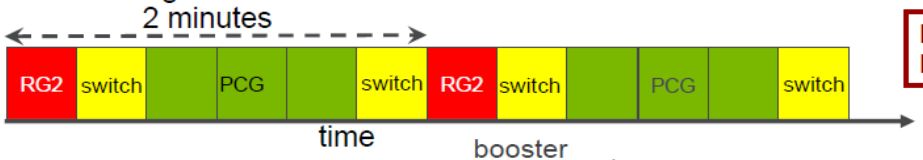


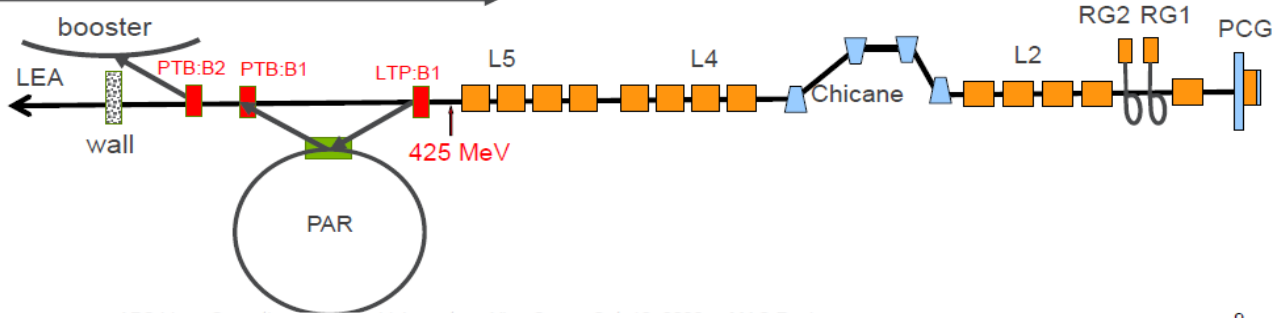


Beam Interleaving

- During present storage ring top-up operation, most of the time the Linac is needed for ~20 seconds every two minutes to inject the RG2 beam into PAR;
- There is no beam in the linac during rest of the two minutes → PCG beam can be accelerated through and transported to LEA;
- **Interleaving Operation** of the RG2 and PCG beams in the APS linac.
  - If RG1 is providing beam to the LINAC, there will be no interleaving.
- Interleaving was demonstrated in Oct. 2017.



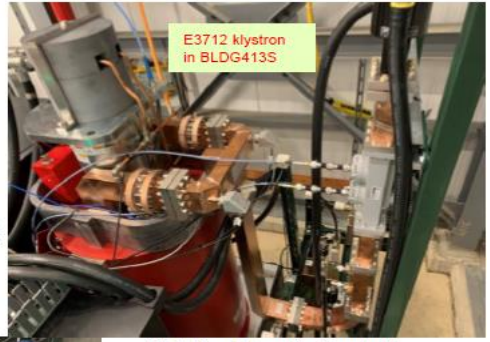




Courtesy Y. Sun

New Solid-State Modulator and 50 MW Klystron (413 RFTS-2)

- A 50 MW rf station composed of a ScandiNova K400 solid state modulator and Canon E3712 klystron was installed in Building 413S*.
- Analog LLRF drive system was used for the rf station test.
- Site Acceptance Test (SAT) completed**: 50 MW rf power at 30 Hz repetition rate and 4.5 μs rf pulse length was demonstrated.
- Installation procedures, valuable knowledge of the new system and operational experience were gained from the SAT of the 50 MW rf station #1. This paved the way for the installation and commissioning of the rf station #2 at K2 location of the linac.



RF station photo credits: Terry Smith

*Bill Berg, Geoff Pile: Building 413S construction and infrastructure

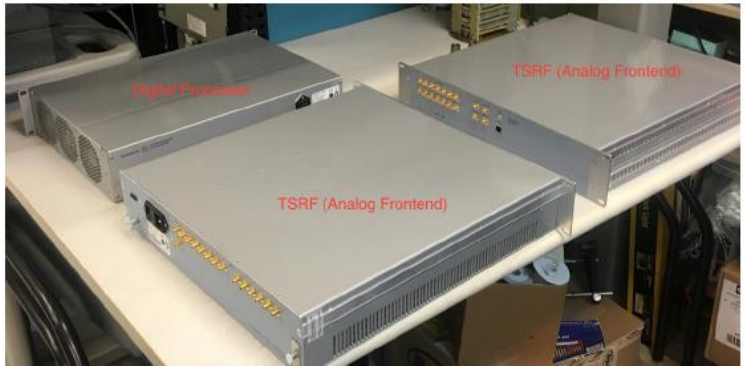
**Terry Smith: Lead RF engineer for the 50 MW rf station SAT

Peak Power Analyzer show +107.01 dBm (50 MW) at 4.5 μs

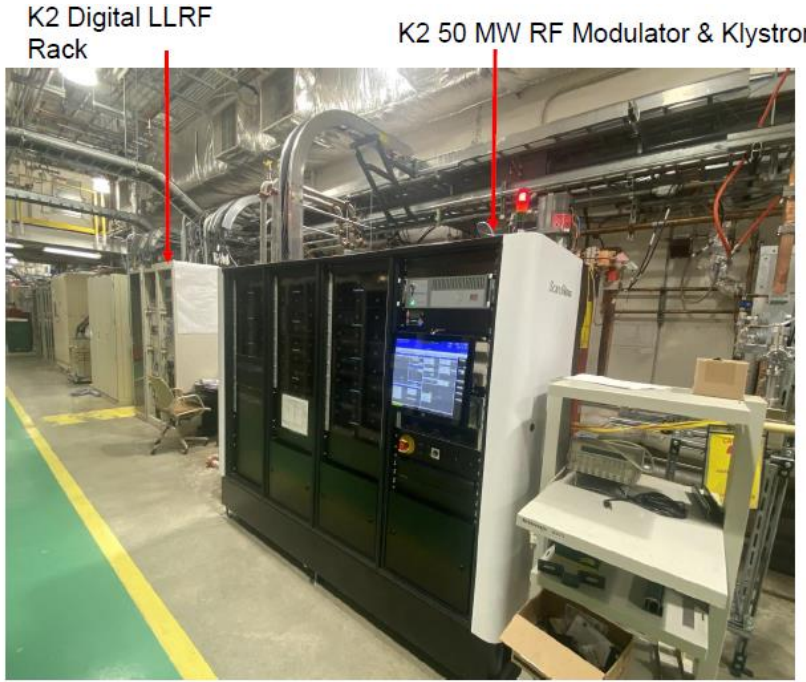
Courtesy Y. Sun

New Digital LLRF

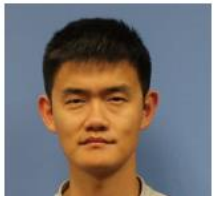
- Some components of the APS linac LLRF are obsolete, and spares are no longer available. For the next 30 years of operations, LLRF control system must be upgraded.
- A customized digital LLRF system has been developed for the APS linac under a collaboration between Argonne National Lab and Instrumentation Technologies.
- Two systems have been manufactured and delivered to the APS*.



Courtesy Y. Sun

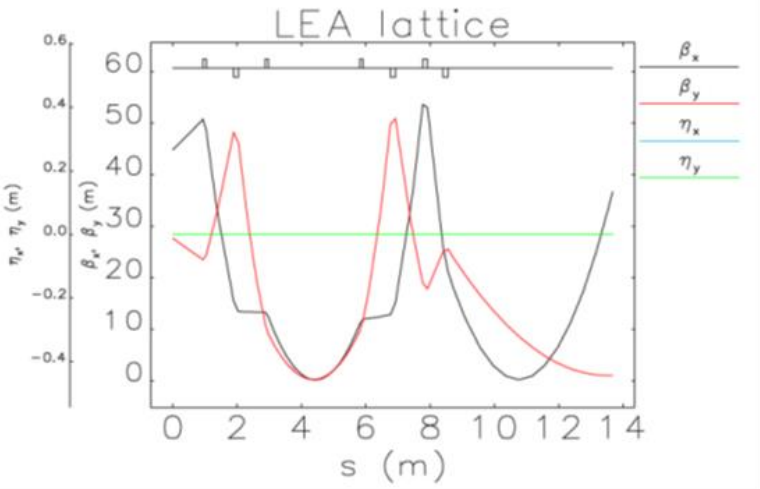


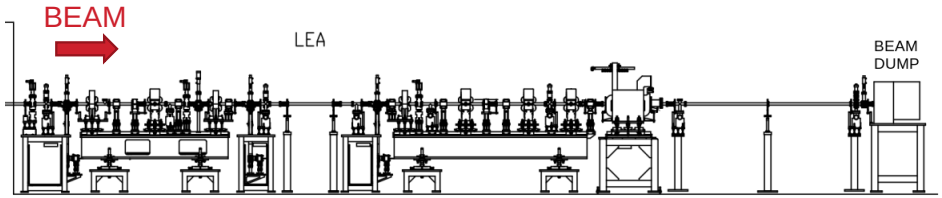
*Yawei Yang, Lead engineer for digital LLRF.
Photos and slide content provided by Yawei Yang.



LEA Beamline

- 300–500 MeV electron beam
- 15 m installed length
- Insertion region supporting round or flat beams

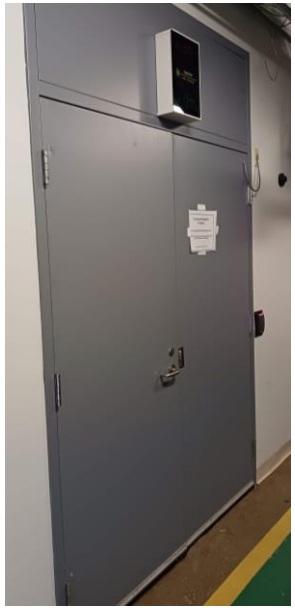




Courtesy K. Wootton

LEA Laser Room

- Temperature controlled room
- HEPA filters for cleanliness
- A laser is not installed at this time



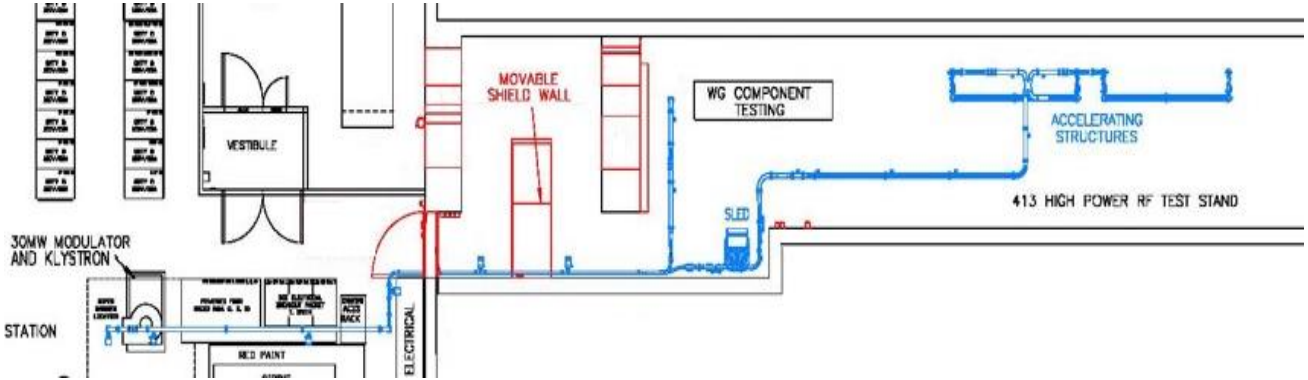
Vestibule, installed safety interlock features support Class IV laser operation

Courtesy K. Wootton

Supporting APS Operation

2856 MHz test stand for accelerating structure, SLED conditioning

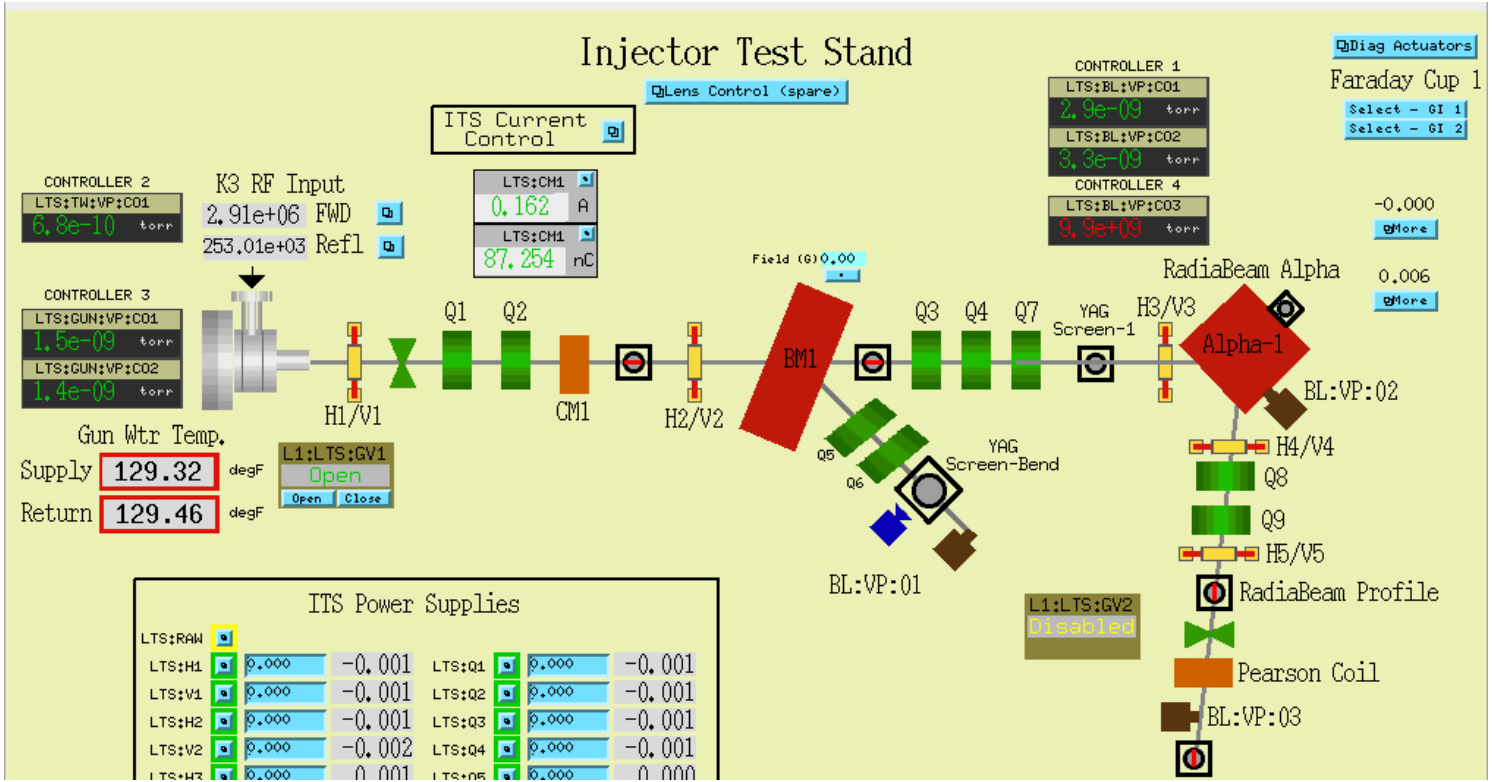
- B. 413 end station supports two 2856 MHz test stands
  - 30 MW modulator and klystron
- Plan for linac spares is to condition 2856 MHz accelerating structures, SLEDs within the LEA enclosure



Test stand capacity for conditioning 2856 MHz accelerating structures

Courtesy K. Wootton

Injector Test Stand (ITS)



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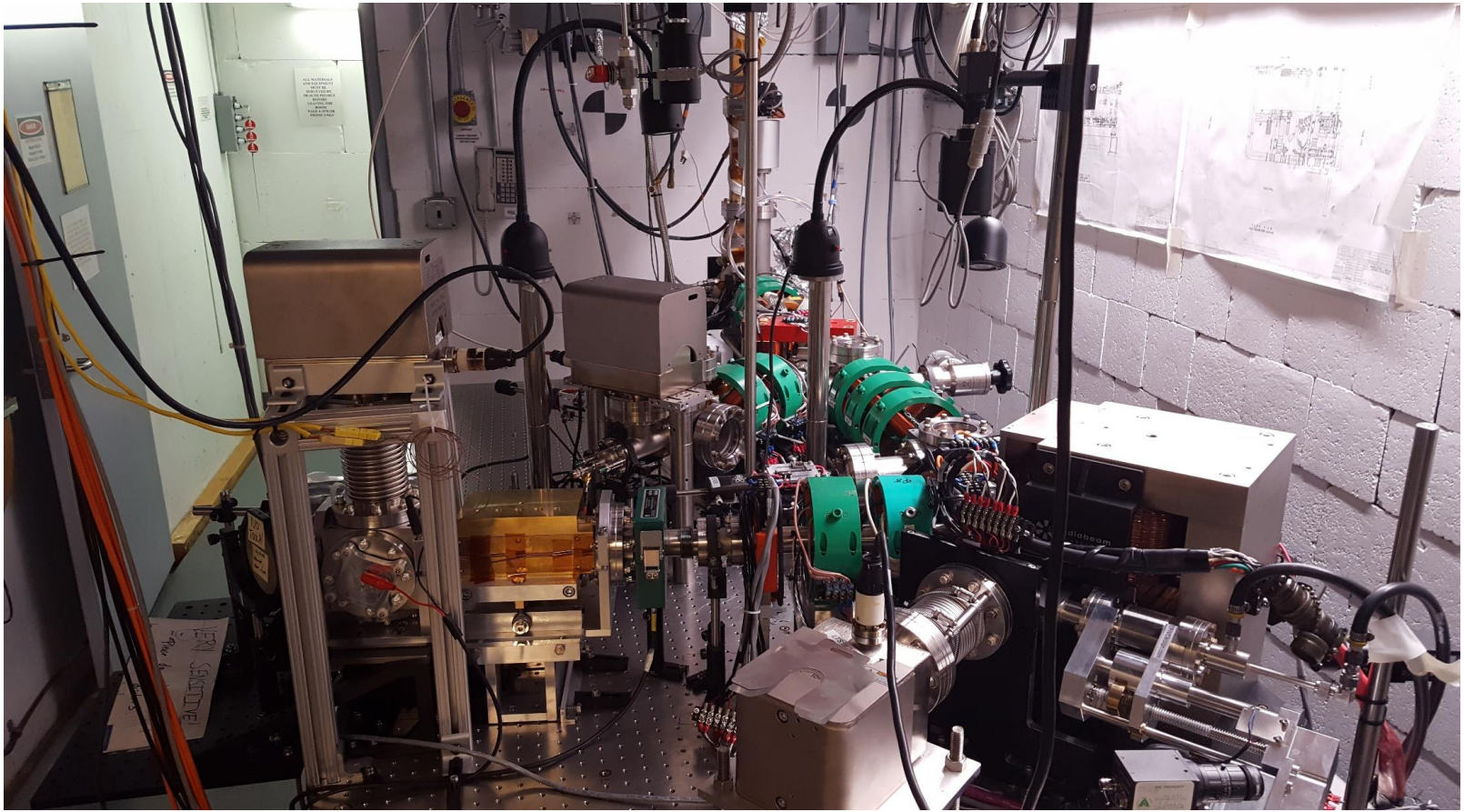

CLOSING REMARKS

- Two certified radiation shielded enclosures are available for C^3 staging tests
  - Linac Extension Area (LEA)
  - Injector Test Stand (ITS)
- LEA is equipped with two S-band high-power system
  - 50 MW with a solid-state modulator and a 60 MW klystron
  - 30 MW with a PFN modulator and a 35 MW klystron
- Linac ITS is fully instrumented including and rf gun and a switchable 30 MW rf source. It can accommodate a short (~ 1m) S-band accelerating structure.
  - Restart activity of electron beam loss studies
- Interleaving operation provides a pathway to operation of LEA simultaneously with APS-U storage ring operations.