FACET-II | Facility for Advanced Accelerator Experimental Tests

FACET-II
Accelerator Commissioning Update

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Mark J. Hogan
Senior Staff Scientist
FACET & Test Facilities
Division Director

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Accelerator Performance

- Now operating with 3 of 4 Objective KPP routinely
- Deliberately running at reduced charge (700pC) while investigating lattice issue upstream of experimental area (transition from chicane to final focus)
- Expect to transition to 2nC by next week – plenty of overhead in the injector and will require some re-optimization
- Transition to primarily User programs afterwards
- Some delay due to DL10 vacuum and Wednesday safety pause

Key Performance Parameter	Threshold KPP	Achieved	Objective KPP	Achieved
Particle Energy	> 9 GeV	9.3 GeV	10 GeV	10 GeV
Bunch Charge	> 0.1nC	0.4 nC	2 nC	0.7 - 2 nC
Normalized Emittance in Sector 19	50 mm-mrad	25 mm-mrad	20 mm-mrad	5x5 mm-mrad
Bunch Length	< 100 μm	70 μm	20 μm	20 μm

Progressing from KPP to Beams for Science Programs Will Be a Gradual Evolution and Require New Capabilities

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Three machine configurations have been identified and are being developed to satisfy all seven experiments:

- **Two-bunch (1.3/0.6nC, 30/15kA , 150μm separation, 5-50cm betas)**
  - PWFA emittance preservation under high beam-loading (E-300)
  - PWFA hosing suppression (E-302)
  - PWFA positron injection (E-303)
  - Wake imaging (E-324)

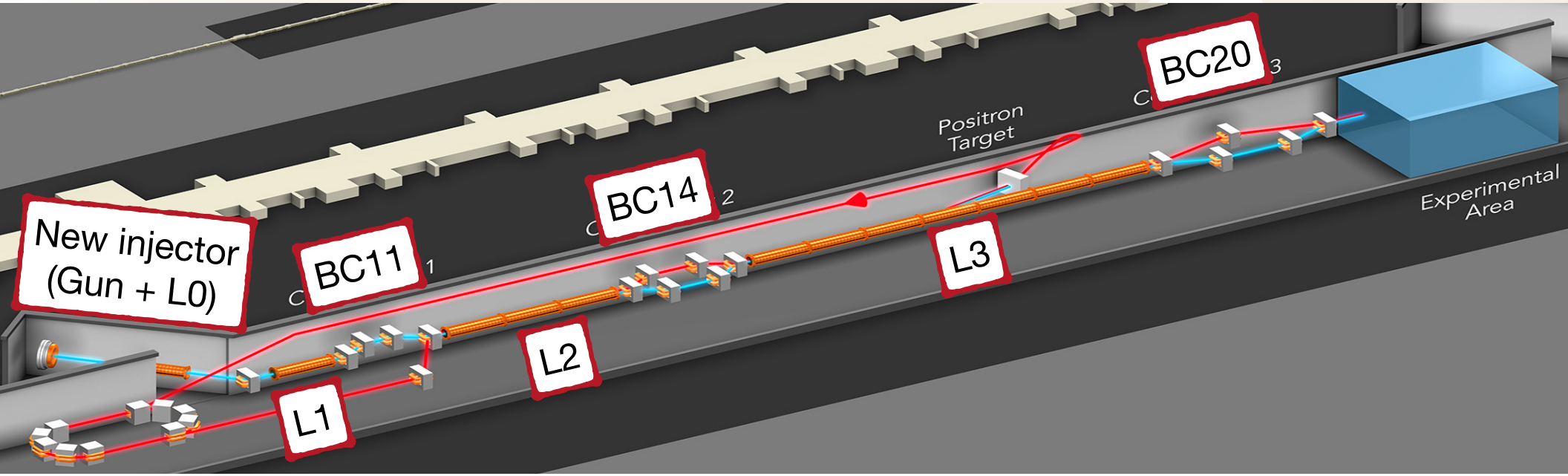
  Summer/Fall
- **Single bunch with high peak current (50-300kA, 0.1-10m betas)**
  - Filamentation & gamma-ray bursts (E-305)
  - 'Trojan Horse' Injection (E-310)
  - Wake imaging (E-324)

  Now
- **Highest Energy low backgrounds and well characterized (13GeV, σ_z = 100μm, 1m betas)**
  - HFQED (E-320)

  In parallel

Minimize configuration changes and gradually introduce new (more extreme) capabilities in the beams and hardware

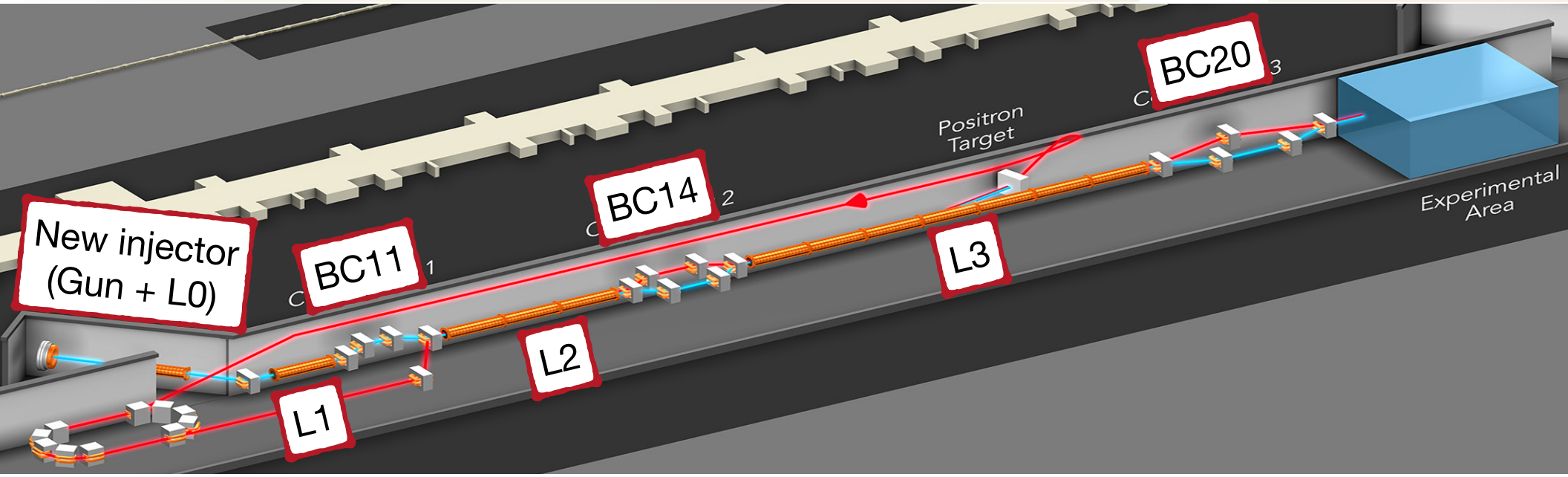
FACET-II Linac Commissioning Status and Linac Overview



- The project installed new elements: injector, BC11, BC14
- This also deprecated much of the SLC infrastructure used at FACET
- Fall/Winter – focussed on stabilizing the injector charge and developing:
  - Diagnostics: wire scanners, bunch length monitors
  - Emittance measurement, matching and correcting lattice errors
  - Feedbacks: RF, energy, bunch length

Significant hardware and software development has been required to characterize and aid delivery of a stable beam

Steady Progress from Injector to (now) S20

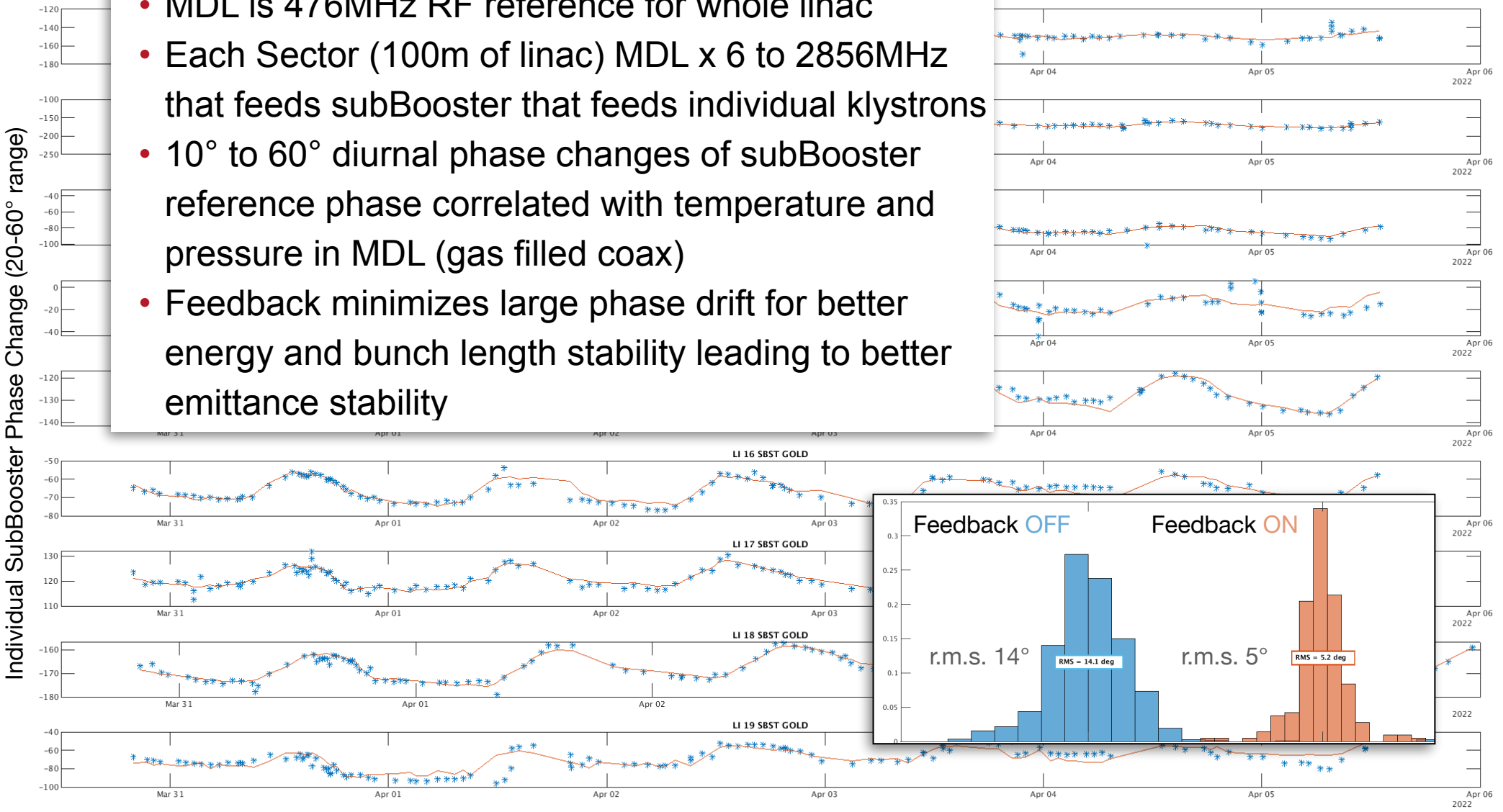


- Cathode and laser wavelength change for the injector
- Lattice errors corrected in L1, L2, L3 and S20 (TBD)
- Diurnal RF phase drifts corrected with MDL feedback (next slide)
- BC11 and BC14 energy and bunch length feedbacks
- Ongoing effort to Identify and correct RF stations with intermittent jitter

Emittance at the end of L3 consistently below objective KPP
Typical values: Injector 4μm, L1 5μm, L2 6μm, L3 10μm (most variation)

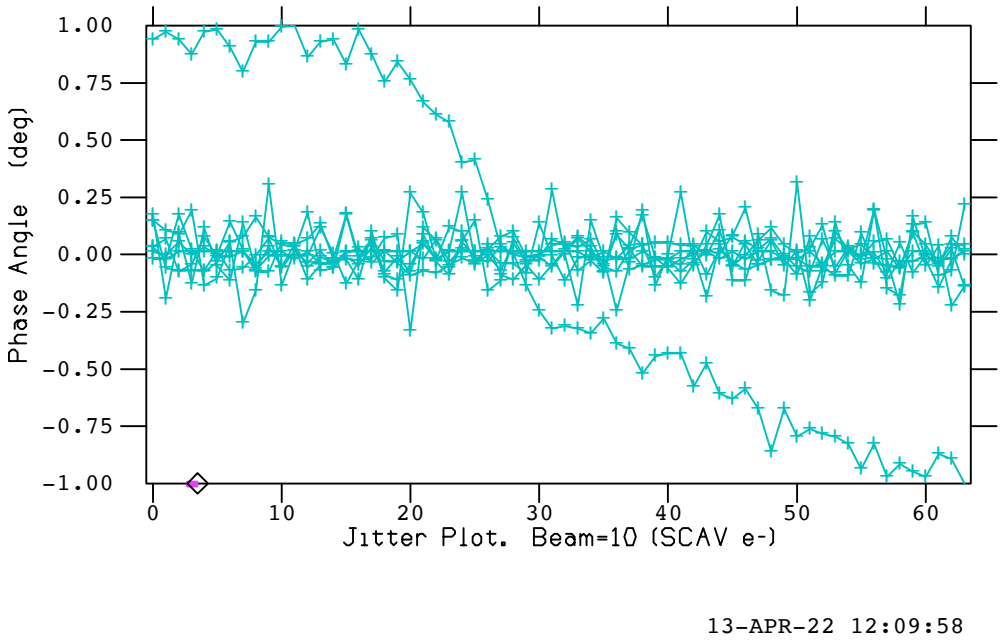
Large Slow RF Drifts Corrected with Main Drive Line Feedback

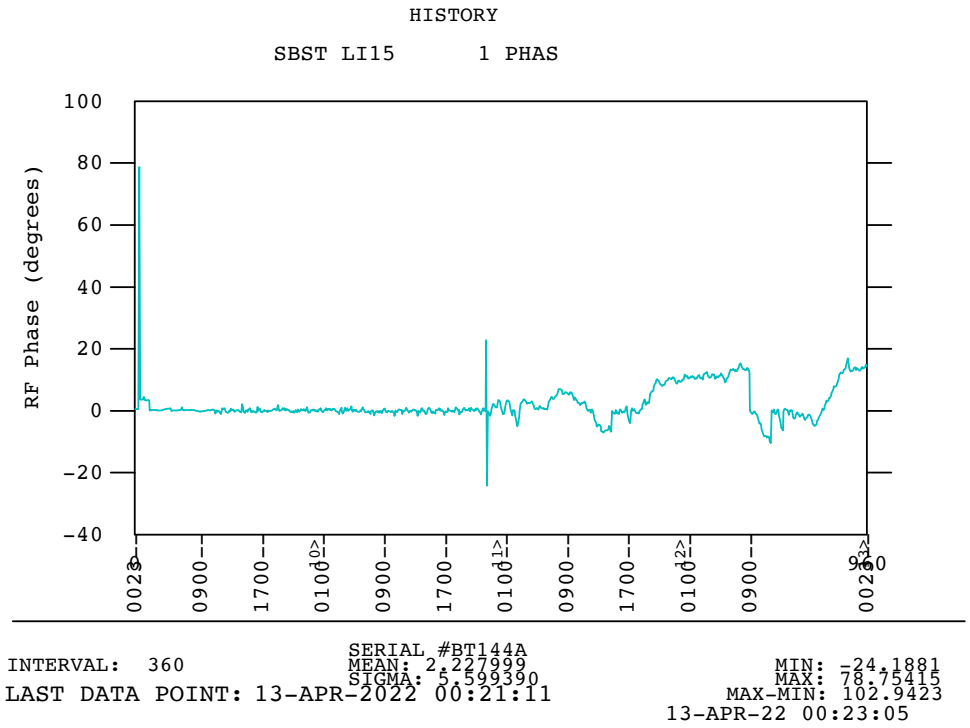
- MDL is 476MHz RF reference for whole linac
- Each Sector (100m of linac) MDL x 6 to 2856MHz that feeds subBooster that feeds individual klystrons
- 10° to 60° diurnal phase changes of subBooster reference phase correlated with temperature and pressure in MDL (gas filled coax)
- Feedback minimizes large phase drift for better energy and bunch length stability leading to better emittance stability



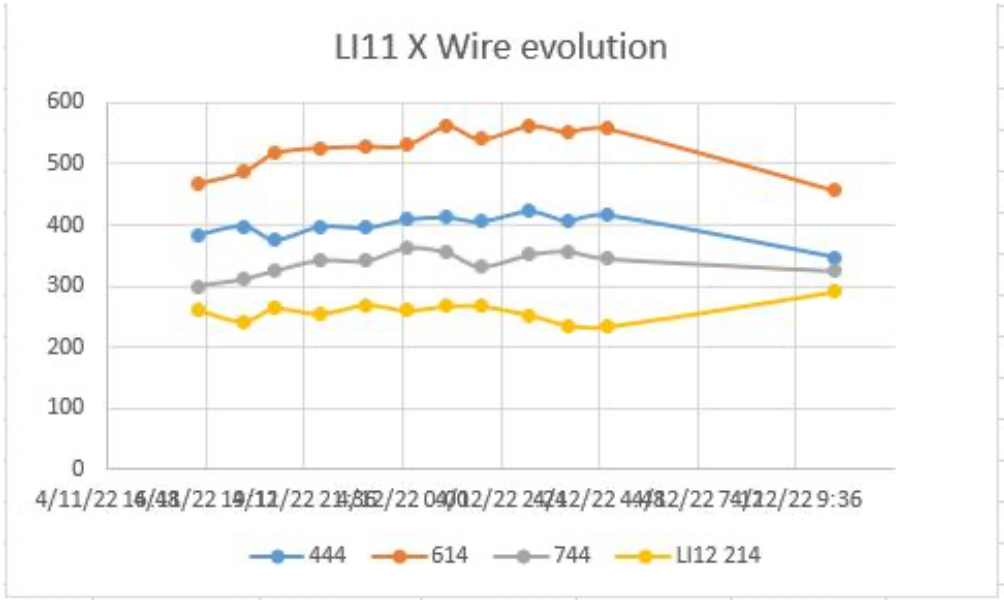
RF Phase and Amplitude Jitter

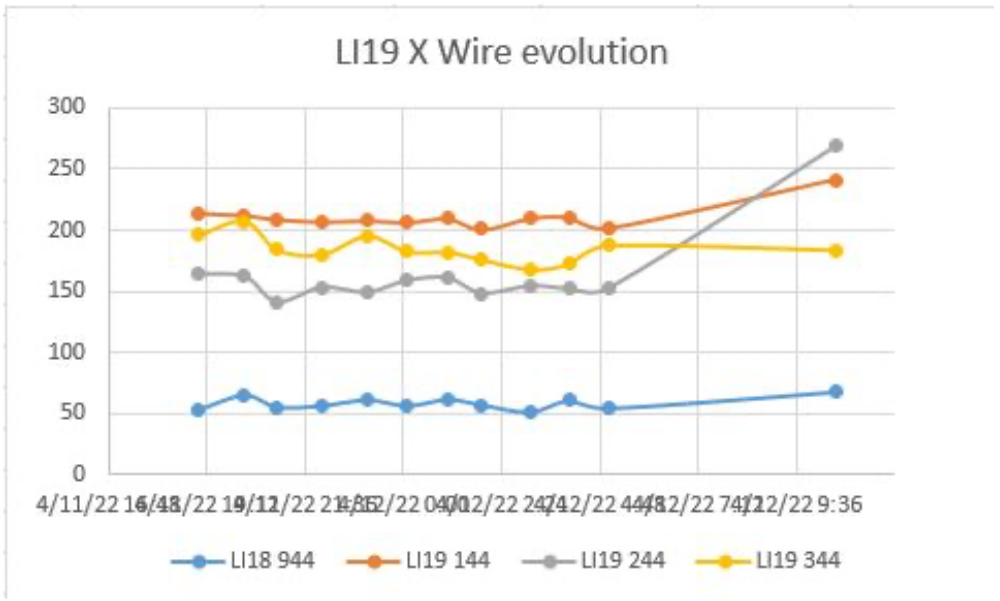
- Ongoing effort to identify individual RF stations that have large or intermittent jitter
- Intermittent nature requires vigilance and some trial and error to identify root cause and correct for it

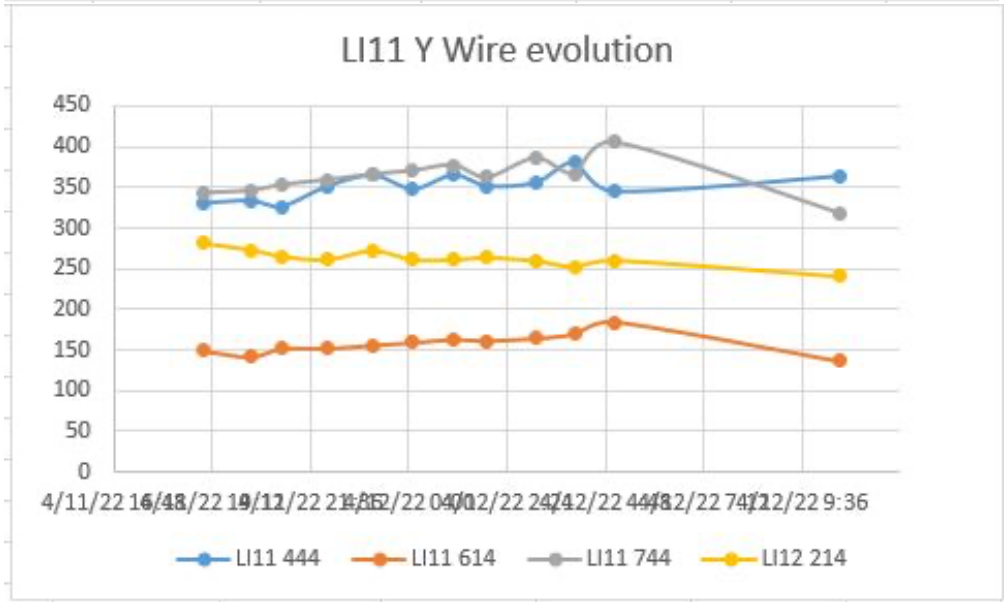


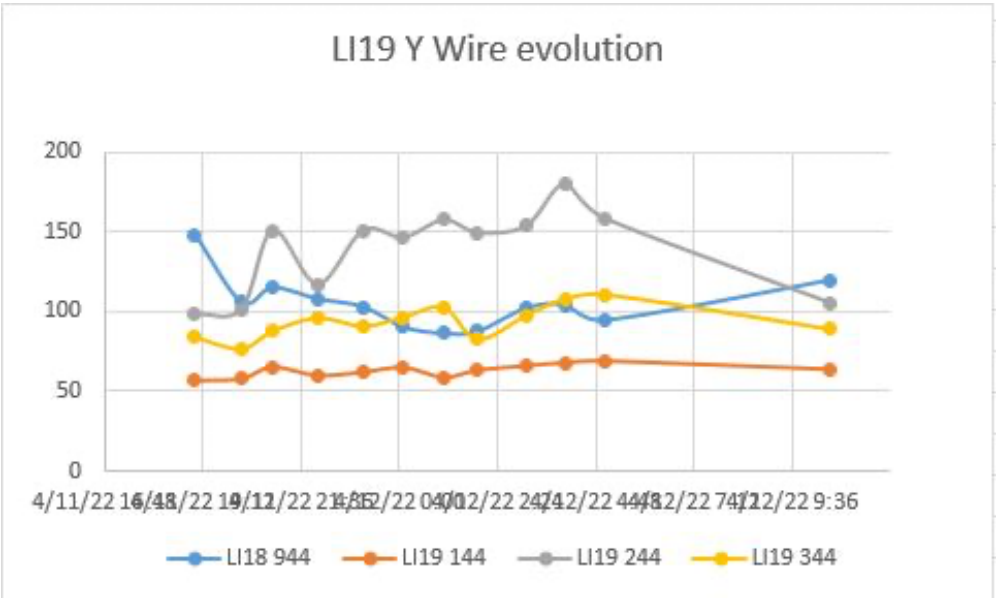


Improved Rf Stability Leads to Better Emittance Stability









Schedule for Remainder of FY22

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LCLS/LCLS-II Schedule continues to evolve

- Summer downtime eliminated except for two weeks plus PPS testing
- LCLS-Cu run extended through August
  - Opportunity for FACET-II to run as well
- LCLS-II will be commissioning through August
  - Limited access to FACET-II area while LCLS-II is running

Current FACET-II Schedule:

- May - June: User programs with transition to 2nC
  - Expect PAMMs every two weeks
  - June 20-29: Downtime with 6+ days tunnel access
- July - August: Opportunity to run pending funding and burn rate
- September: Off for PPS certification and summer downtime
- Other: Ops Review (June 14-15, HEP IR July 6-8, Snowmass July 17-26)

Additional User time is possible in Q4

Summer FY22:
Continued Upgrades Towards Beam Quality

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Sector 20 Final focus:

- **Electron beam spectrometer focusing** ✓
  - Compatibility with round beams and differential pumping
- **Final Focus** ✓
  - Compatibility with differential pumping
- **Differential pumping** (see talk by Doug) ✓
  - Windowless operations with intense low emittance beams
- **Deflector cavity relocation** ✓
  - Horizontal deflection -> single shot longitudinal phase space measurement

In progress:

Sector 20 chicane upgrade (electron arm) On hold

- Improved beam quality enabling compression to extreme beam currents

Sector 10 Injector Laser heater (see talk by Claudio) Spring/Summer 2022

- Control and beam quality for compression for two beam operations

Sector 11 X-Band linearizer TBD

- Control and beam quality for compression to extreme beam currents

Additional upgrades coming for improved performance, stability and control

Ongoing Challenges for Li Oven and 1Hz

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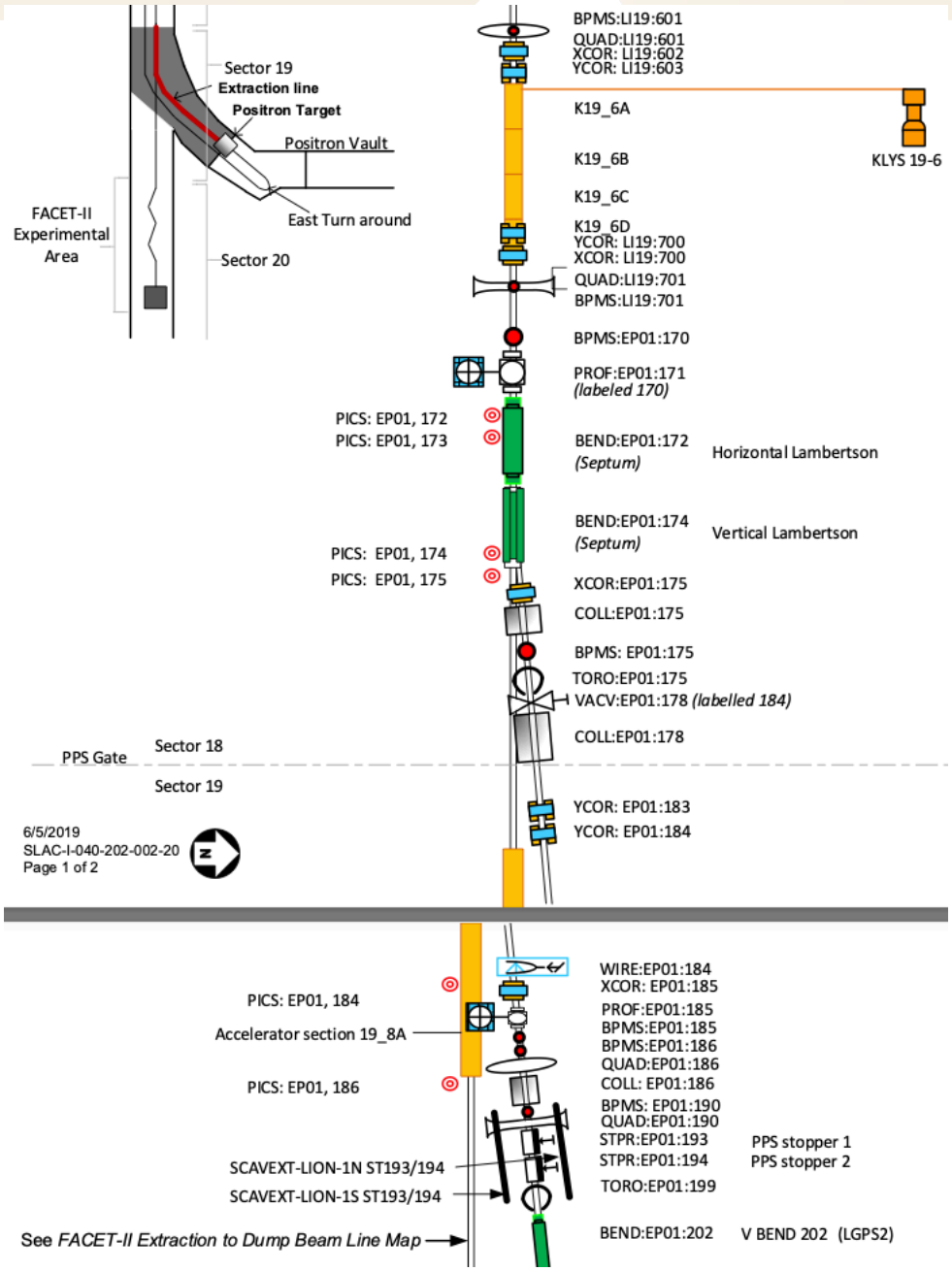
Beam to scavenger line and/or positron target

- FACET sent 0-10Hz to positron target
  - Allowed feedbacks to work while experiments get lower rate if needed
  - Avoids beam loss around experimental instrumentation while tuning
- Per RP, no beam to target until plan to replace or fix the target is in place
- Plan A – negotiating to send beam to scav line stoppers as interim solution
  - Working through concerns about ground water activation, penetrations…
  - Considering longer cooldown before tunnel access
  - Initial estimates are not encouraging (>15 tons of shielding)
- Plan B – remove magnet and build temporary dump away from aisle, penetrations
- Plan C – positron target repair (uncertainty in scope and timeframe)

Capability to send stable beam to IP at 1Hz with higher rate in the linac is more than a month away – topic for discussion

Overview of Extraction Line and Stopper Location

- Designed for 32GeV, 8nC/ bunch, 120Hz
- FACET 20GeV, 3nC, 10Hz
- FACET-II 10GeV, 2nC, 30Hz
- Stopper location is near S19 staircase used to access experimental area
- Use of stoppers may require longer cooldowns, additional shielding or other mitigations per ALARA



Summary

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- 3 of 4 Objective KPP routinely delivered (Energy, bunch length, emittance)
- Expect 4th Objective KPP (bunch charge) expected soon
- Continuing to identify and address items affecting stable delivery to User Area
- Planning for User delivery May-June with possibility for some of July-August
- LCLS-Cu/LCLS-II schedules present opportunity for additional running July-August pending funding and burn rate
- **1Hz operating will not be available for some time presenting options:**
  - Common need for diagnostic and spectrometer characterizations
  - Need MD shift to characterize how quickly beam quality deteriorates when drop linac to 1Hz (mover bellows have lifetime/cycle limit)
  - Alternatively: 2nC, 10GeV, 10Hz = 200W, with 50% into wake = 100W extra oven power over nominal 560W(?) – can we run with profile that allows safe variation of oven length by 10-20%?