FAST Linac Experiments for the Development of LCLS-II Injector Diagnostics:

A unique and enabling test-bed

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SLAC NATIONAL ACCELERATOR LABORATORY

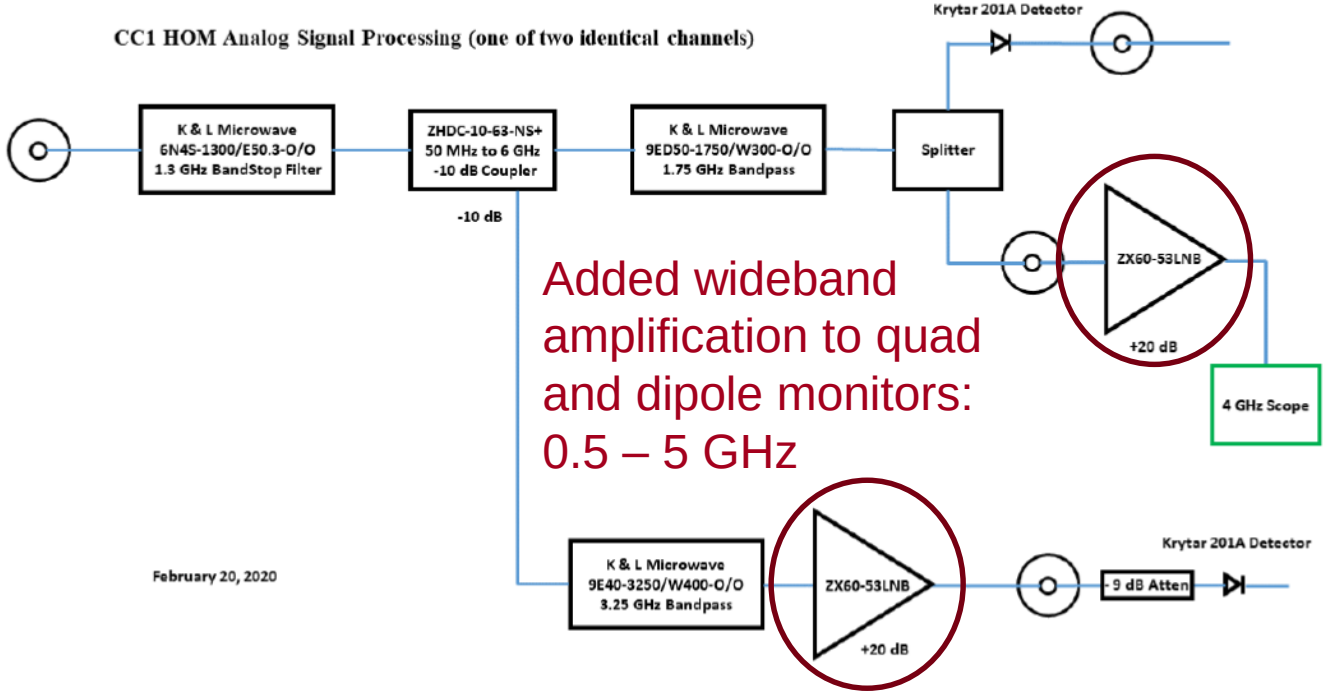
Motivation: SLAC concern for LCLS-II injector

- LCLS-II cryomodules:
  - Only 1 BPM and located at the downstream end
  - No information on low-energy cavity steering, most critical
- Issues with HOM wakefields excited by off-axis bunches in SRF Tesla cavities
  - Long-range wakefields (LRW) – bunch train oscillations
  - Short-range wakefields (SRW) – head/tail emittance dilation
  - Especially for low energy injection (750 keV)
- Excitation detected through HOM damping antennas (2/cavity)
  - Minimized signals corresponds to best trajectory through cavity
- Goal: Instrument LCLS-II injector cavities with HOM beam offset monitors for commissioning (human operators) and FEL optimization (feedbacks, machine learning, fault prediction)

Project background and overview

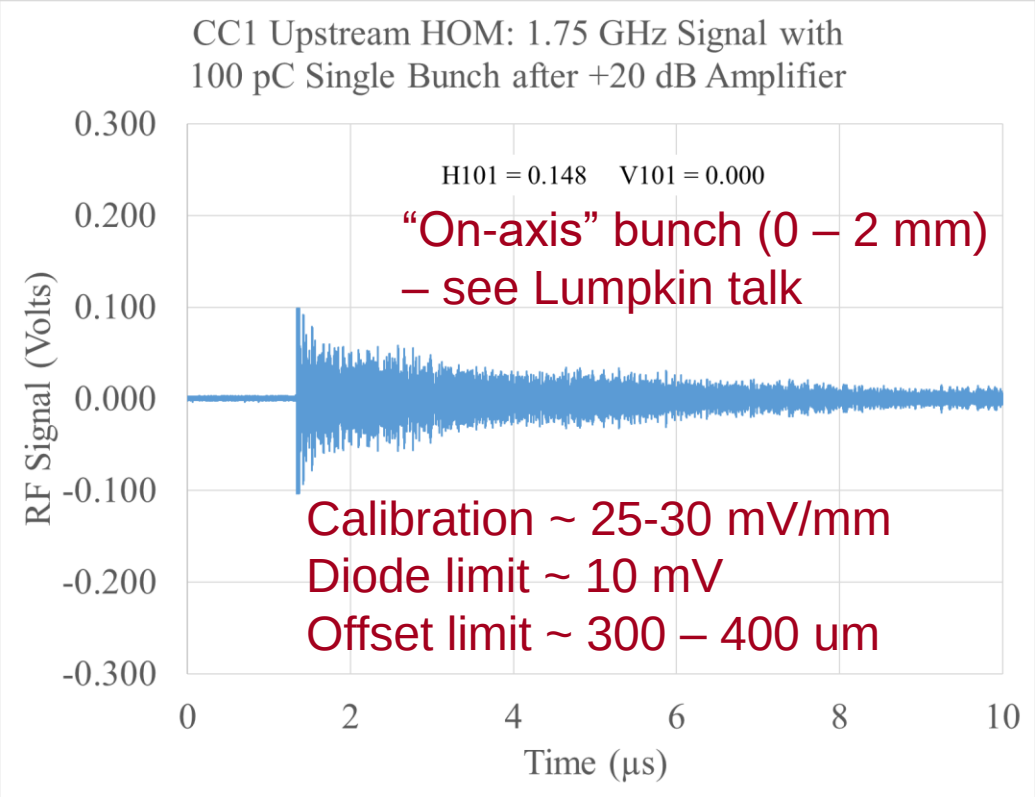
- Initial conversations between SLAC and FNAL at FEL and IBIC in 2019
- Proposed study at FAST fall 2019
  - Physics studies, signal characterization, detector prototype test
  - **Proposal process straightforward (especially w/ insider guidance)**
- 6 shifts approved in Run 2 **(ended up with 2 bonus ½ shifts)**
- Tested modified detector for use @ SLAC optimized for LCLS-II beams
  - 100 pC and lower bunch charges
  - Needed 20 dB wideband amplification
  - Successful demonstration informed HW requirements (now in procurement)
- Proposed shifts in Run 3
  - 5 shifts to test detector prototype and LRW/SRW analysis applications in CC1/CC2
  - 3 shifts with detector prototype LRWs in CM2 at typical injected beam energies
  - 4 – 6 shifts HW, ML, SRWs (*if OTR available) in CM2 at typical and lower energy injection
- Deploy full system at SLAC for LCLS-II injector commissioning
  - Early 2021 + Covid19 delay

Milestone met: modified detector electronics



- The 1.75 GHz signal from a single 100 pC bunch was recorded on a 4 GHz scope, with different settings of magnet V101.

Scope monitor tests: LCLS-II style bunch Feb. 2020



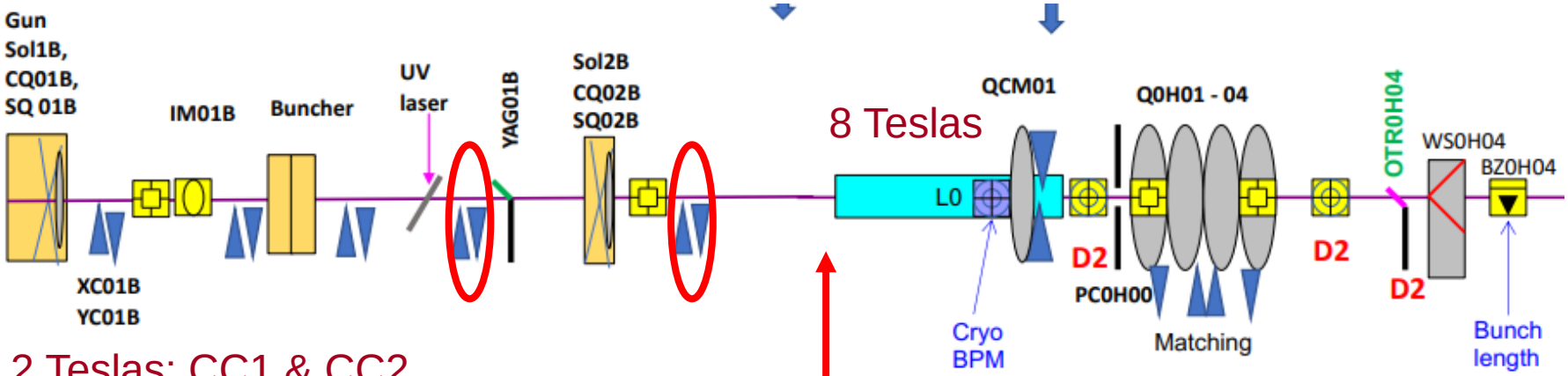
Shift amplifier tests:

- 20 dB amplifier added to CC1 HOM signals after the 3.25 GHz (quadrupole mode) filter inside the chassis
- For a single bunch low charge experiment, same model of amplifier added to the RF monitor of the 1.75 GHz (dipole) mode.

Conclusion:

For a single bunch of 100 pC, as for LCLS-II injector, the variation in the dipole mode signal from CC1 is easily observed by adding an amplifier

Sector 0 injector and FAST beamline comparison

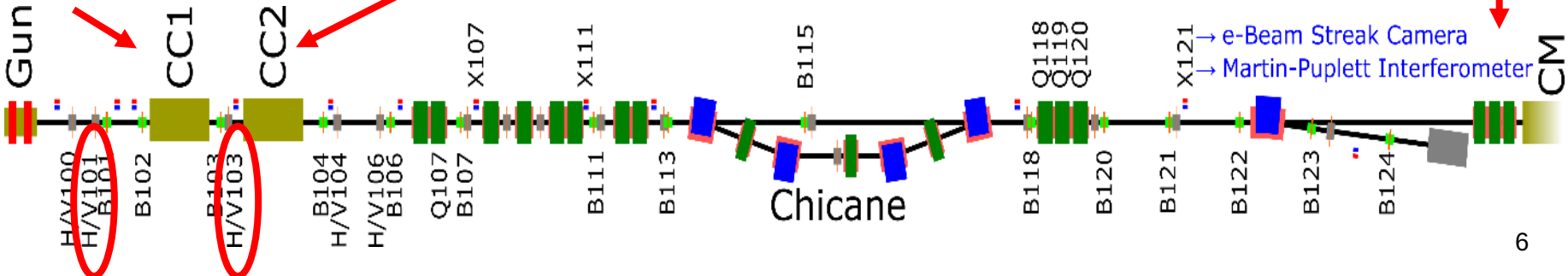


2 Teslas: CC1 & CC2

2 dipole
2 quad

2 dipole

Low energy transport to CM2 would inform LCLS-II injector commissioning



Plans for next run

- Propose new shifts for Run 3 as described in Alex's talk
- Maintain coordination with FAST team:
  - Prepare simulations of beam dynamics and transport for proposed operation modes ahead of shift assignment
  - Work with operations to translate simulated transport lattice into accelerator control system for setup verifications
  - Coordinate shipping and installations of prototype detectors
  - Consider the possibility of Covid-19 related travel restrictions and remote collaboration during beam shifts??
- Goals to achieve for LCLS-II commissioning:
  - Verification of modified HW – 2 chassis w/ 4 channels each
  - Understanding low-energy injection in 8-cavity cryomodule
  - Explore SRWs in CM2 with new OTR & streak camera *if approved

Summary – User experience at FAST: Very Nice!

Beam time scheduling was good overall thanks to run coordinators

- Willingness to accommodate lab-sponsored travel
- Working around unanticipated delays and equipment failures
- Reasonable shifts (all day, all swing, extra configuration setup times)

Availability of critical support personnel excellent

- Operations staff superb
- Expedited data collection and orbit changes through scripted automation
- More complex future setups can be obtained/optimized prior to arrival
- RF experts for detector modification
- Physics and analysis

User arrival and onboarding at FNAL pretty smooth

- Site access easy
- NML badge access
- Computing access
- E-log
- Calendar didn't work

We accomplished all goals for Run 2

Measured signals from 100 pC single bunches
Understand detector HW
Only use dipole modes

Synergy between labs/groups

Unable to develop this technology without NML test facility
Enhances SLAC accelerator and the larger DOE BES program
Develop tools that can stay at the user facility
Facilitate collaboration
Good sharing of cost between labs

Thanks to our collaborators!

- SLAC: Bryce Jacobson, John Sikora, Andy Benwell, Feng Zhou, Auralee Edelen, Jorge Diaz-Cruz
- Fermilab: Alex Lumpkin, Randy Thurman-Keup, Dean Edstrom, Jinhao Ruan, Peter Prieto
- AST Department for informative meetings
- Everyone at NML to help provide this great opportunity