LCWS13

Status of ASTA, CM-2 at Fermilab

Elvin Harms

International Workshop on Future Linear Colliders/SCRF Technologies

13/14 November 2013

U.S. DEPARTMENT OF ENERGY

Fermilab

Talking Points

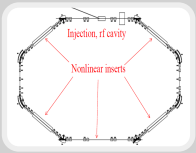
- Introduction to ASTA – an AARD User Facility (Advanced Superconducting Test Accelerator)
- Major Subsystems
  - Laser
  - Photoinjector Gun
  - Capture Cavities
  - Cryomodules
  - Electron Production
- Future plans
- Summary

the contents of this presentation reflects the work of many dedicated, highly motivated people at Fermilab and partner organizations

ASTA Science Thrusts

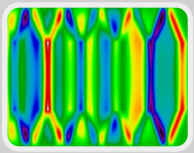
LCWS13

Intensity Frontier of Particle Physics



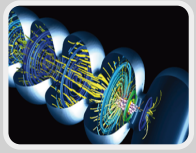
- Nonlinear, integrable optics
- Space-charge compensation

Energy Frontier of Particle Physics



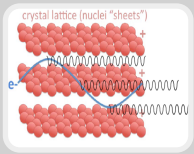
- Optical Stochastic Cooling
- Advanced phase-space manipulation
- Flat beam-driven DWFA in slabs

Superconducting Accelerators for Science



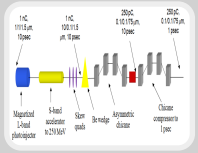
- Beam-based system tests with high-gradient cryomodules
- Long-range wakes
- Ultra-stable operation of SCLs

Novel Radiation Sources



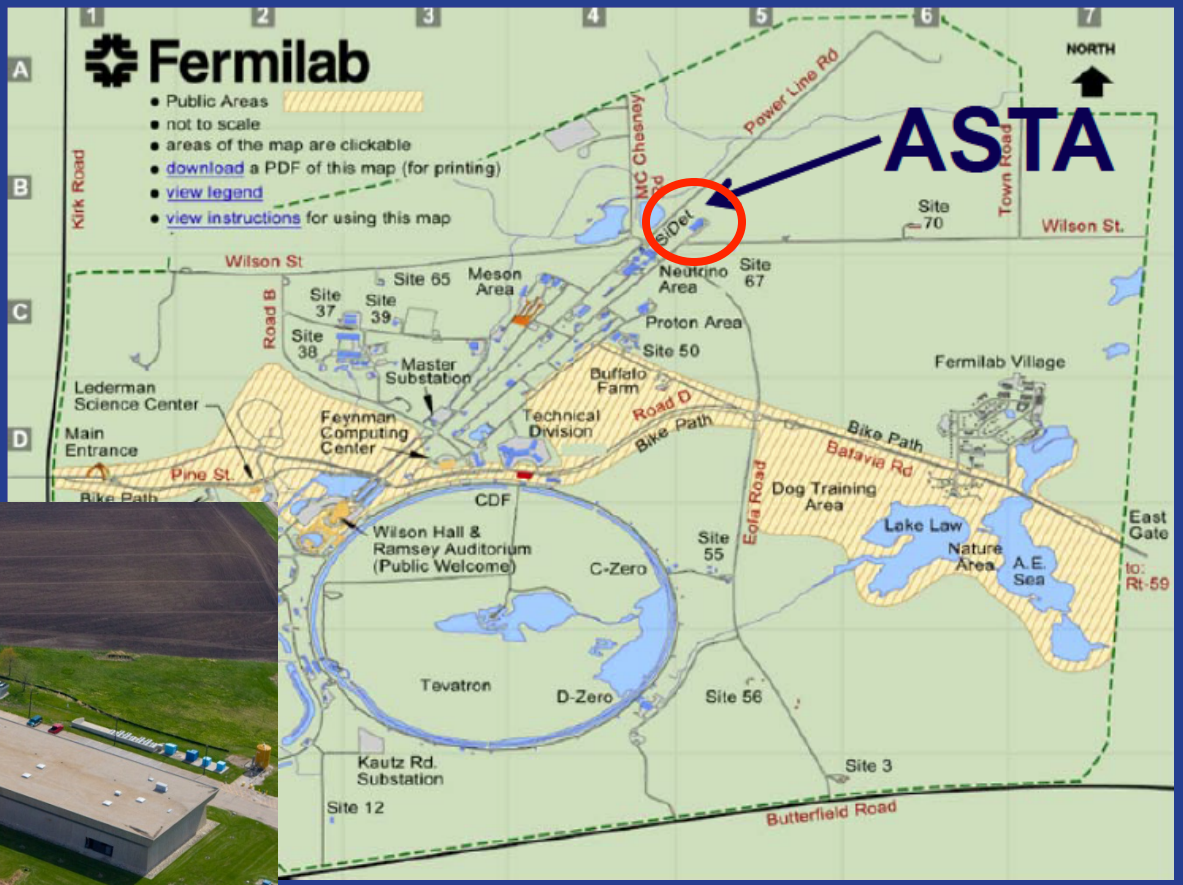
- High-brightness x-ray channeling
- Inverse Compton Gamma Ray source and applications

Stewardship and Applications

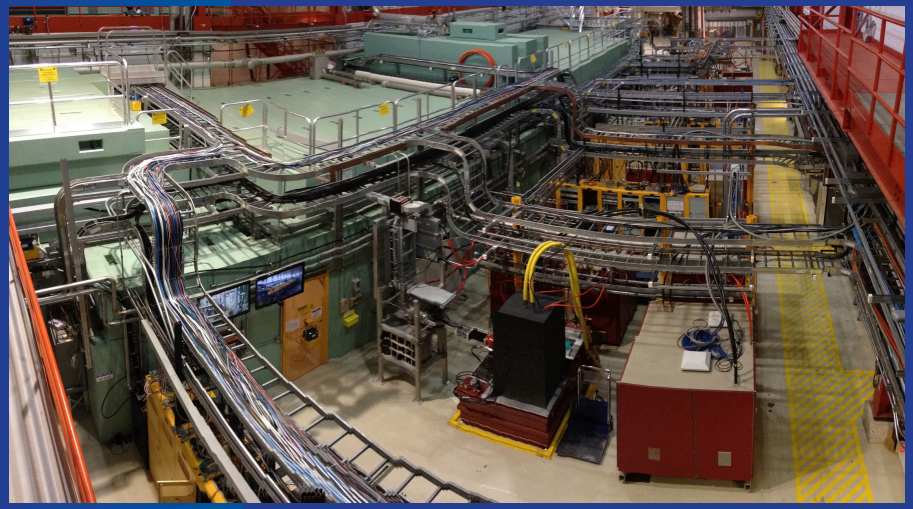


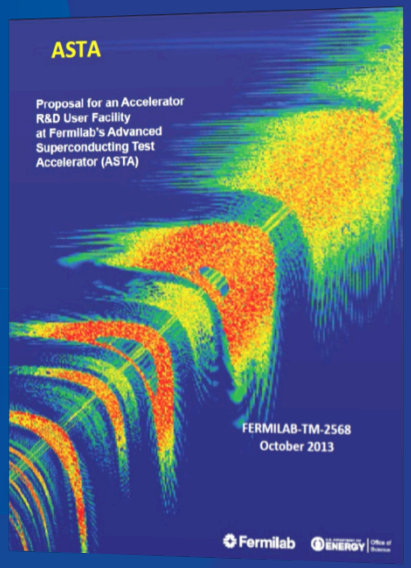
- Generation and Manipulation Ultra-Low Emittance Beams for Future Hard X-ray FELs
- Beam Dechirper for FELs

Overview of ASTA Facility



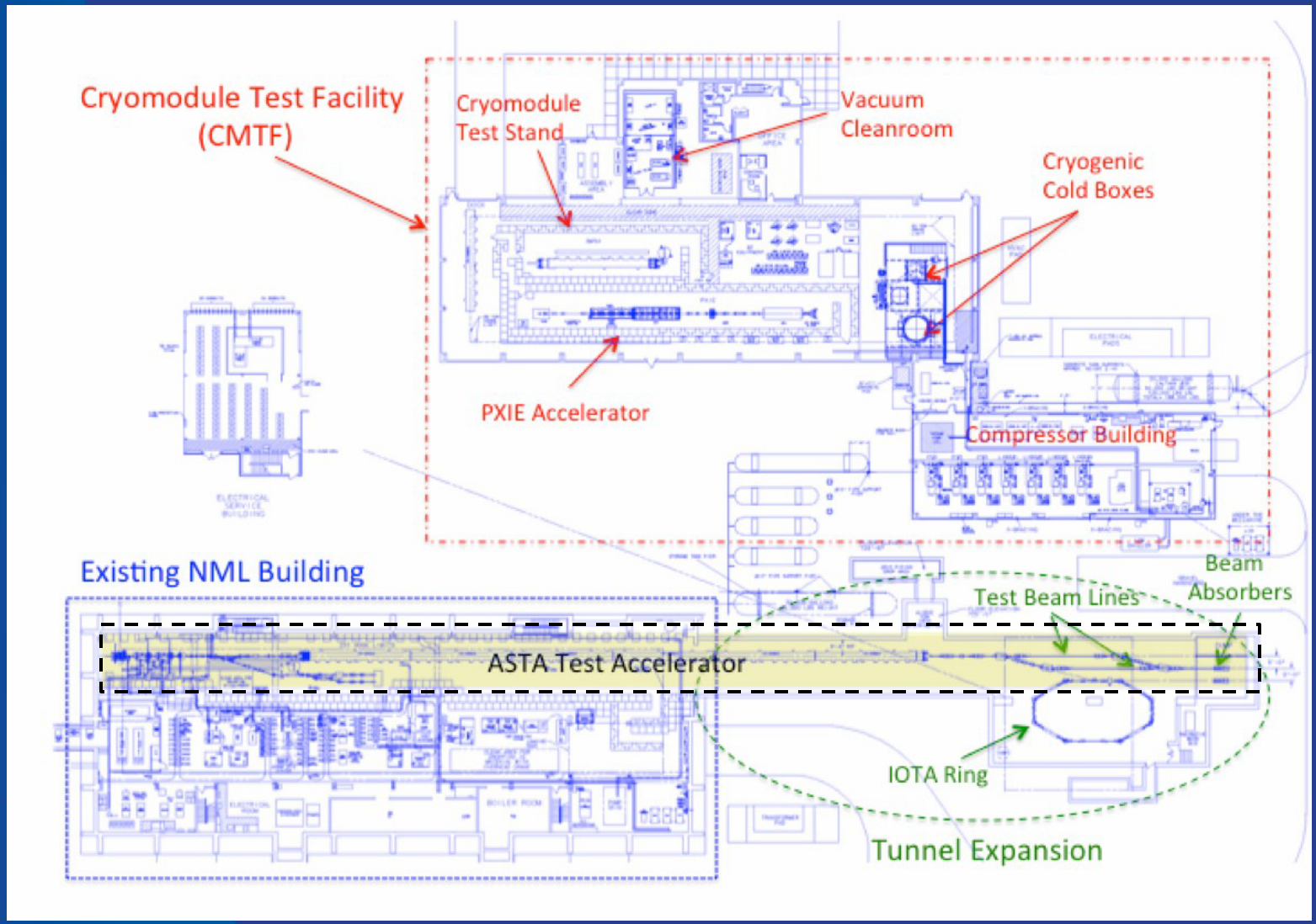
Overview of ASTA Facility





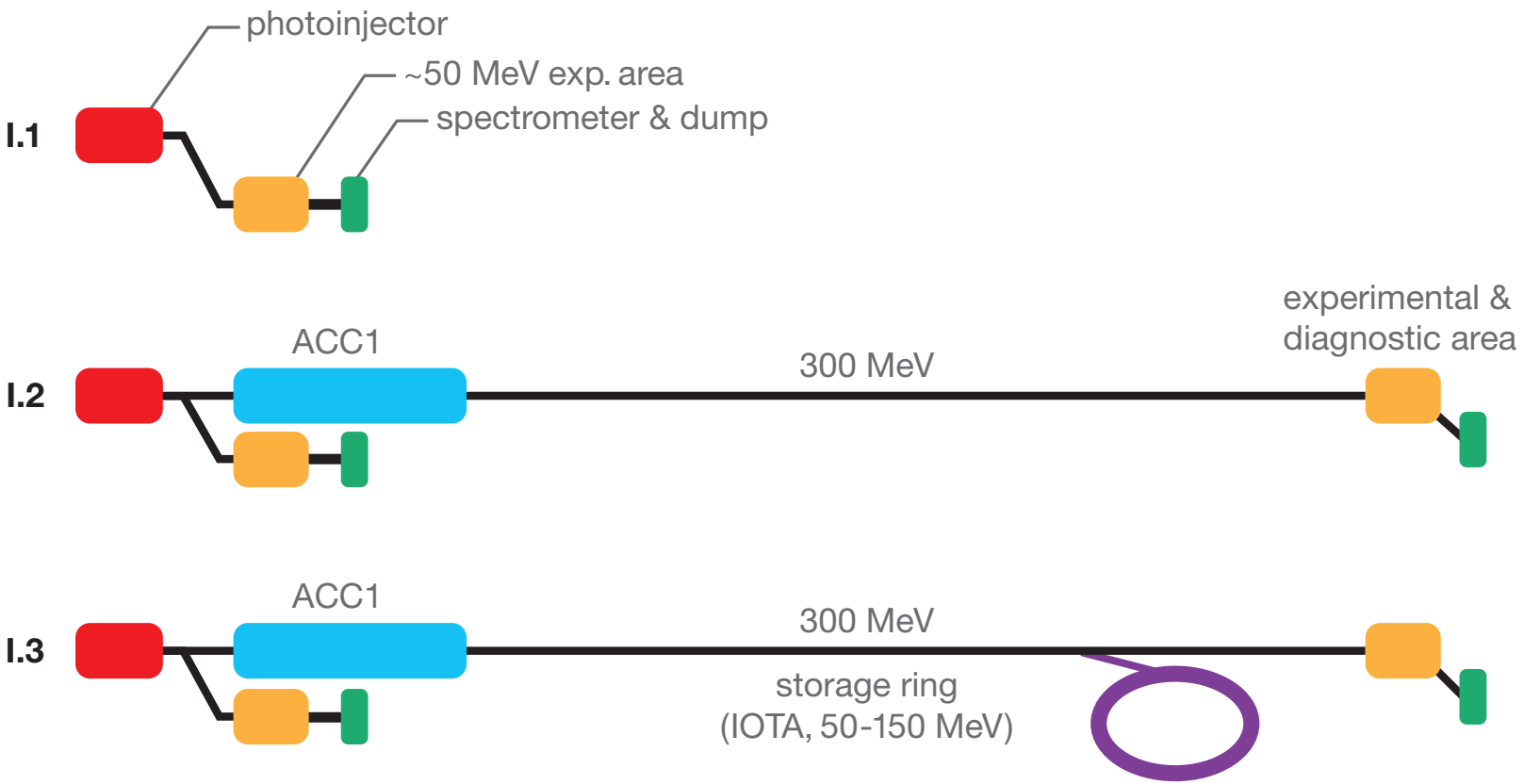
Proposal recently updated: asta.fnal.gov

Full ASTA Layout



ASTA Buildout and Operation Occurs in Stages: Stage I

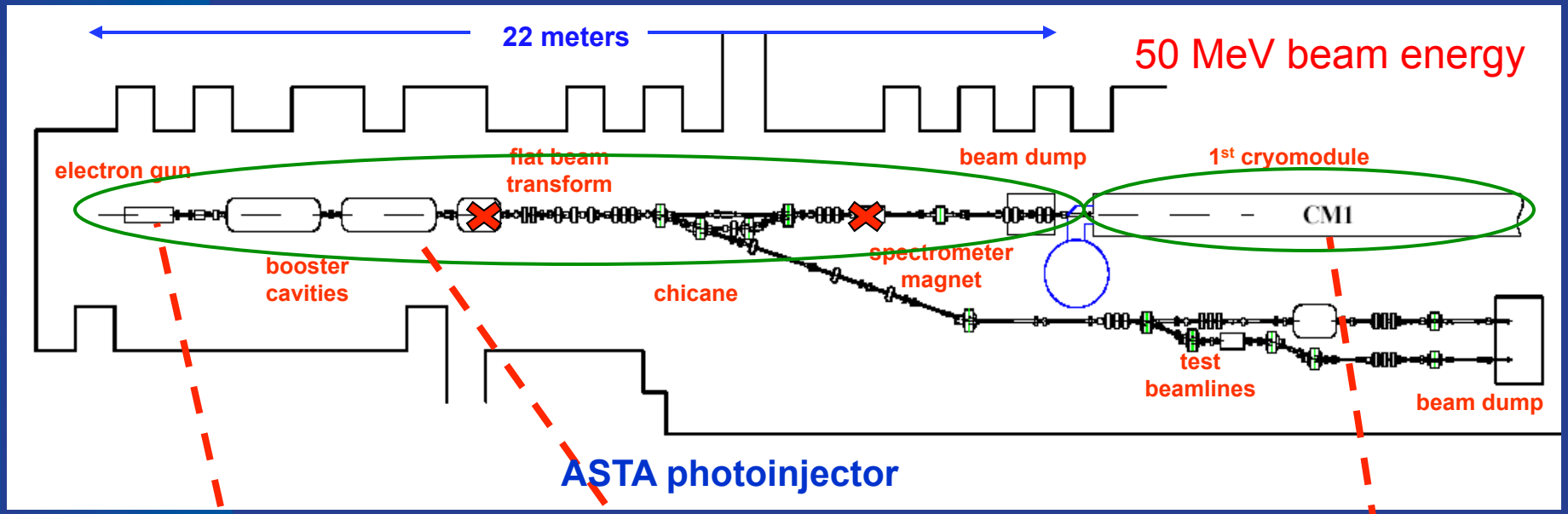
Stage I

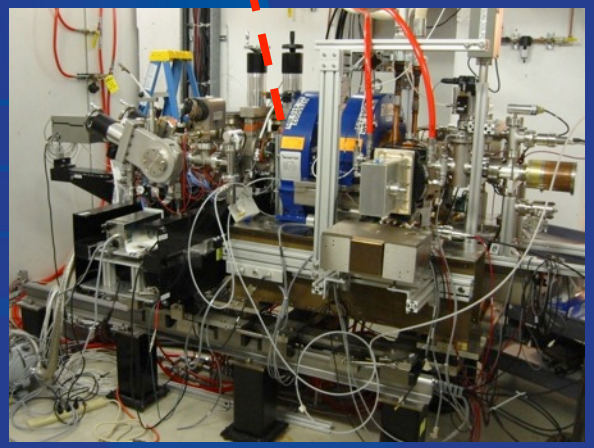


50 MeV Injector + 1 Cryomodule

- Goal: Installation complete and beam commissioning started in 2014
  - RF gun + RF system and photocathode laser system
  - 2 SRF booster cavities (CC1 and CC2) + RF systems
  - 50 MeV Injector beam line elements and instrumentation to the low energy dump
  - Low energy beam dump
  - SRF cryomodule (CM2)
  - High energy beam line to dump
- Installation of 1st AARD experiment (high brightness X-ray channeling source)

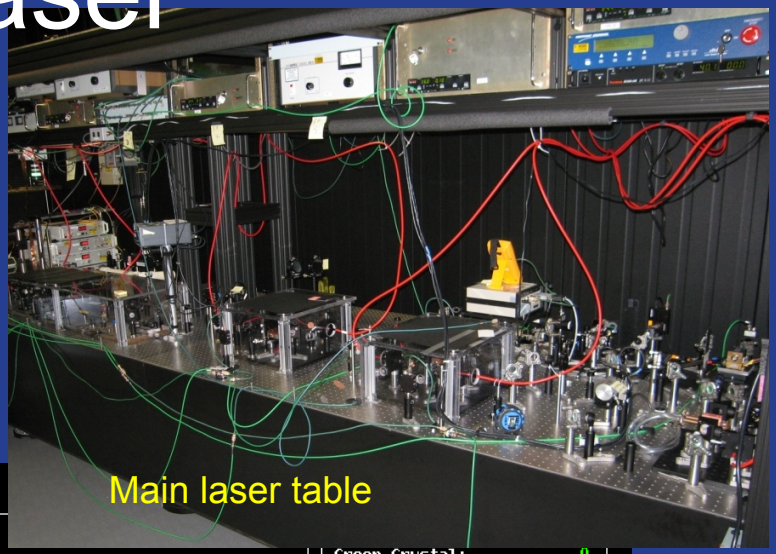
Stage I.0: Expected Configuration in 2014 (Completed 50 MeV Beamline)

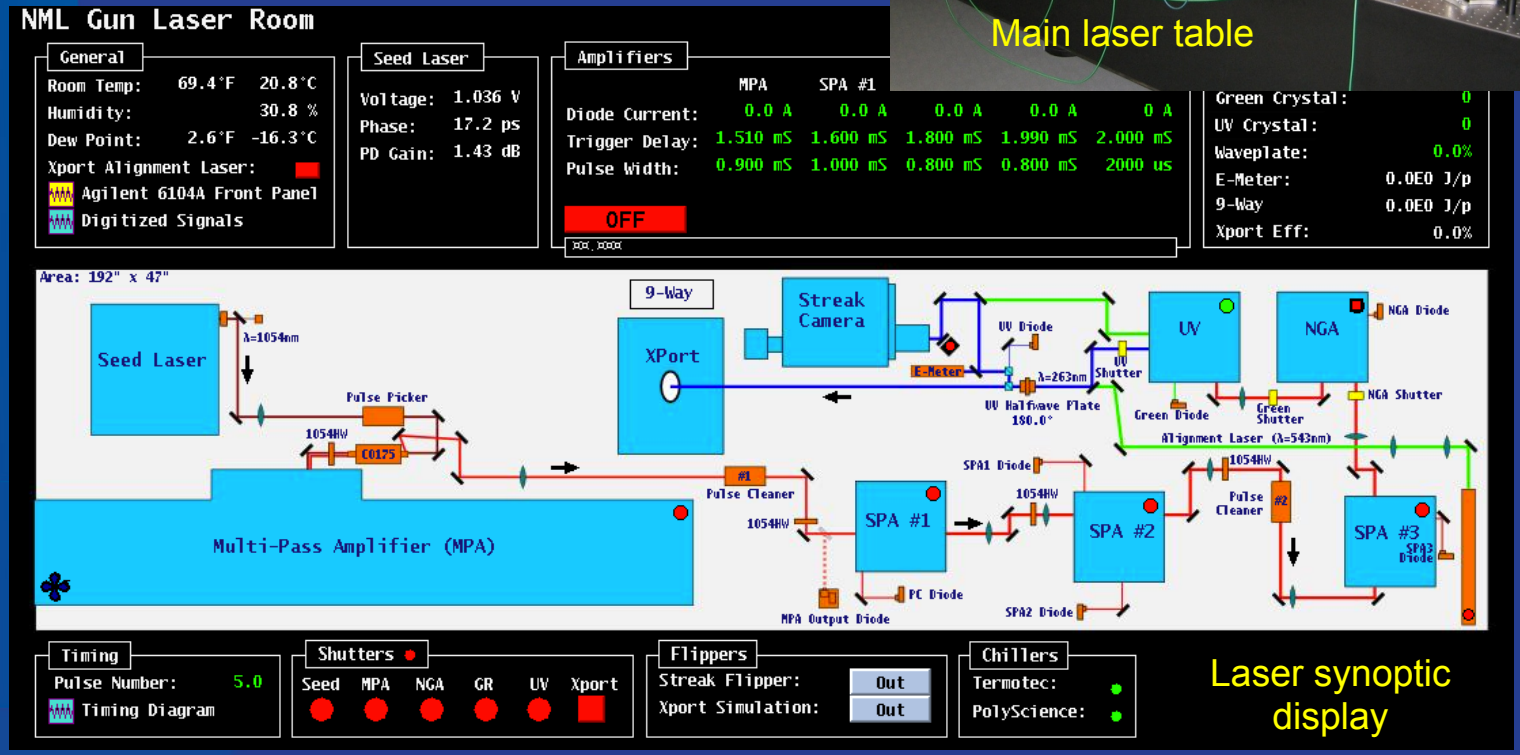




Photoinjector Laser

- Commercial 1054 nm Yb-fiber seed laser operating at 1.3 GHz; followed by 1 multipass, 3 single pass, and commercial amplifier, pulse-picked to 3 MHz, and frequency quadrupled to 263 nm UV
- Can now deliver 25 μJ, 300 μsec pulse train (UV): delivered charge - 37.5 nC

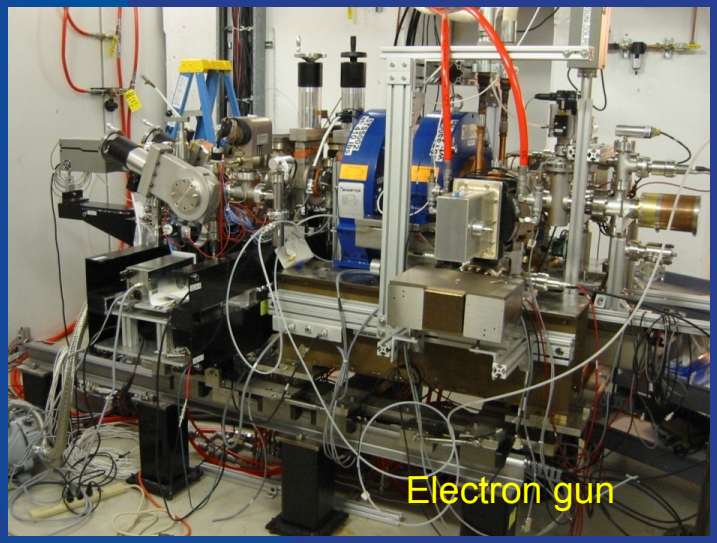


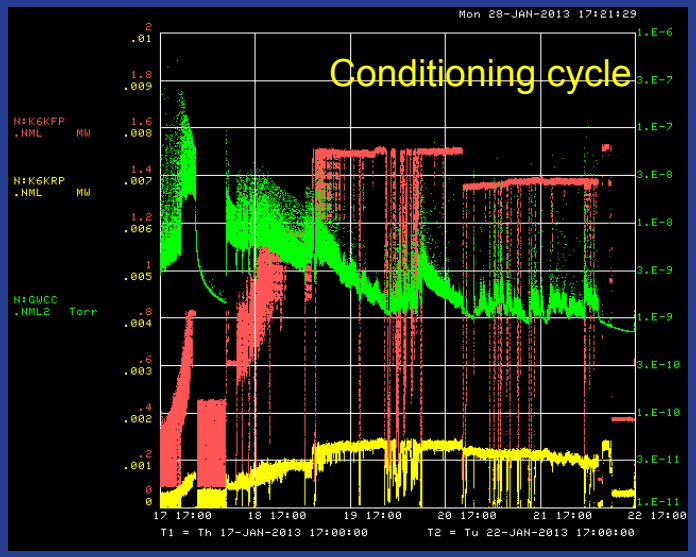


Laser synoptic display

Photoinjector Gun

- 1.5 cell copper L-band (1.3 GHz) photocathode gun (identical to FLASH design)
- Focusing Solenoids
- Water cooled
- Installation of cathode system, gun, and coupler was completed in Nov. 2012
- Conditioning started on Dec. 27, 2012.



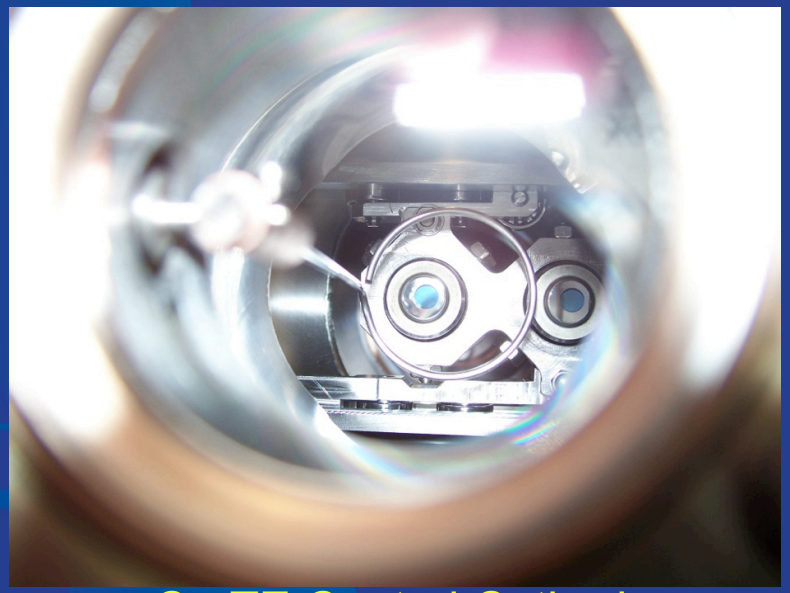


Photoinjector Gun

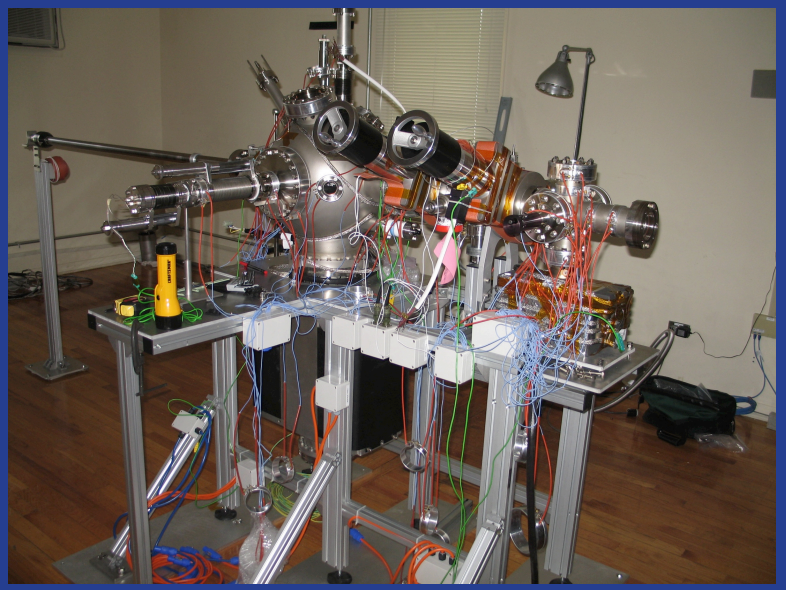
- Five RF Windows high power tested (conditioned) to 3.8 MW, 1 millisecond pulse width in 2011
- First stage Coupler/Gun Conditioning completed to 1.2 MW, 1 ms pulse width, 5 Hz repetition rate
- Second stage of conditioning in progress
  - Up to 2.55+ MW, 1 ms, 5 Hz
  - 2.68 MW, 1 ms, 1 Hz continuous for 4 hours achieved
- Typically running at ~1.8 MW now
- Klystron will be upgraded to a 5 MW model
  - Gun-cavity will be conditioned up to ~ 4 MW / 1ms / 5Hz.

Photoinjector Cathodes

- Currently operating with an uncoated Molybdenum plug
- 3 Cs_2Te 'coated' cathodes in hand
- Preparing to install
- Coating/Preparation done at Fermilab



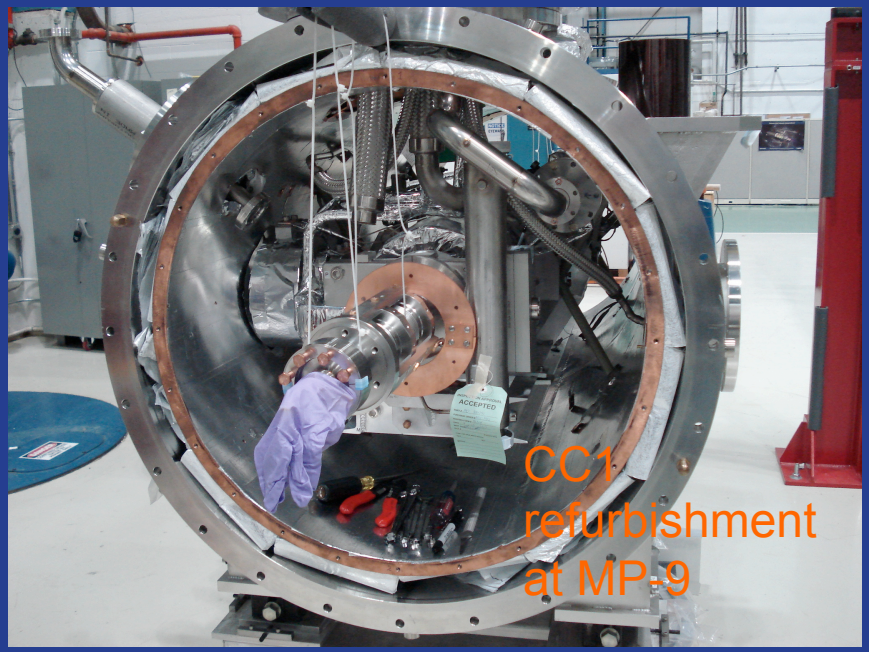
Cs_2TE Coated Cathode



Coating and Transport Chamber

Capture Cavities

- Two 'Booster' 1.3 GHz cavities – single cavities each in their own cryomodule
  - Each cavity is powered by its own 300 KW RF system.



Capture Cavities

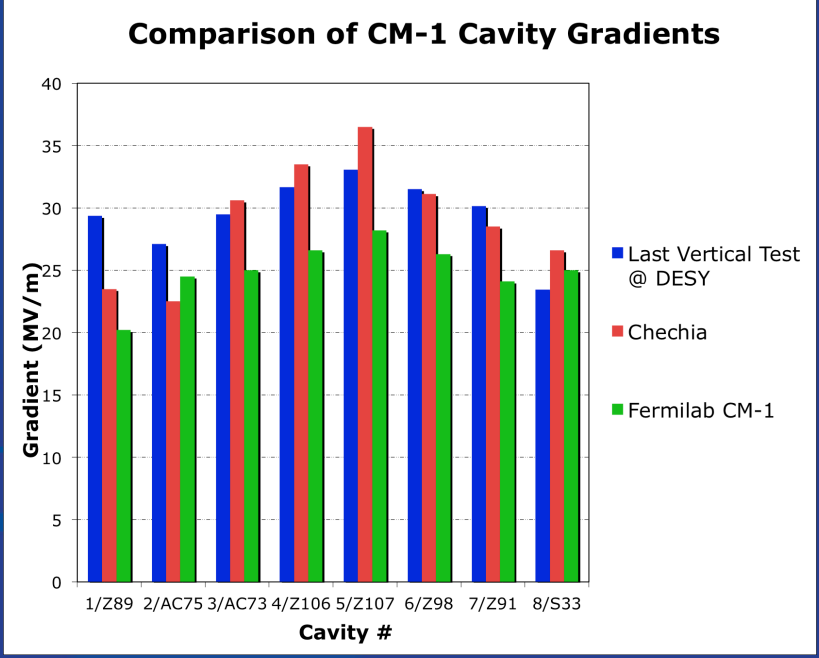
- Capture Cavity 1 was previously the A0 Photoinjector workhorse
  - (Significant) Upgrade in progress including new cavity
  - Dressed Cavity achieved ~29 MV/ m in January 2013 test at Fermilab's Horizontal Test Stand
  - 'Modern' cryomodule
  - Installation expected in December

Capture Cavities

- Capture Cavity 2 - first SRF device delivered and operational at NML
  - 22 MV/m, 1 ms pulse, 5 Hz
  - LLRF & LFDC operational
  - Recommissioning in progress
    - Warm Coupler Conditioning completed
    - Cooled to 2K this week and tuned to resonance (1300 MHz)
    - Begin cold powering today

Cryomodules – CM1

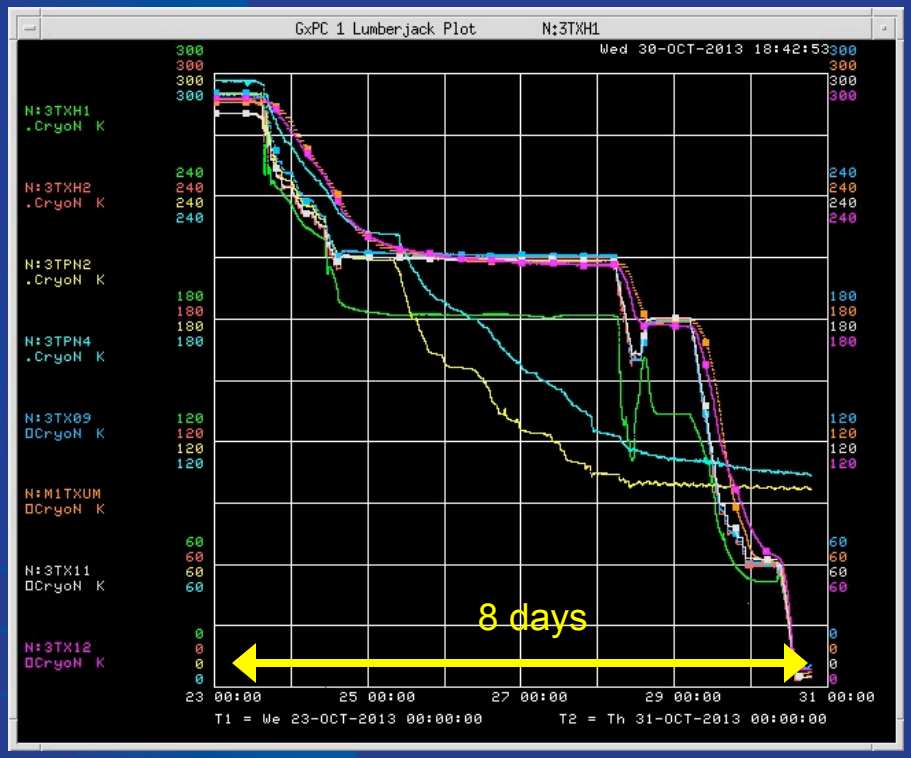
- Installed, cooled to 2 Kelvin, commissioned and operated from October 2009 – April 2012
- Peak gradients from 20 – 28 MV/m
- Detailed LLRF & LFDC studies
- Valuable experience on many aspects of SRF operation



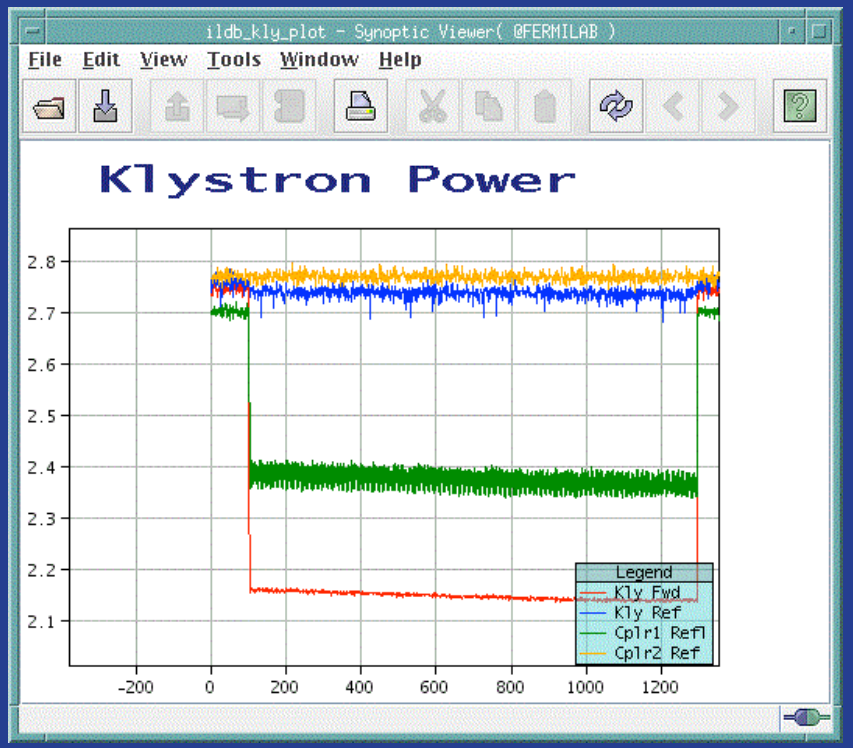
Cryomodules – CM2

- CM2 Commissioning in progress
  - Cryomodule installed in April 2013
  - Welding and cryo circuits leak checking and pressure testing complete
  - Warm Coupler conditioning complete (9 May – 18 June)
    - Each cavity powered to up to ~1MW with short pulse (tens of μs)
    - 500 kW long pulse (up to 1 ms)
    - 5 Hz operation
  - Cooldown to 2 K completed this past Monday
  - First powering earlier today, begin on-resonance conditiong of Cavity #1 tomorrow
  - Test plan includes individual cavity characterization followed by full module powering

Cryomodules – CM2

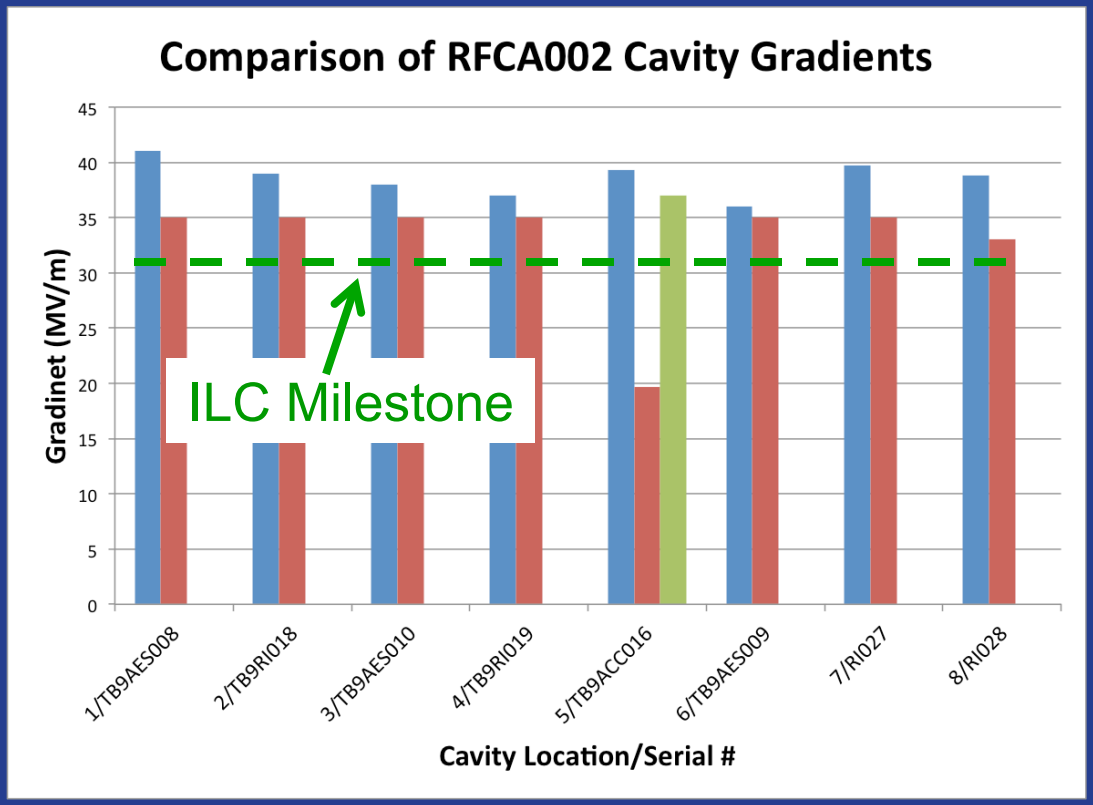


Cool down to 4 Kelvin



3 kW on CM-2 Cavity #1

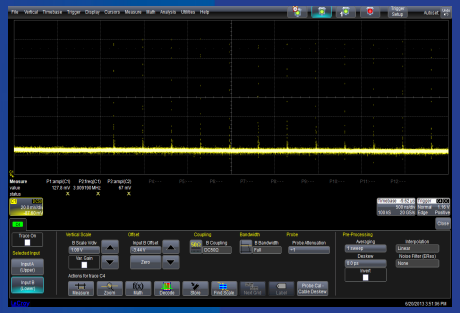
Cryomodules – CM2

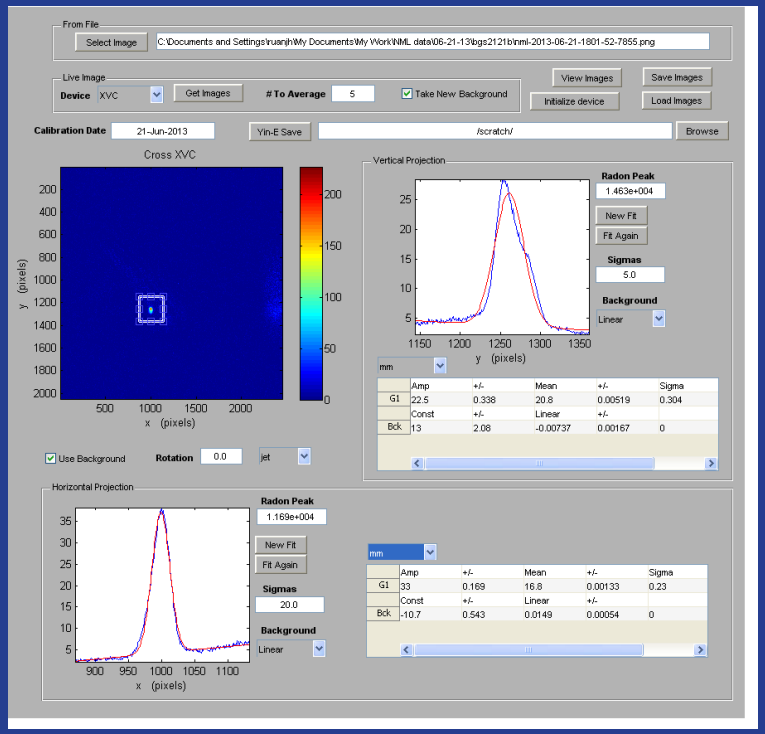


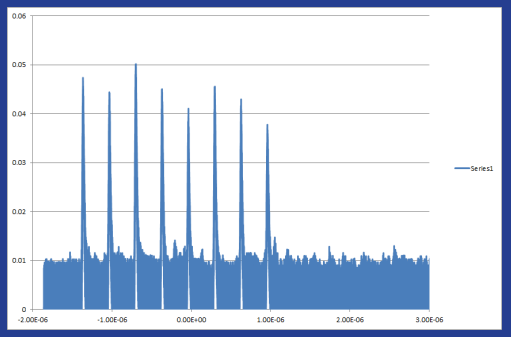
Electrons

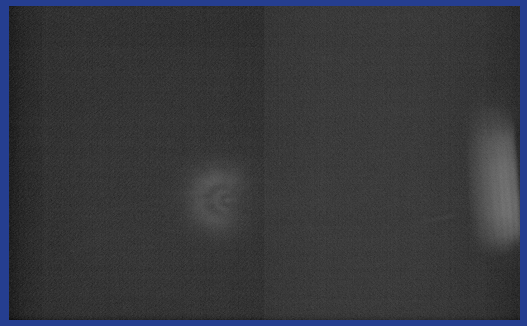
- Photoelectrons first produced at ASTA on 20 June 2013
  - Molybdenum (uncoated) cathode
  - Visible on Loss Monitor, Faraday cup, and Wall Current Monitor
- Electron operation since
  - 80 μs pulse, 1.8 MW peak power typical
  - Calibrate FC, WCM, look for BPM signals
  - RF Phase scans to optimize electron output
  - Low Level RF operated in closed loop
  - Extend pulse length/laser for more bunches
  - Exercising trim dipoles – verify beam movement, perform energy measurements

First Electrons









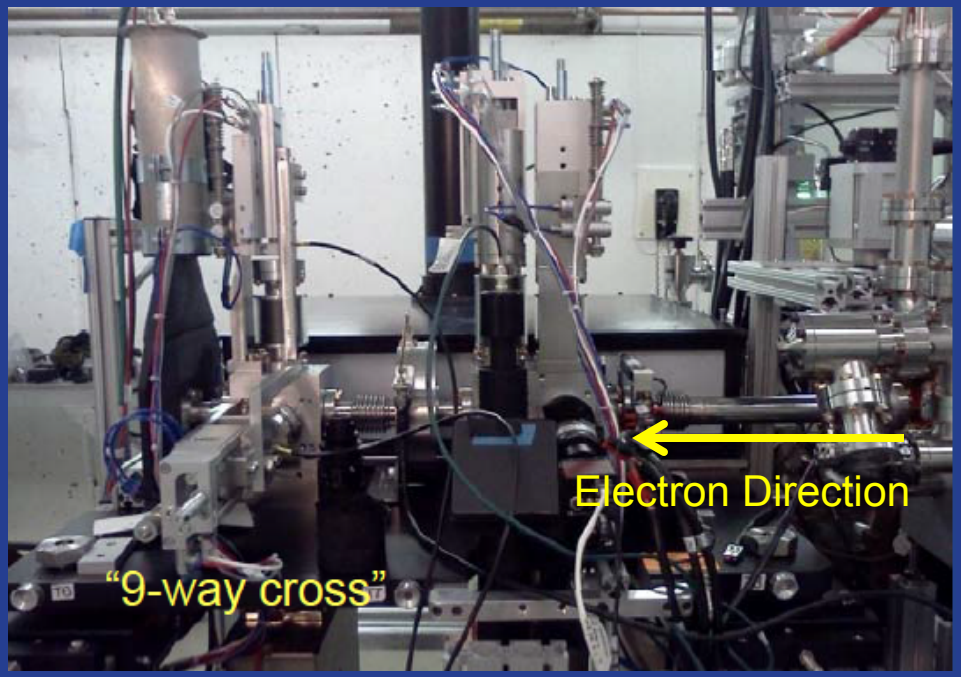
Electronic Logbook entry from first electron production:

5280, Mike Church (church), Thu, 06/20/2013 17:53:24 Gun/Commissioning

Summary of this afternoon's activities: We successfully produced our 1st photelectron beam from the gun into a Faraday cup. 8-15 pulses at 1 Hz rep rate. Conditions were approximately as listed in entry Entry #5273. Signal was observed on the resistive wall monitor, loss monitor, and YAG screen as shown in the last 3 entries. Hooray!

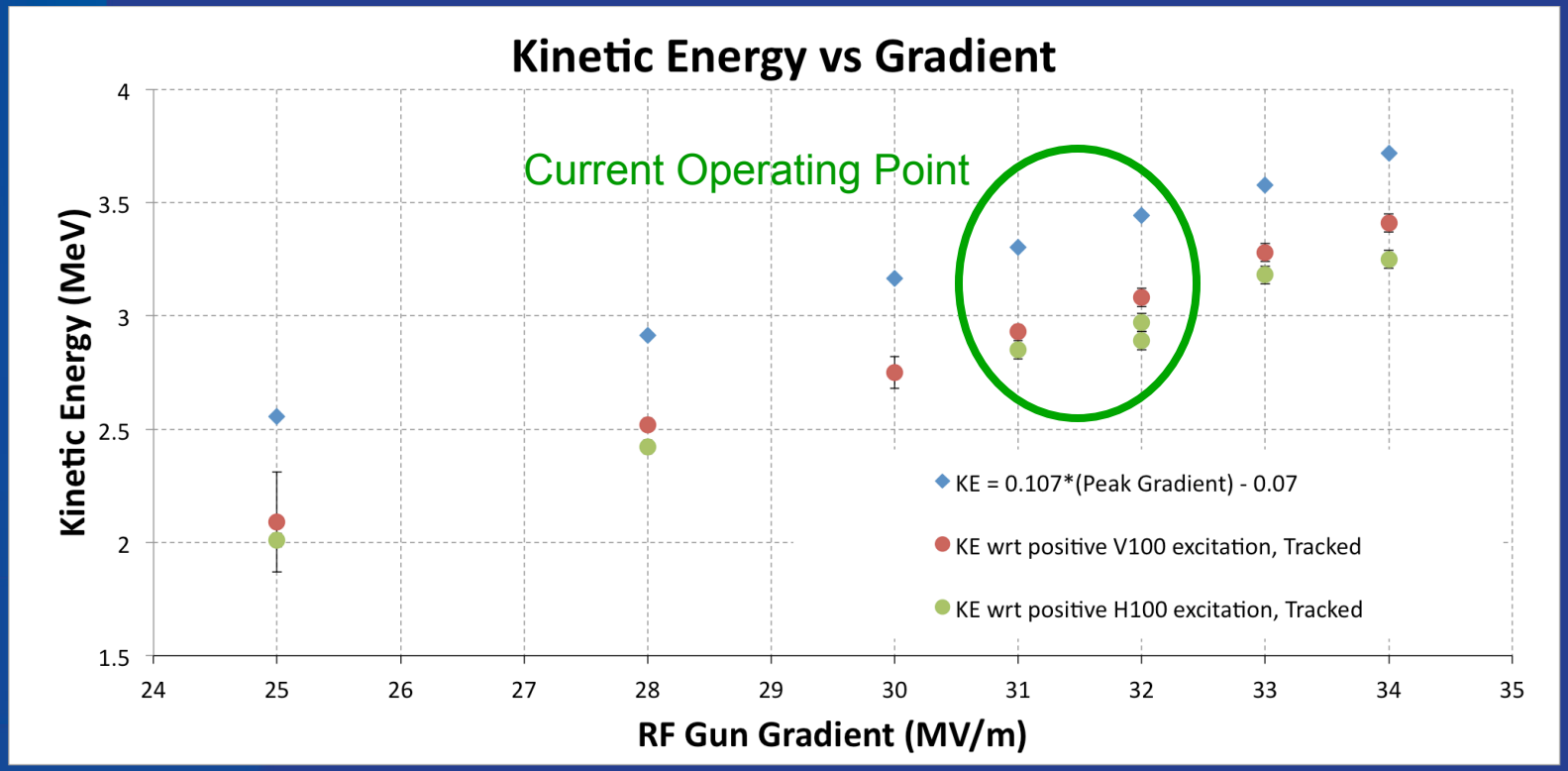
Electrons – 9-way Cross

- Instrumentation platform directly downstream of the gun containing
  - Laser optics
  - Laser Injection Mirror
  - YAG profile monitor
  - Cathode viewing mirror
  - Dark current collimator
  - Faraday cup
  - Wall Current monitor
  - 2 BPM's
  - 2 Corrector magnets
  - Vacuum pumping



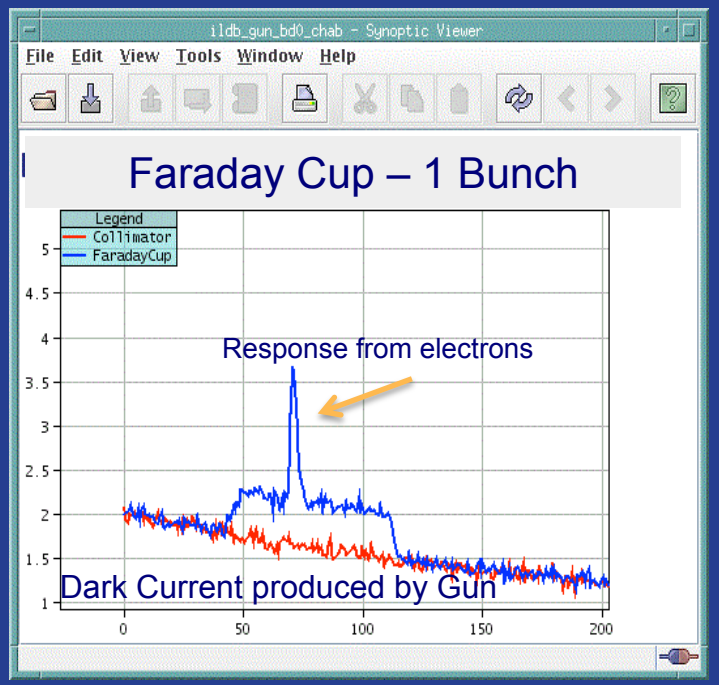
Electrons – Energy Measurement

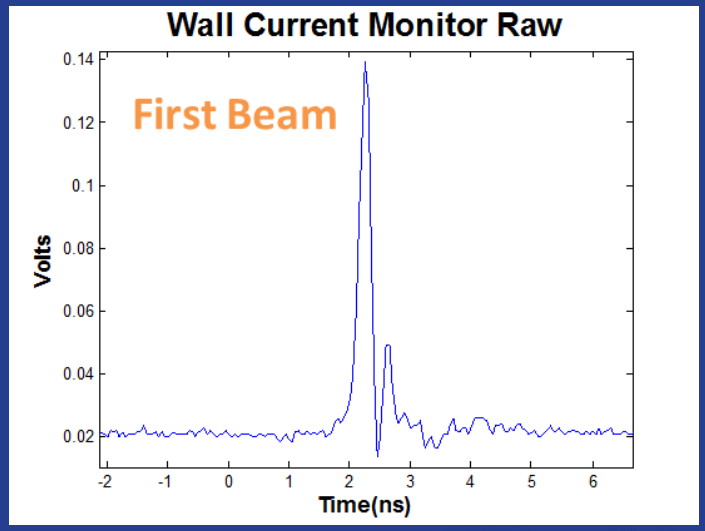
- Estimating Electron Kinetic energy by means of dipole scans
- Next step to scan solenoids



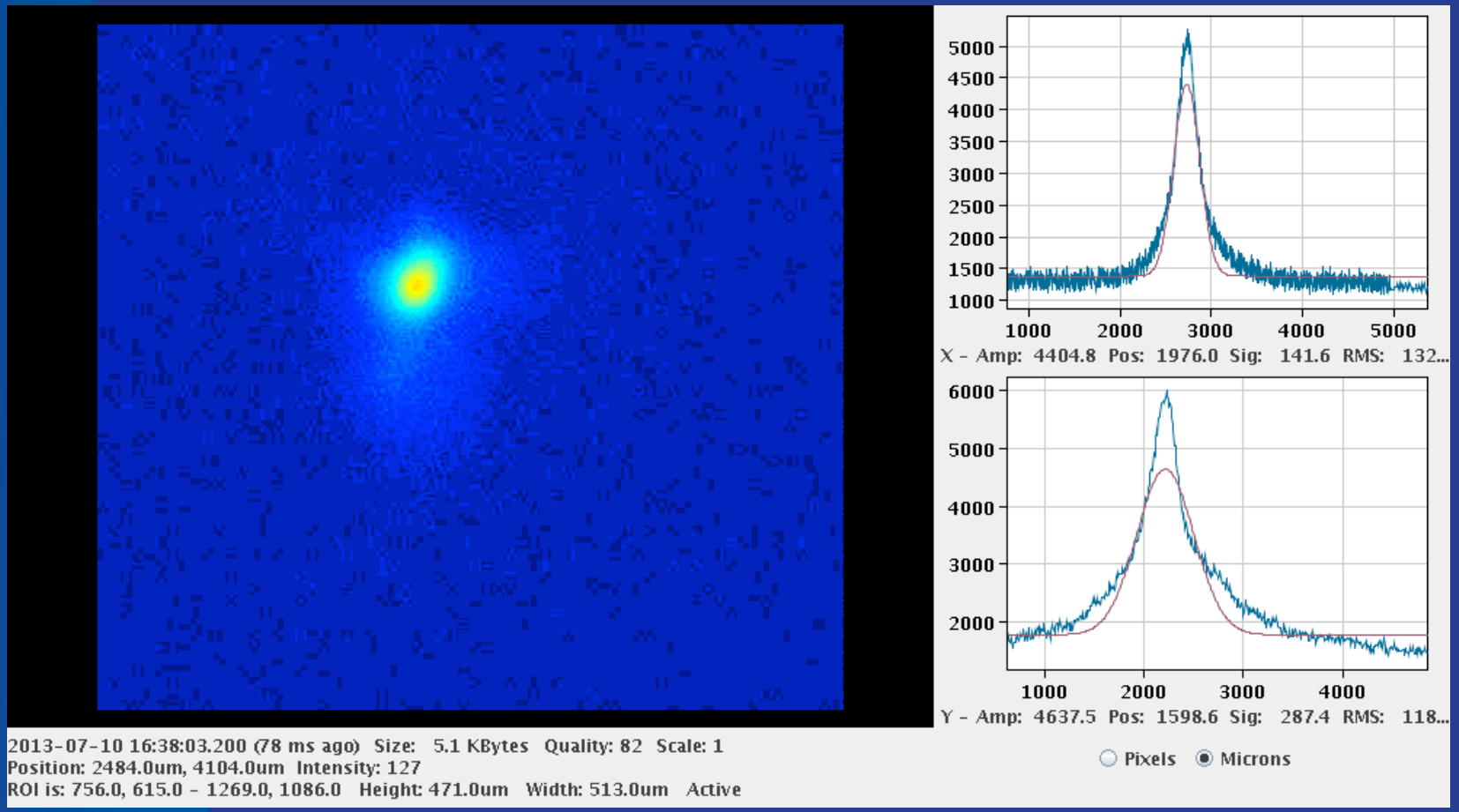
Instrumentation

- Faraday Cup measures total current on each pulse
  - Nominal Bunch Charge measured to be 0.5 picoCoulomb
- Wall Current Monitor is a complementary, non-invasive monitor
  - Verified charge produced with Faraday Cup





Instrumentation (2)



9-way Cross YAG Screen – 5 Bunches

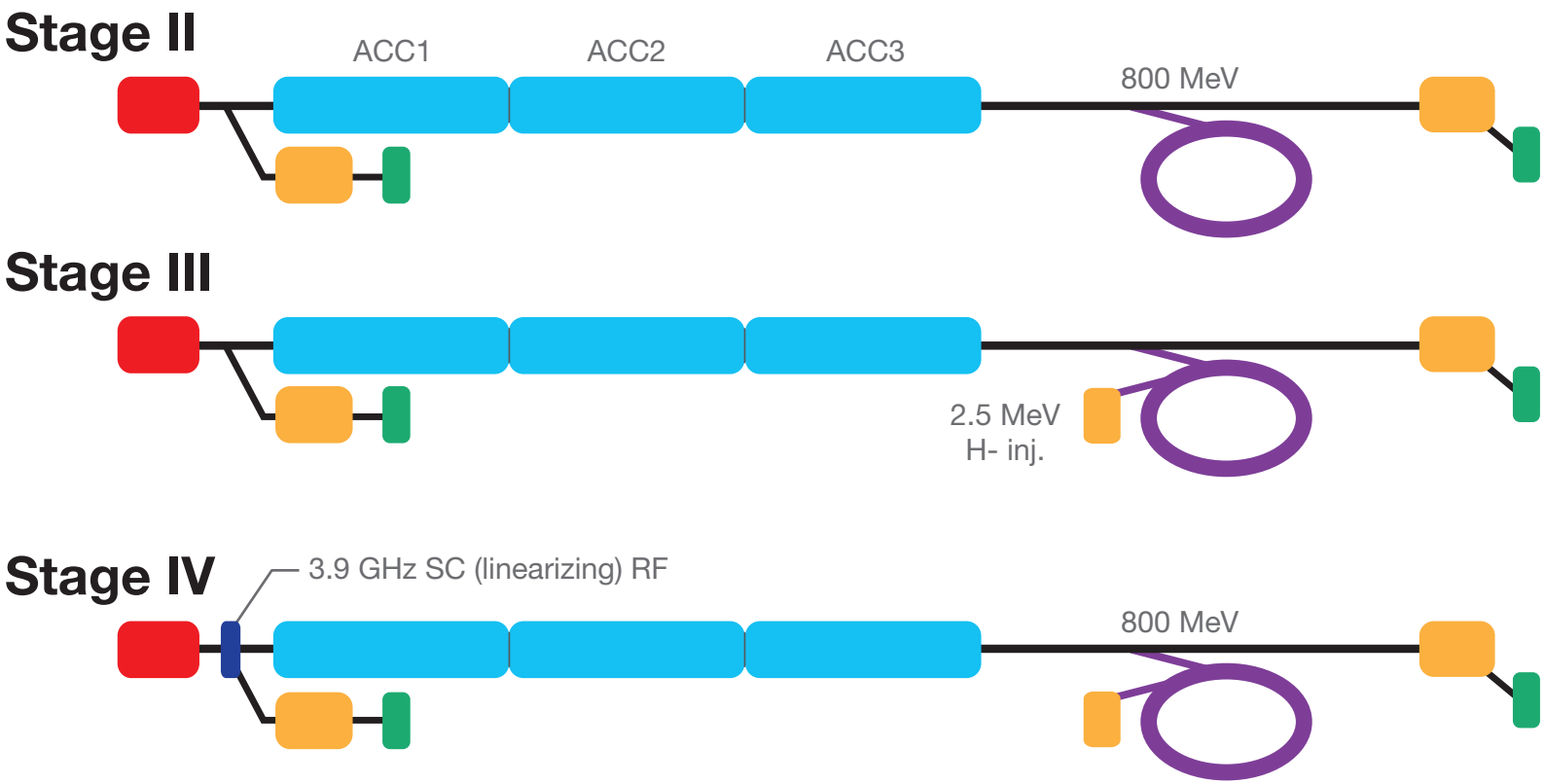
Accomplishments in 2013

- Laser installed & Commissioned - UV to ASTA cave
- CM2 Installed and ready for cooldown
- CM2 Warm Coupler Conditioning completed
- Gun installed and first phase of conditioning complete
  - 2nd stage in progress
- 9-way diagnostic cross installed and operational
- Electrons
  - Beam sensed on Faraday cup, Loss Monitor, Wall Current Monitor, and BPM
  - Instrumentation commissioning & calibration
- Gun energy measurements

Planned Activities in FY14

- Complete RF Gun conditioning – 45 MV/m
- Install ‘coated’ cathode – generate a real beam
- Bring CM2 into operation
- Complete upgrade and install CC1
- Re-commission CC2
- Complete installation & begin commissioning 50 MeV Injector to low energy dump (Stage I.0)
- Begin installation of high energy beam line to dump (Stage I.2)

ASTA Buildout and Operation Occurs in Stages: Stages II, III, IV



Summary

- Major components of ASTA Stage I.0 are nearly in place
- Commissioning is in progress
- Collaborations and interactions with young scientists and other have already begun – other guests welcome!
- Look forward to first 50 MeV beam in early 2014

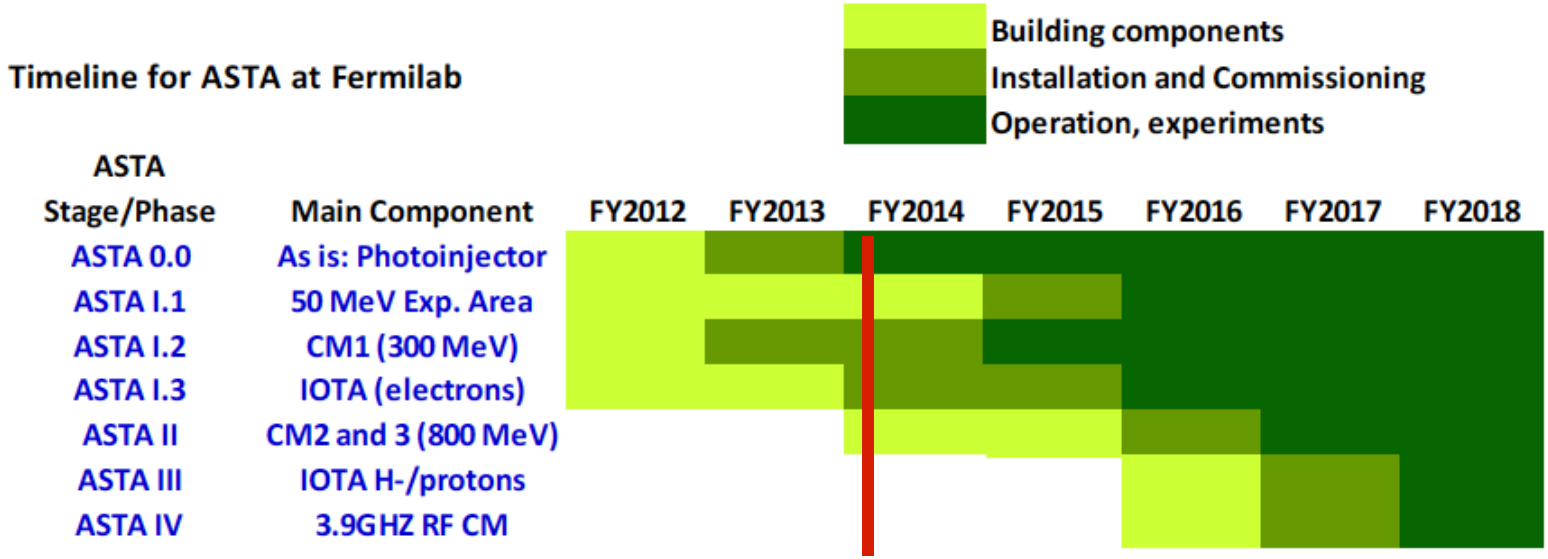
Thank you for your attention

Questions?

Ancillary Systems

- Gun, CC2, Cryomodule RF systems in place and operational
  - some upgrades, improvements planned including Gun Klystron replaced with 5 MW model (in hand), 10 MW multi-beam klystron for CM's (installation beginning)
- CC1 RF installation in progress
- Protection systems, Vacuum, water, Controls verified functional in early stages
- Some life testing carried out as part of commissioning systems

Timeline


Timeline for ASTA at Fermilab
Building components
Installation and Commissioning
Operation, experiments
ASTA Stage/Phase
Main Component
FY2012
FY2013
FY2014
FY2015
FY2016
FY2017
FY2018
ASTA 0.0
As is: Photoinjector
ASTA I.1
50 MeV Exp. Area
ASTA I.2
CM1 (300 MeV)
ASTA I.3
IOTA (electrons)
ASTA II
CM2 and 3 (800 MeV)
ASTA III
IOTA H-/protons
ASTA IV
3.9GHZ RF CM