CEBAF Overview

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Deputy Group Leader of the Operations Group

- CEBAF Timeline
- Machine Overview
- Injector
- Linear Accelerators
- Recirculation Arcs
- Extraction Systems
- Beam Specifications
- Beam Operations and Safety
- 12 GeV Upgrade

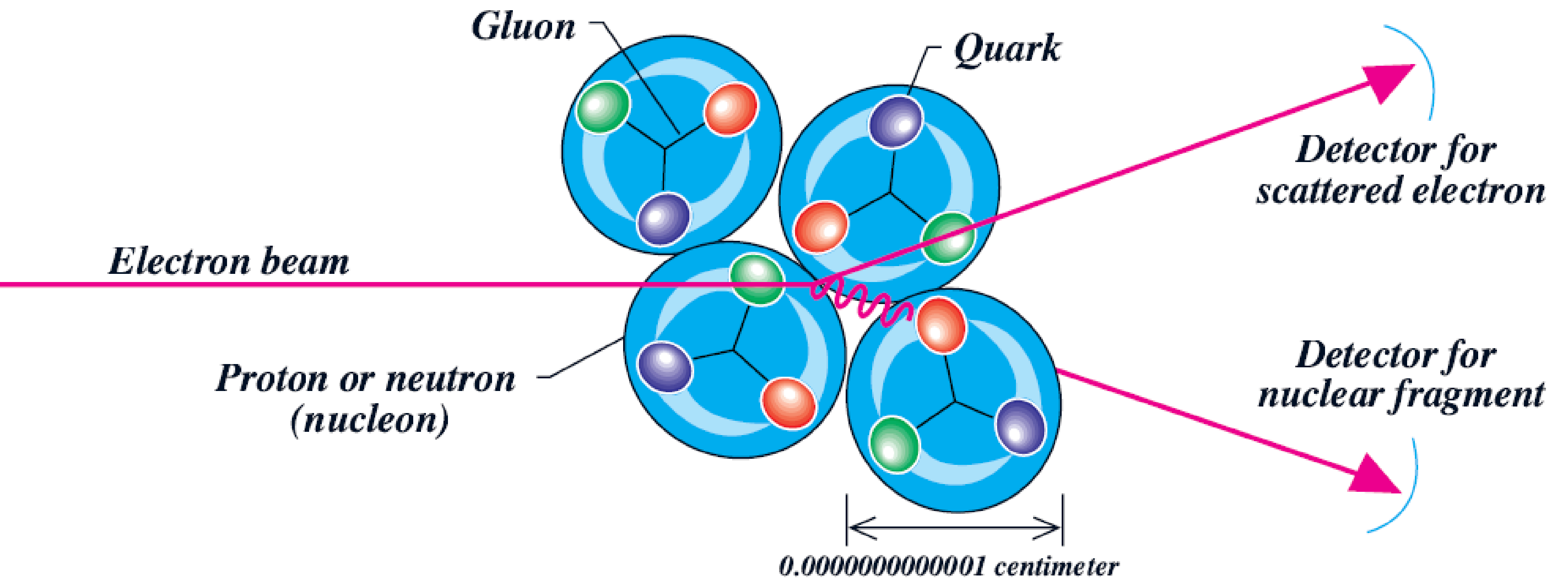
What is CEBAF (Jefferson Lab)

Jefferson Lab used to be called CEBAF,
Continuous Electron Beam Accelerator Facility.

Jefferson Lab (CEBAF) is a basic nuclear physics research laboratory operated for the US Department of Energy by the Jefferson Science Association, LLC.

Jefferson Lab's mission is to provide forefront scientific facilities, opportunities, and leadership essential for discovering the fundamental nature of nuclear matter, to partner with industry to apply its advanced technology, and to serve the nation and its communities through education and public outreach, all with uncompromising excellence in environment, health and safety.

CEFAF Overview   Electrons and Nucleus Collide!



CEFAF Overview Timeline

- 1984 DOE provides funding for new facility
- 1987 Construction Begins on CEBAF
- 1995 First Physics Experiments Begin
- 1997 4 GeV Three-Hall Simultaneous Operations
- 2004 12 GeV Upgrade Development Team Formed
- 2004 Engineering/Design of 12 GeV Machine Begins
- 2005 C-50 Program to Reach 6 GeV Begins
- Today operating CEBAF at 6 GeV
- 12 GeV Installation in 2011 and 2012
- 12 GeV Commissioning starting in 2013

CEFAF Overview   Aerial View

- 5-pass CW Electron Accelerator
- Three user facilities (A, B, C)
- CW photo Injector
- Two 1497 MHz Linacs
- Two Recirculation Arcs
- Dynamic Physics Program Requiring Frequent Energy & Pass Changes
- >85% Polarization
- Small Helicity-Correlated Beam Asymmetries

CEFAF Overview   CEBAF Tunnel

- 7/8 mile around (1.4 km)
- Tow superconducting linacs (linear accelerator), each ~1/4 mile long.
- The base of the tunnel is 30’ below the surface.
- The tunnel is 10’ high and 13.5’ wide.

CEFAF Overview   Tunnel Under Construction

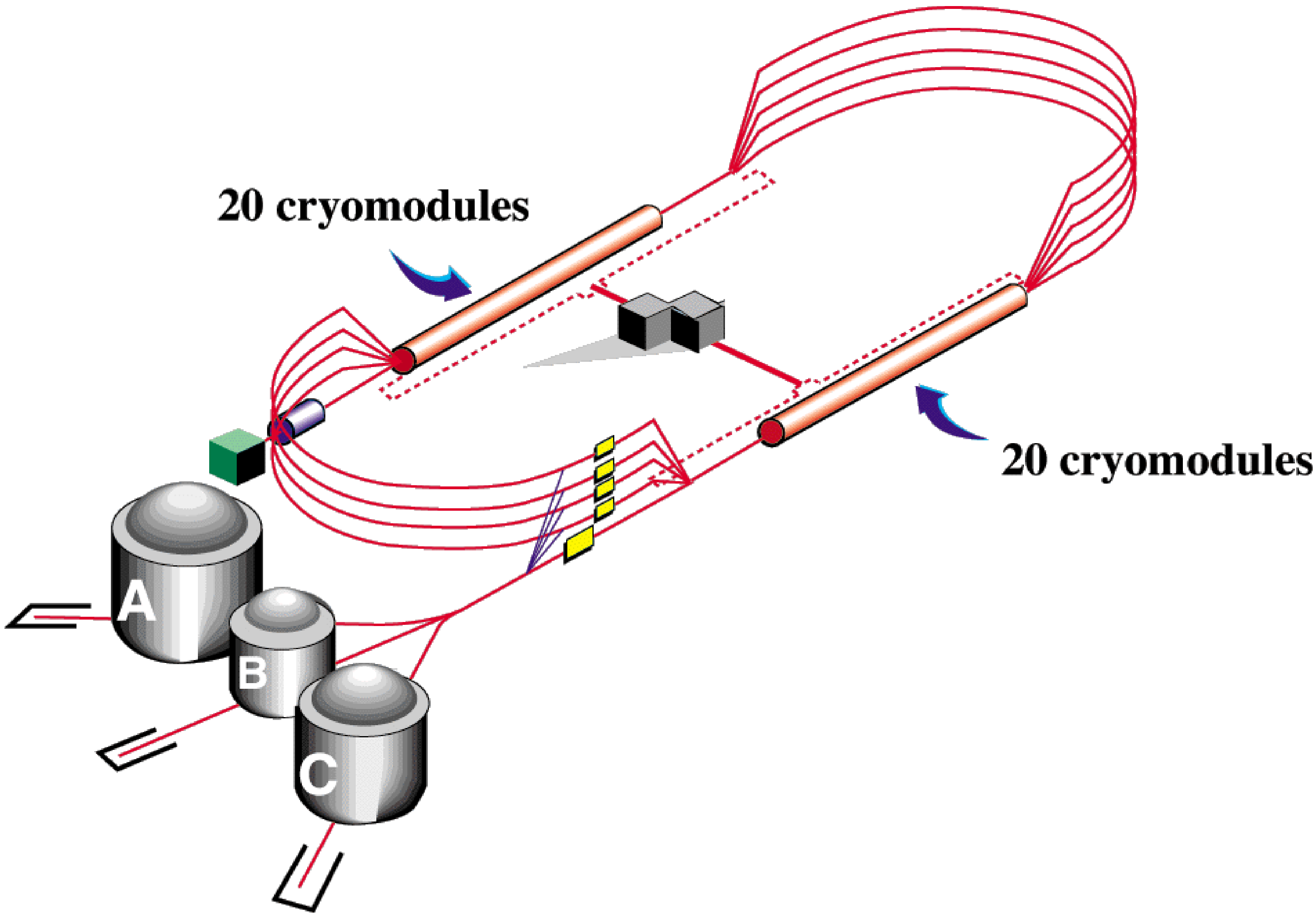
CEFAF Overview   In the Tunnel

CEFAF Overview   Tunnel with Beamlines

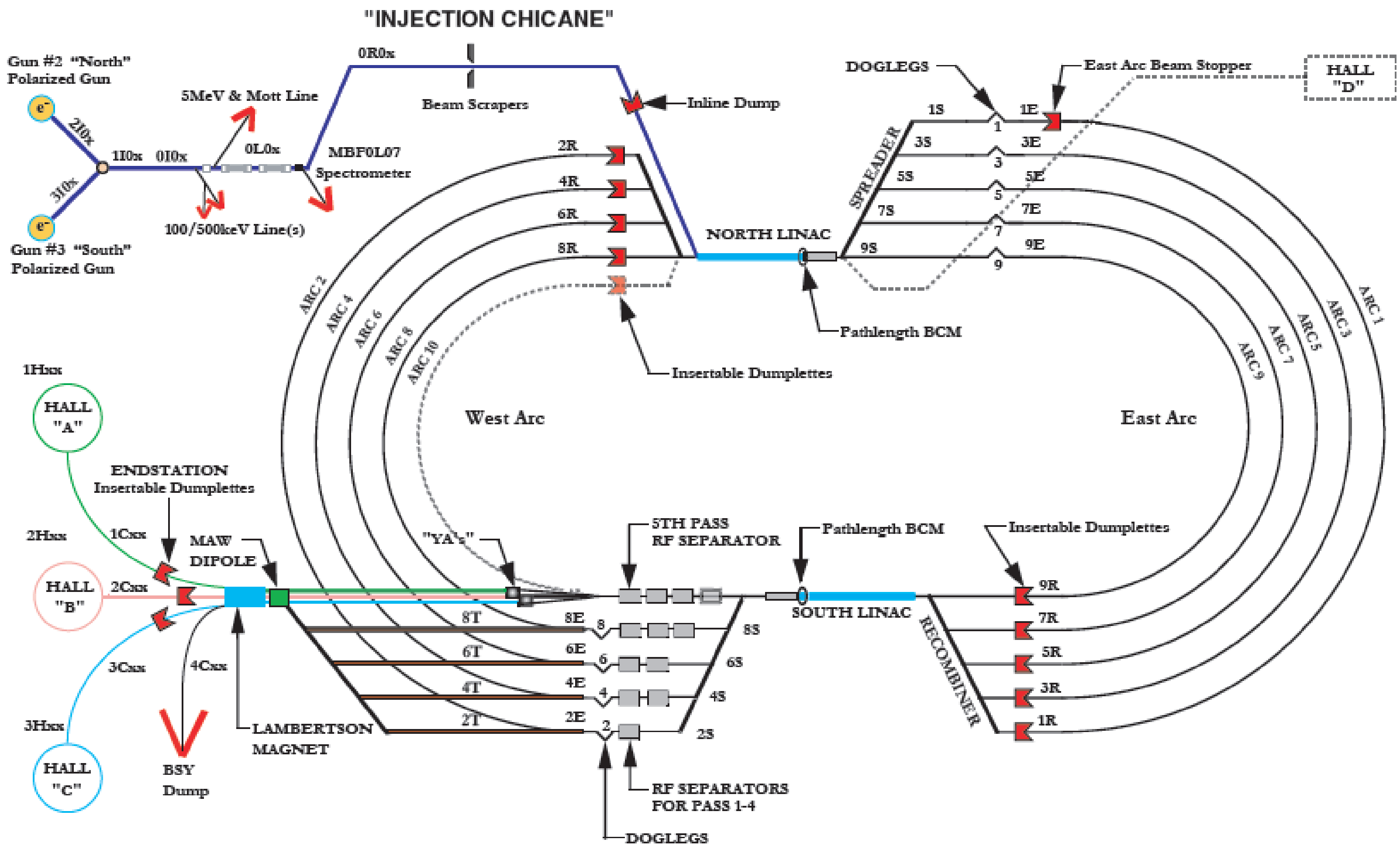
Beamline Under Vaccum

- CEBAF beamlines are made of stainless steel with diameters from 1inch to 24 inches.
- The beamlines are under vacuum ranging from E-6 to E-11 torr.
- There are many vacuum pumps and valves.

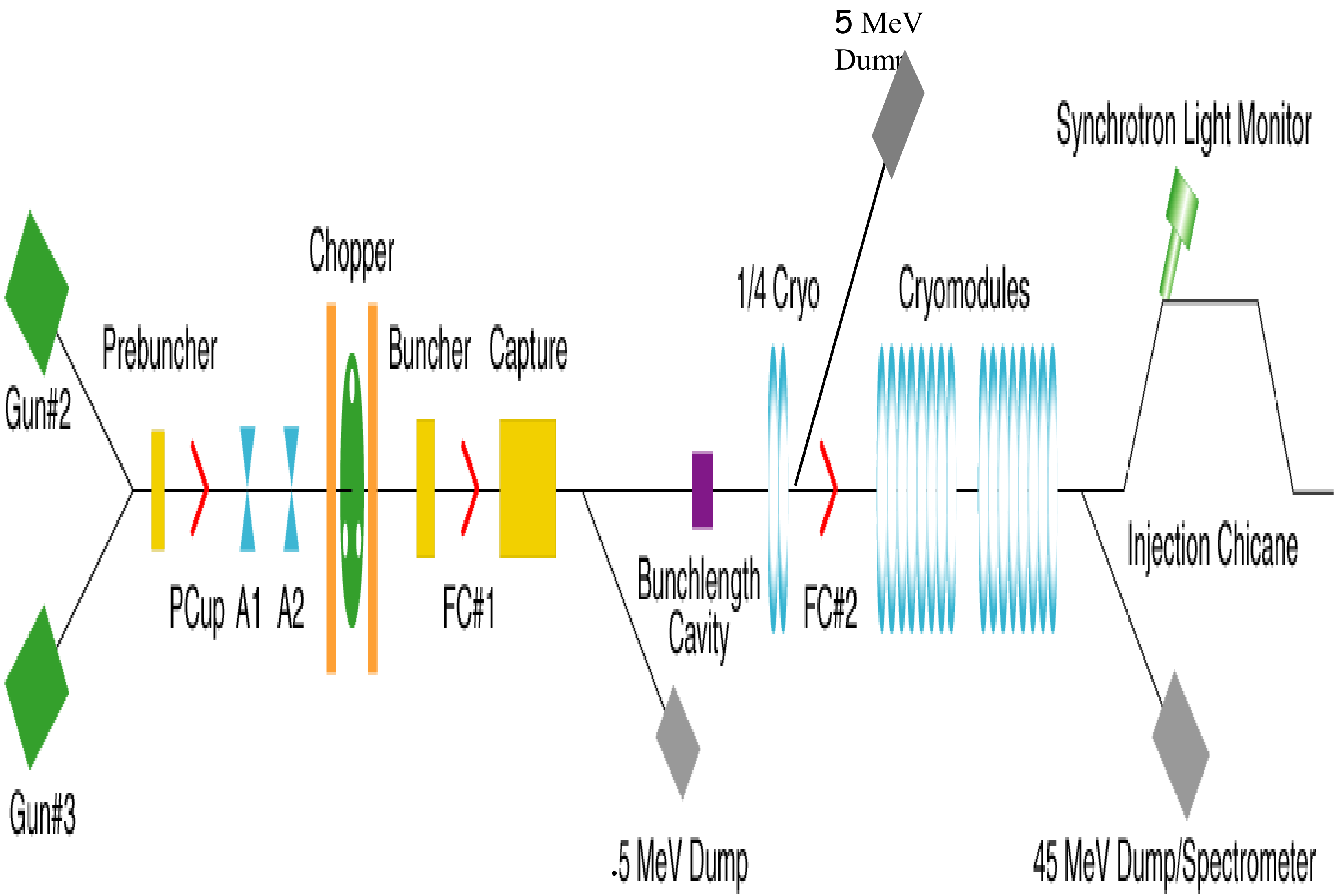
CEFAF Overview   CEBAF Beamline



CEFAF Overview   CEBAF Beamline



CEFAF Overview   Injector Layout

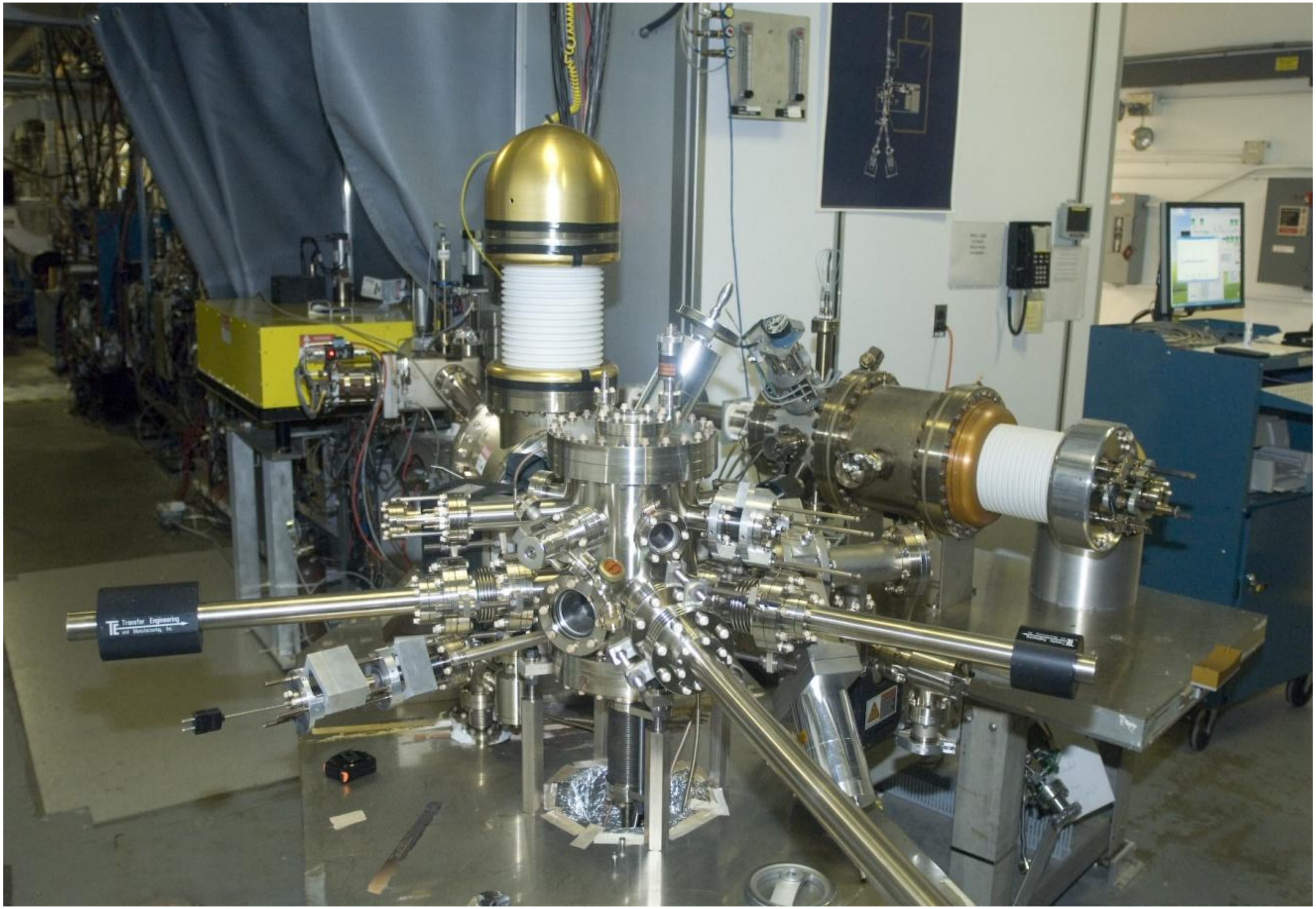


Synchronous Photoinjection

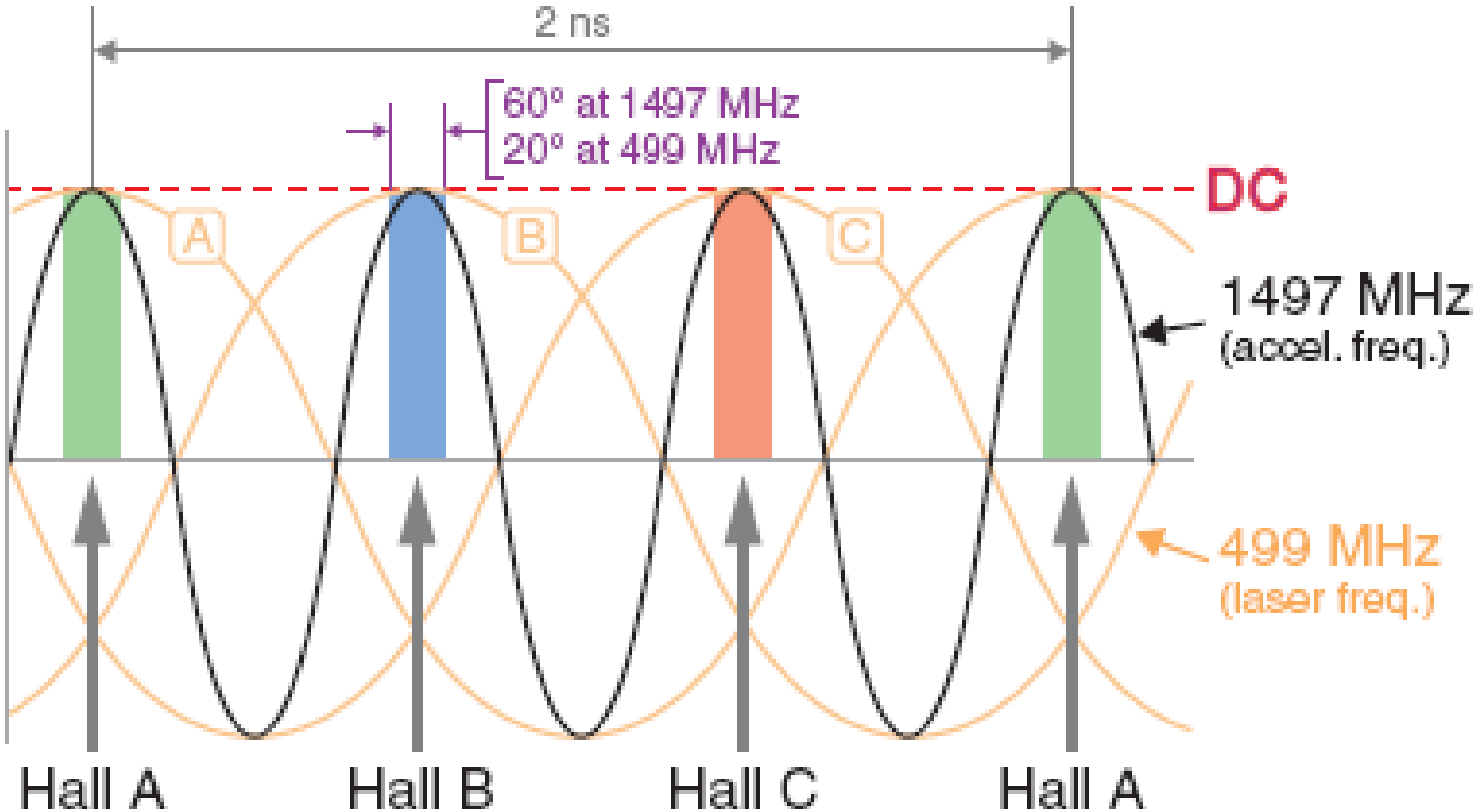
- Laser light that shines on the Gallium Arsenide photocathode is RF pulsed at 499 MHz and creates an RF microstructure on the electron beam
- 499 MHz is a sub-harmonic of the fundamental accelerator operating frequency 1497 MHz
- During three-hall operations, three separate 499 MHz lasers—one for each hall—are used to generate three interlaced electron beams
- Continuous Wave Beam for Physics
- Pulsed beam for optics tuning

- Once the electrons come out from the photocathode the high voltage GUN pushes them into the beam line.
- There are two GUNs in the injector. One is a spare.
- CEBAF GUNs operate at -100 kV.

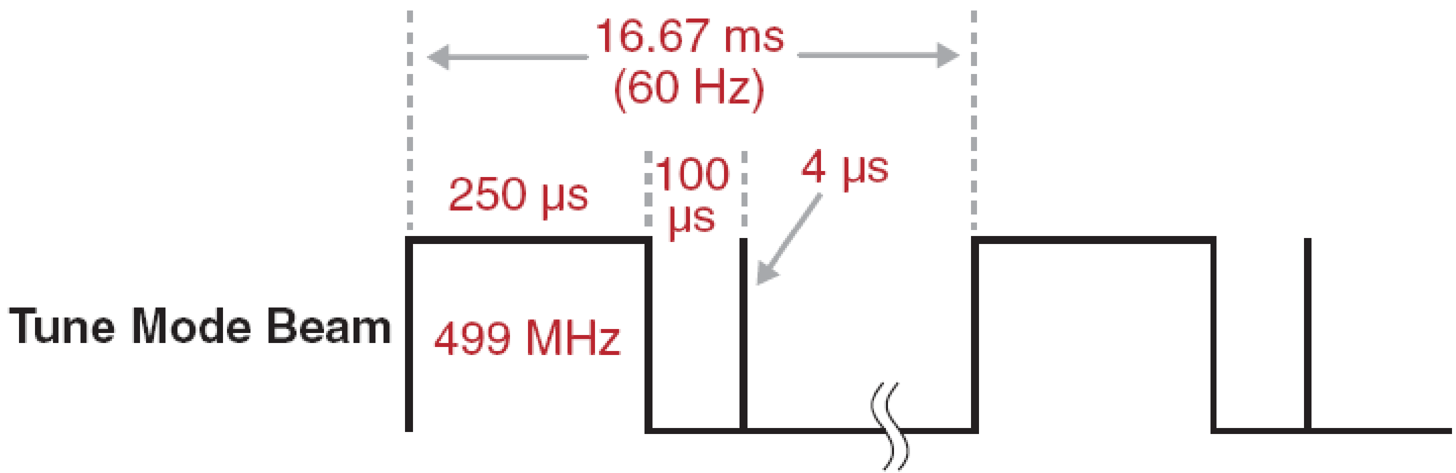
CEFAF Overview   CEBAF GUNs

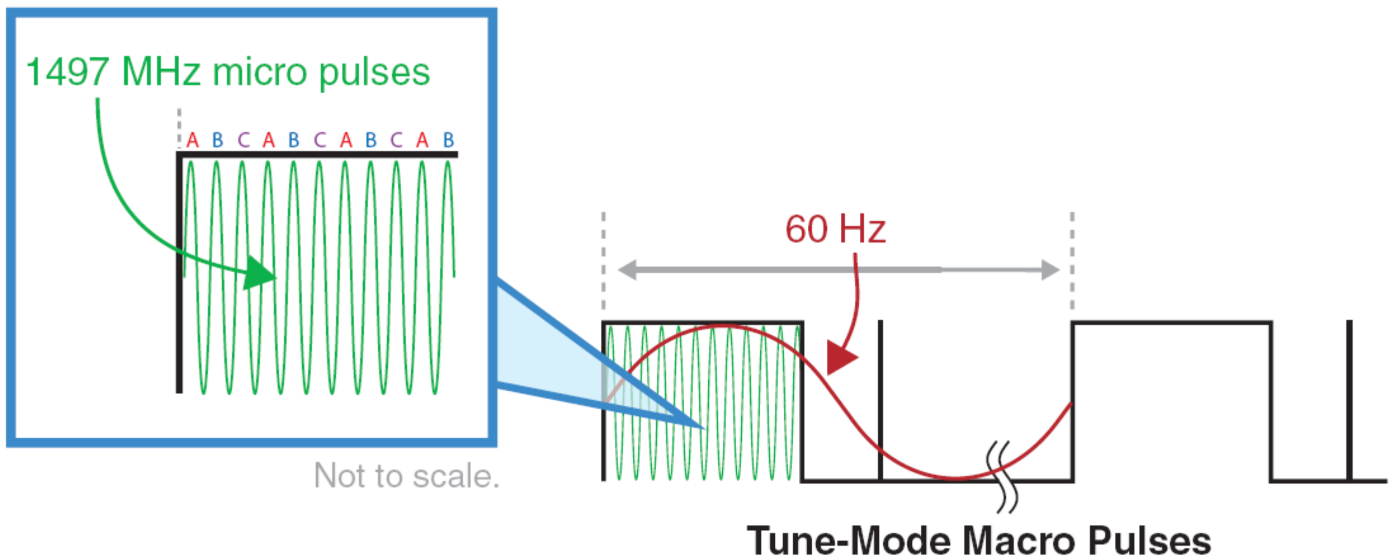


CEFAF Overview   Continuous Beam Formation



CEFAF Overview Tune Mode (Pulsed) Beam Formation

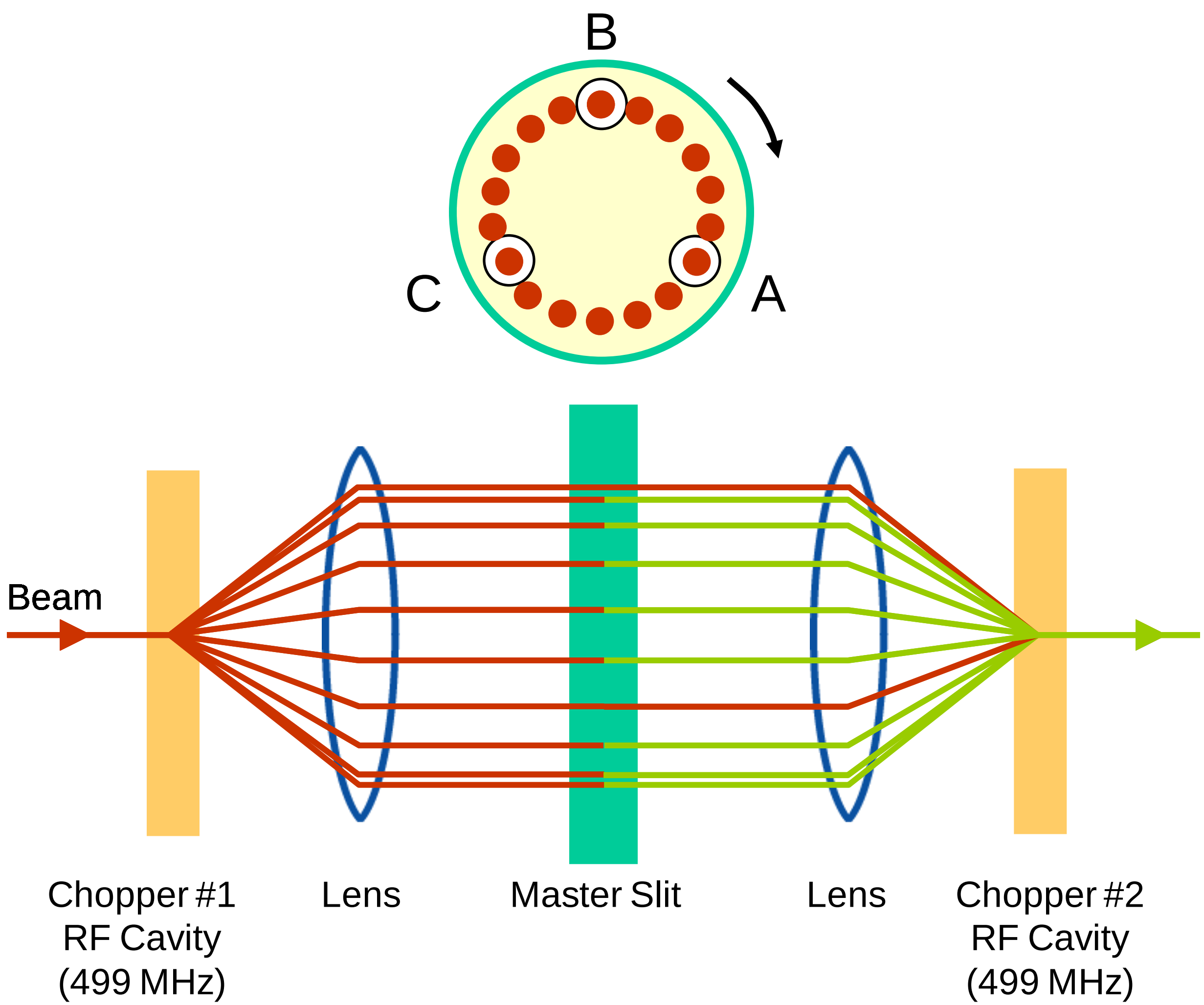




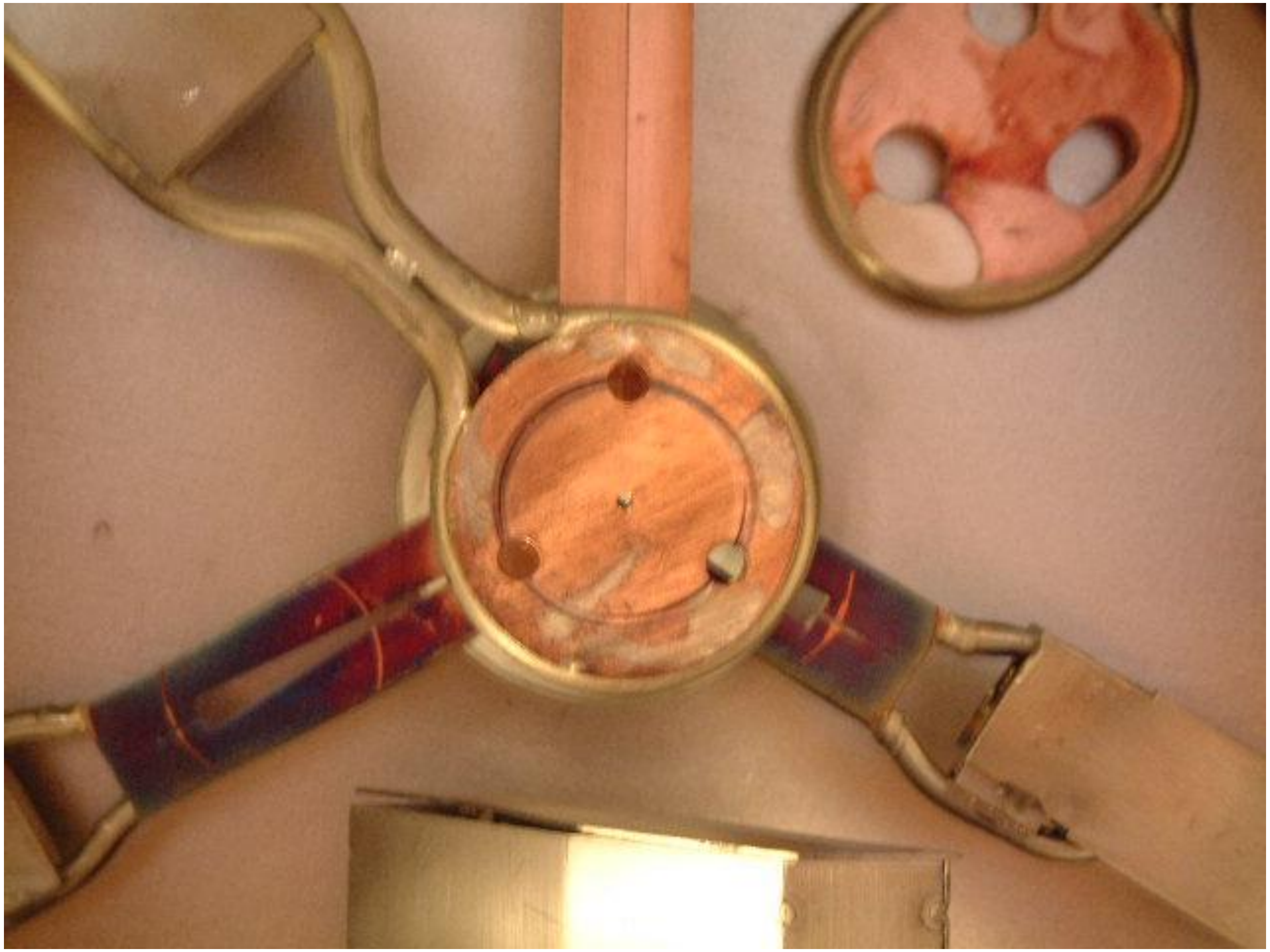
CEFAF Overview   Chopping System

- Beam from 100 kV photocathode gun is sent through 499 MHz chopper cavity
- Transverse orthogonal magnetic fields rotate the beam in a circle of ~1.5 cm radius
- Slits at 240°, 0° and 120° degrees allow bunches of electrons to pass
- Chopper slits and laser intensity are individually controlled to regulate currents for Halls A, B & C
- The three beams are recombined by another 499 MHz chopper cavity

Chopping System

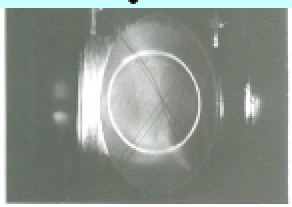


CEFAF Overview Chopping System

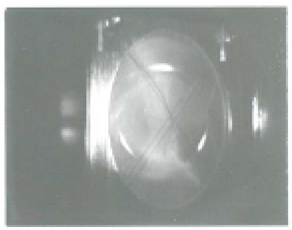


CEFAF Overview   Chopping System

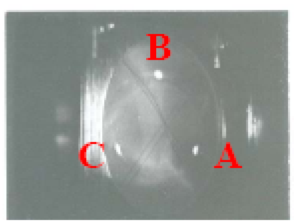
Shared Injector Chopper



DC Light,
Most beam
thrown away



Three
independent
RF-Pulsed
lasers



Now add
prebuncher

Efficient beam extraction prolongs operating lifetime of photogun.

Lasers with GHz pulse repetition rates have been hard to come by

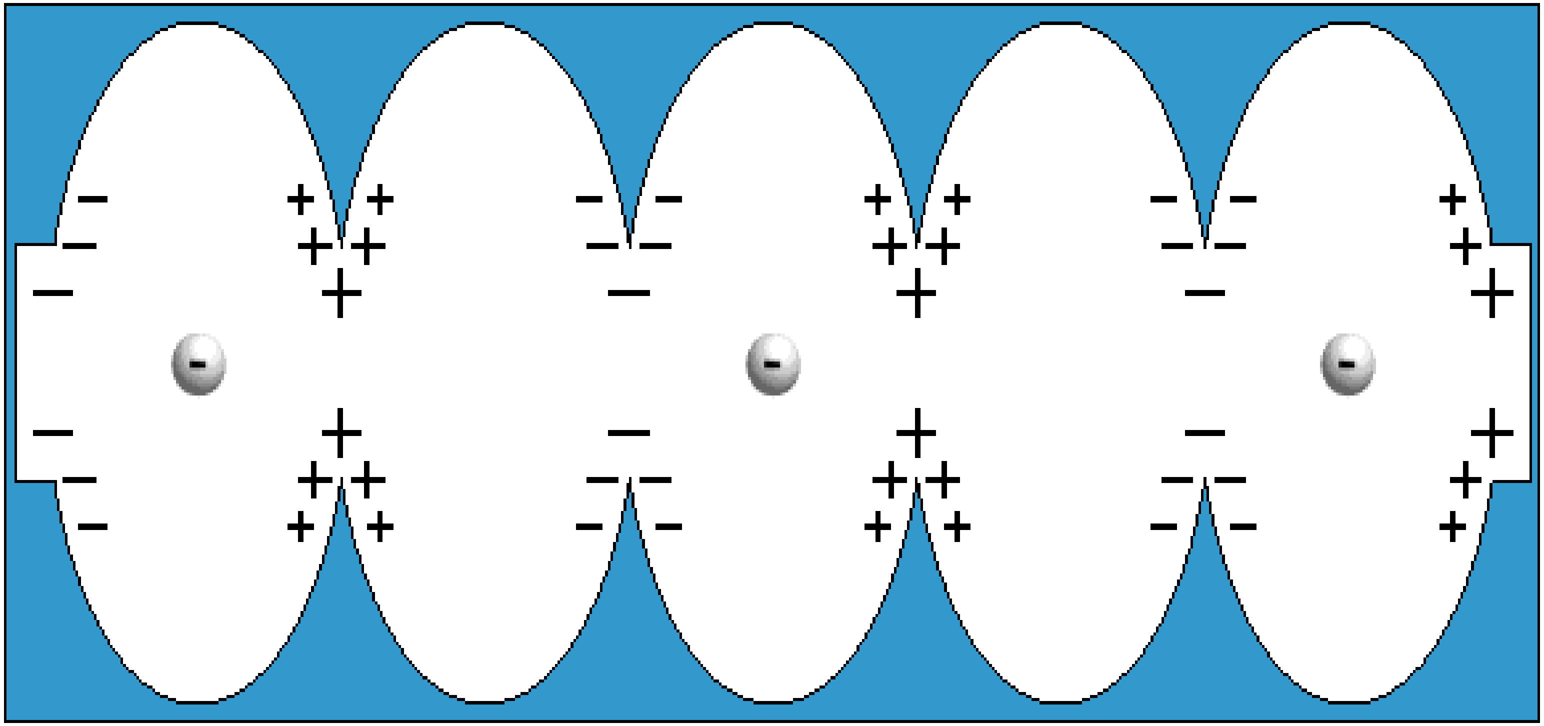
Lasers don't turn completely OFF between pulses: Leakage (aka crosstalk, bleedthrough)

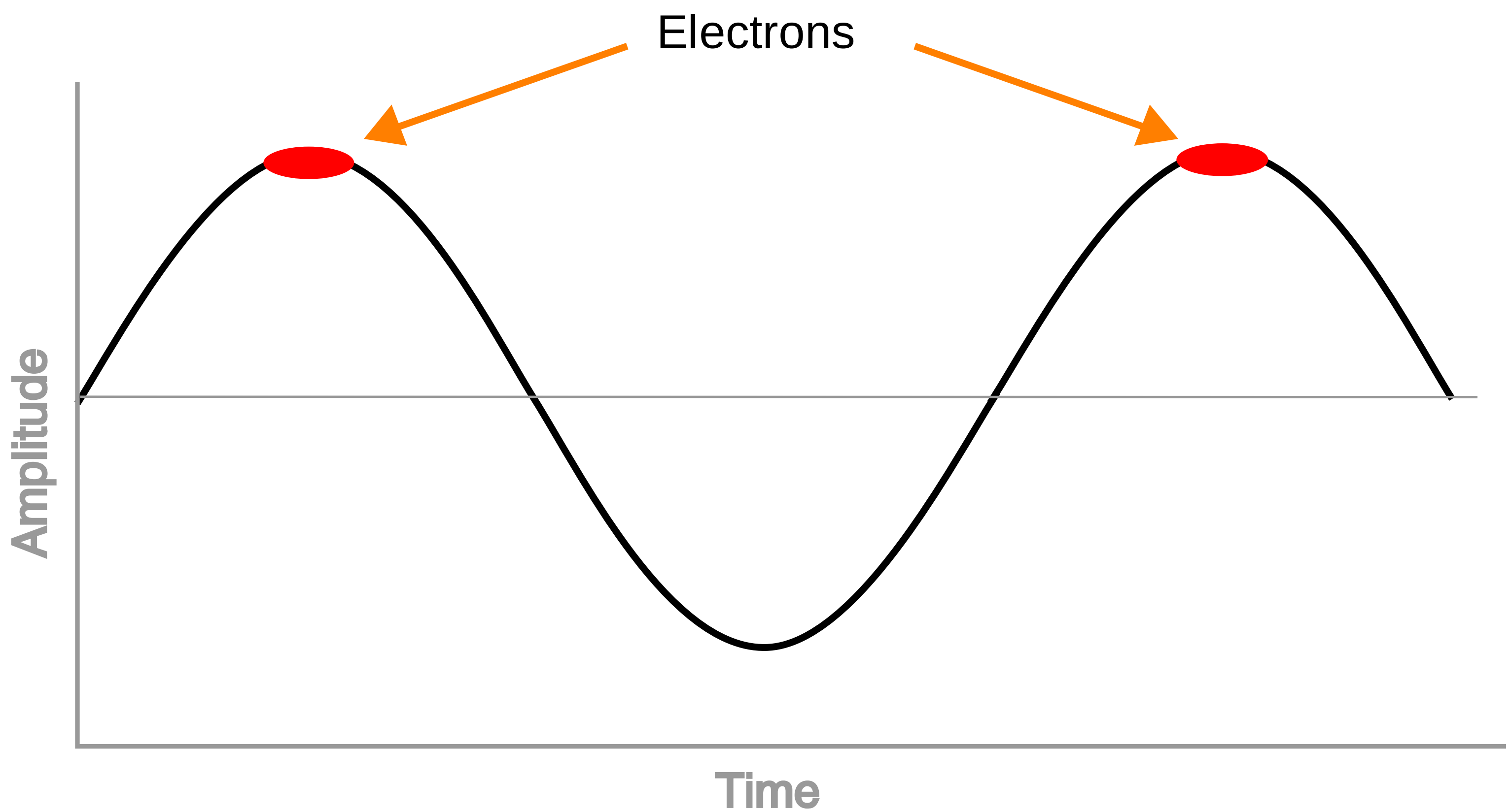
- CEBAF makes electrons gain energy by placing negative charges behind them and positive charges in front of them. Devices called cavities are used to achieve this goal.

- Cavities are hollow shells made from niobium. Jefferson Lab's accelerator uses 338 cavities. Microwaves are directed into the cavities and push the electrons.

- The frequency used is 1497 MHz (Radio Frequency).

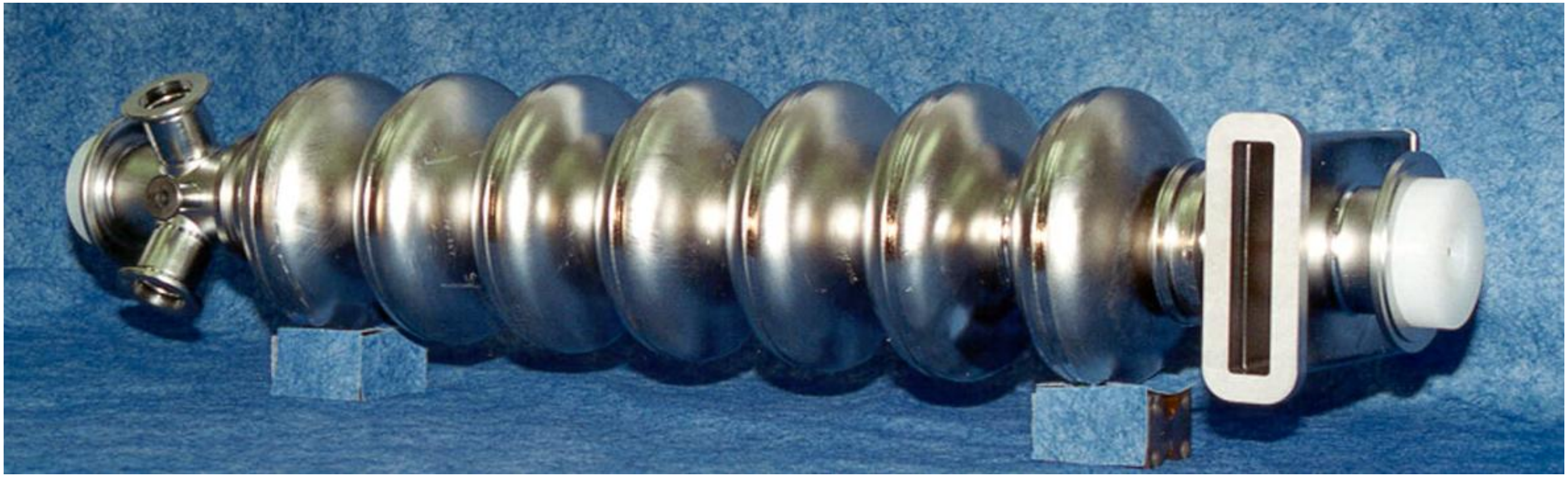
CEFAF Overview Acceleration of Electrons





Beam gains energy when it goes through the cavities

7-cell 1497 MHz Niobium SRF Cavity for CEBAF



- The cavities cannot be operated in room temperature due to the heat generated.
- The heat would lower the efficiency or melt the cavities.
- When niobium is cooled to very low temperatures, it loses all electrical resistance and becomes a superconductor.
- Superconductors have no electrical resistance, electrical currents flowing through them do not lose any energy and do not produce any waste heat.
- The use of superconductive niobium cavities allows CEBAF to operate efficiently.

In order for niobium to become superconductive, it must be cooled far below the freezing point of water. The cavities are immersed in a bath of liquid helium at a temperature of -271°C (-456°F). This is only 2°C above absolute zero, the coldest possible temperature. The cavities and liquid helium are shielded from the heat of the outside world inside large, very well insulated containers called cryomodules.

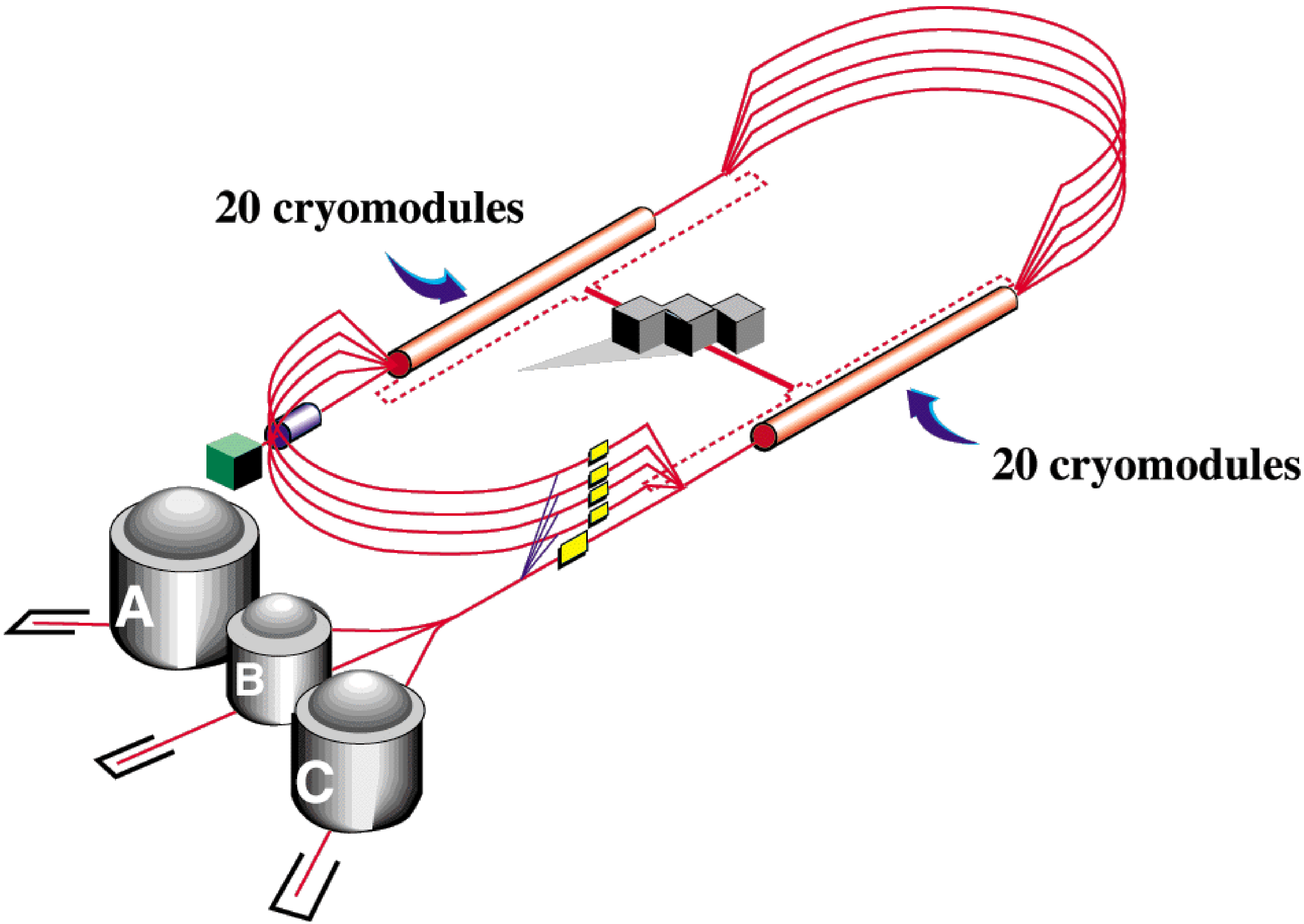
CEFAF Overview   Cryomodules

CEFAF Overview   Cryomodules

- There are eight RF cavities in each crymodule
- Cost ~$1 million per crymodule during construction
- There 42 and1/4 cryomodules
- Inside modules, the RF cavities sit in a bath of 400 gallons of liquid helium cooled to 2 Kelvin.

- Central Helium Liquifier (CHL) keeps the crymodules super cold.
- CEBAF has the world's largest 2K liquid helium refrigerator.
- The cryogenic system holds ~17000 gallons of liquid helium.
- The CHL runs continuously 24/7.

CEFAF Overview   CEBAF Beamline

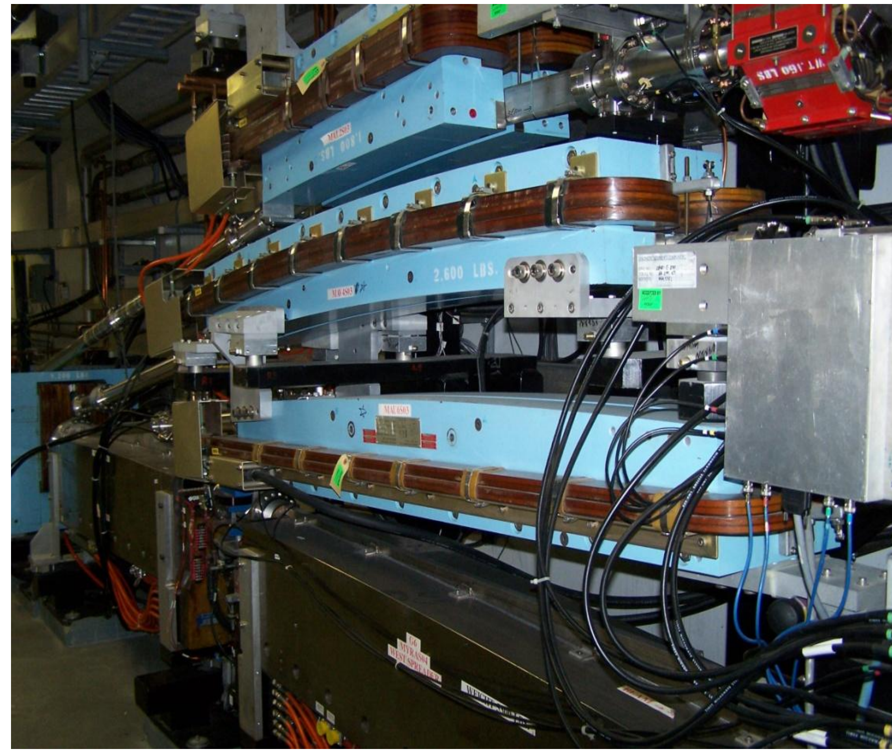


CEFAF Overview Magnets

- Magnets steer, focus and defocus electron beam.
- There are about 2200 magnets in CEBAF
- Heaviest magnet is about 20,000 pounds.
- Magnets can be powered up to 300 Amps.

CEFAF Overview Spreaders and Recombiners

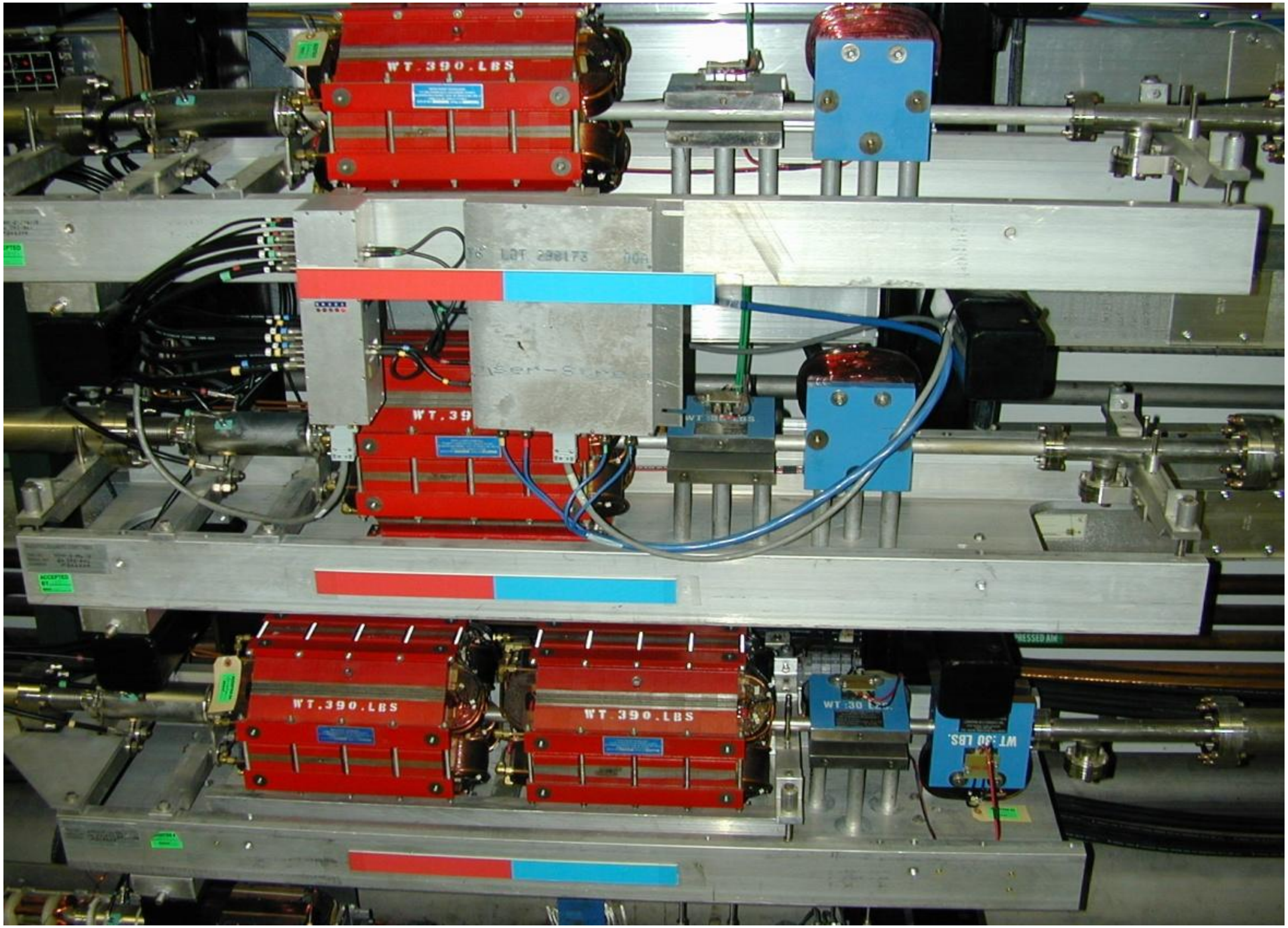
- Spreader and Recombiner sections of the machine connect linear accelerators to recirculation arcs.
- Magnetic dipoles are powered in series for each Arc.



CEFAF Overview   Arcs

- Recirculation arcs transport the beam between linacs
- Low energy beam at the top
- High energy beam at the bottom
- 16 or 32 dipoles are used to complete the 180 degree bend

CEFAF Overview   Beamline Girders

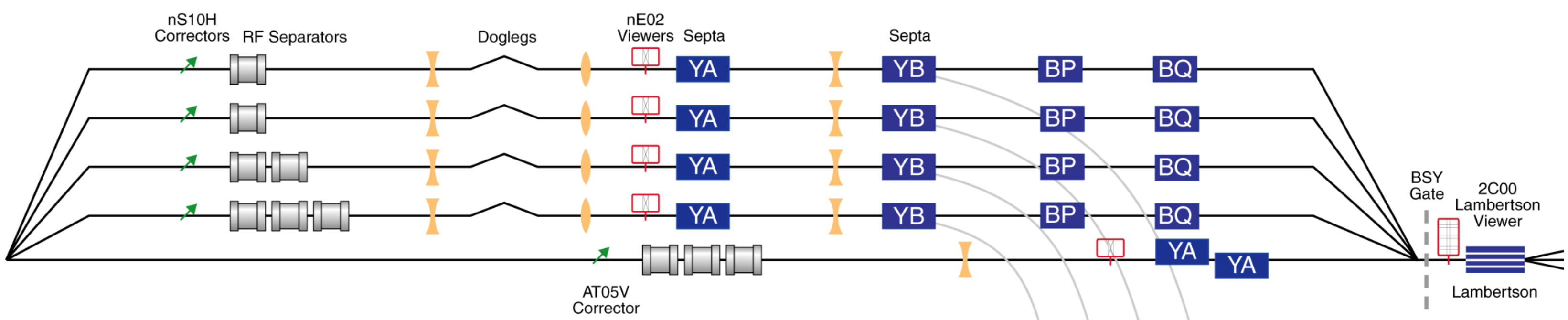


CEFAF Overview   Extraction of Beam

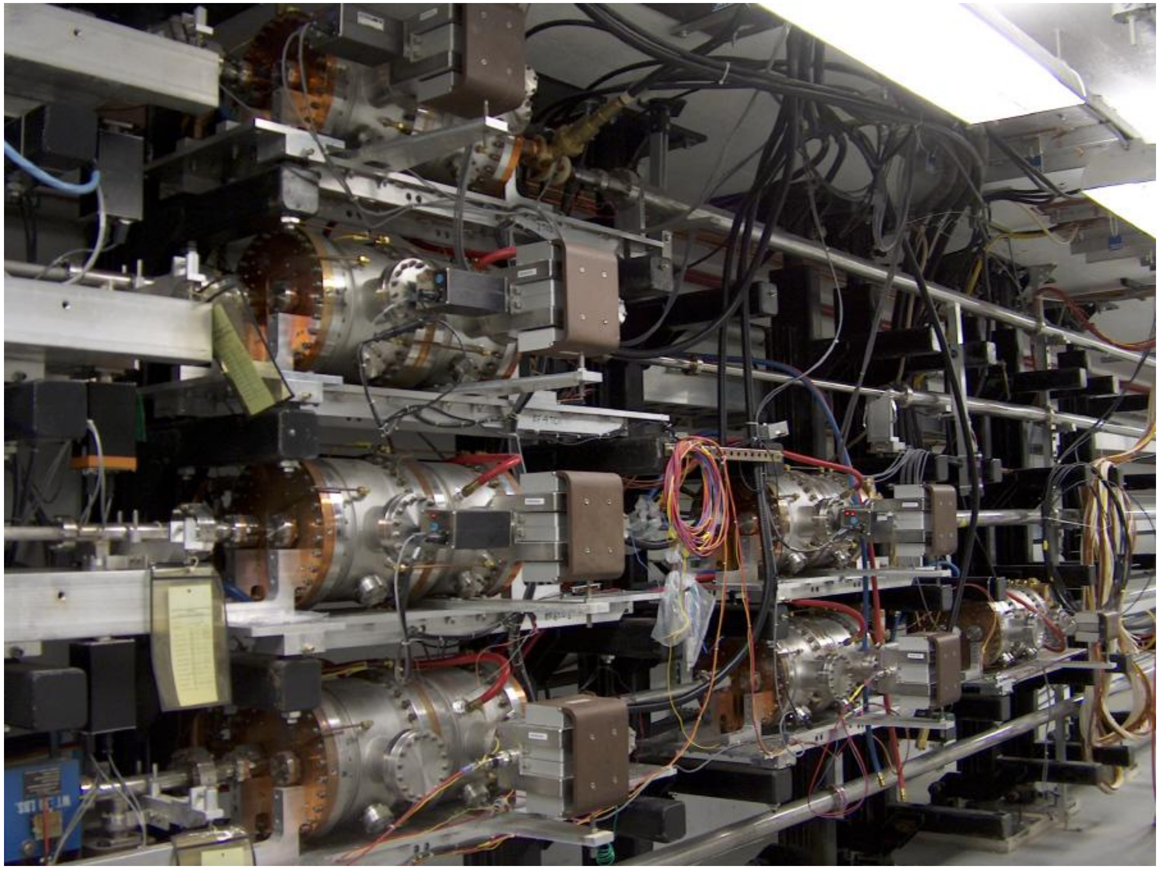
- Any single user can receive beam from the first four passes
- All three users may receive beam from the fifth pass
- Time-dependent transverse kicks are applied to the microbunch structure to selectively direct beams along the correct path
- Accomplished with RF Separator cavities operating at 499 MHz
- Also use dipoles and quadrupoles at fixed field strengths to change the path of the beam

Extraction of Beam

- Extraction system consists of RF Separators, Septa and Dipole magnets
- 1-4 pass uses horizontal separation to deflect one beam to halls A, B or C
- 5th pass uses vertical separation and all 3 halls can have the maximum energy at the same time



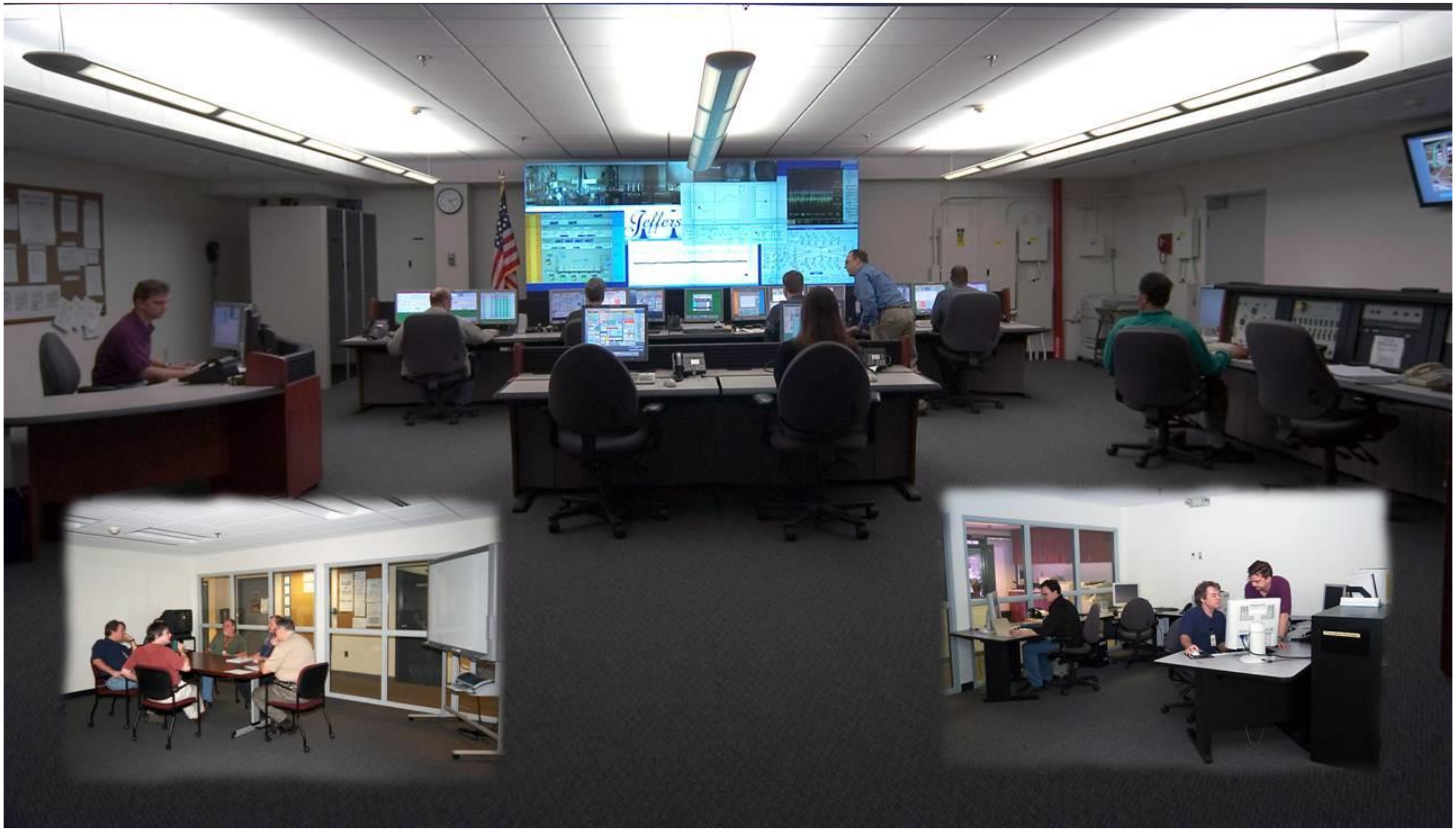
CEFAF Overview Beam Separators



Just name a few:

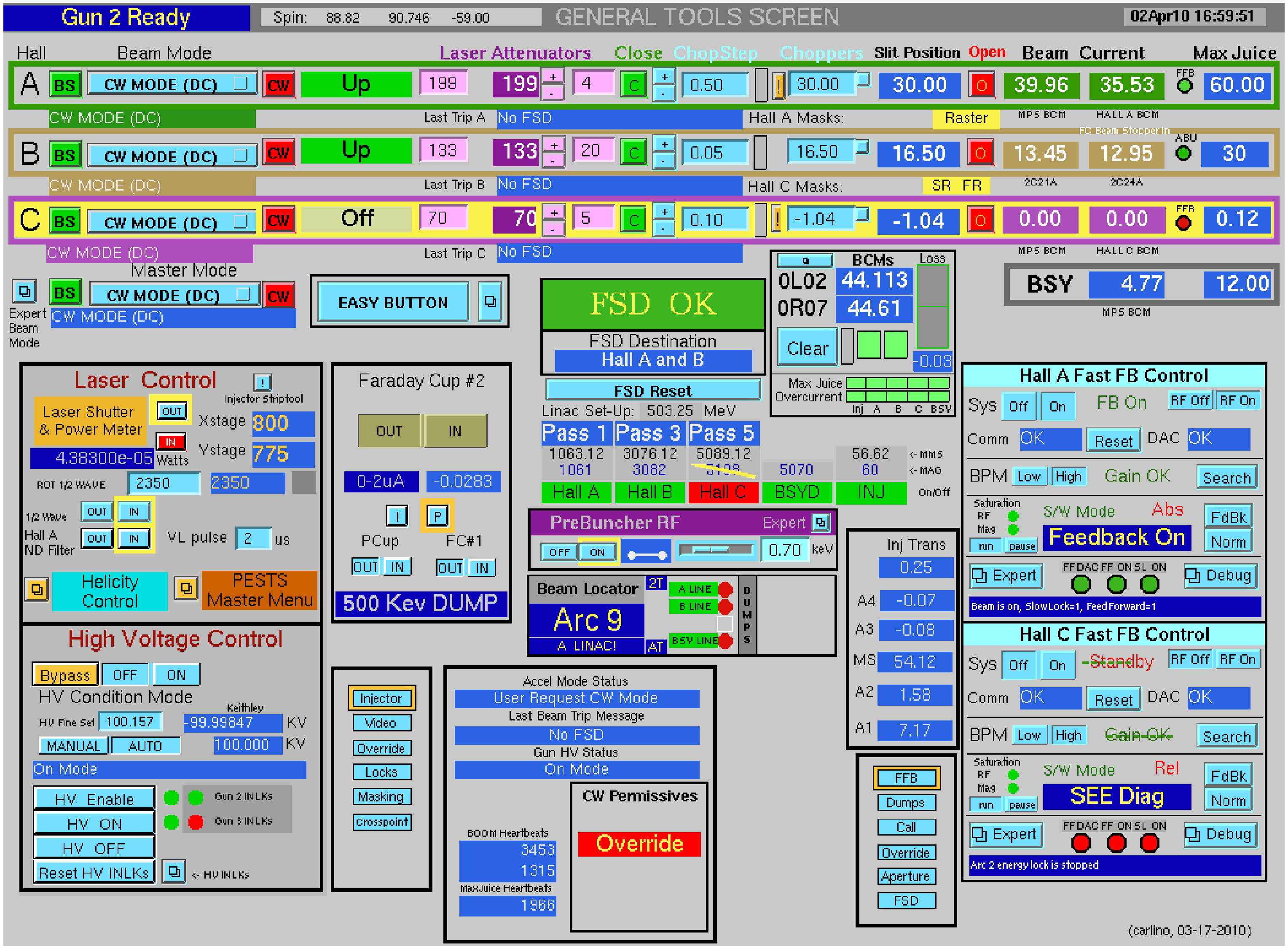
- Beam Energy: up to 6 GeV
- Energy Stability: ~ E-5
- Beam Current Range: a few pA to 180 uA.
- Current Stability: < a few percent
- Beam position Stability: -/+ 0.1 mm
- Beam polarization: ~85%

CEFAF Overview   Machine Control Center



- Beam operations are conducted in the Machine Control Center (MCC) by the Operations personnel using the control software called Extensible Display Manager.
- Any request for machine parameter changes must go to the MCC, and the Operations personnel will do the changes.
- The MCC is staffed 24/7 during beam operations.

CEFAF Overview How to Control the Beam

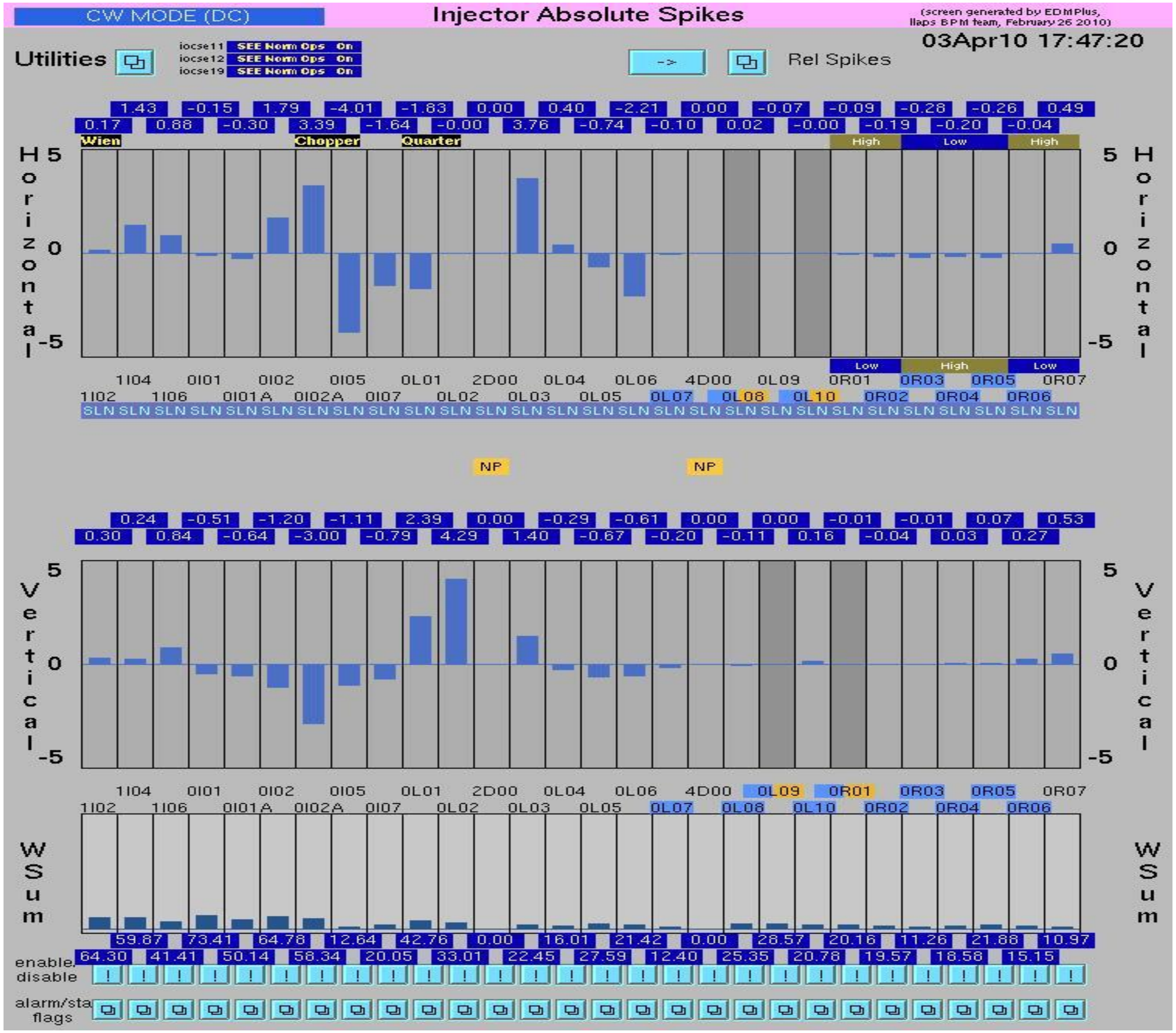


- Beam travel in vacuum tubes with the speed of light.

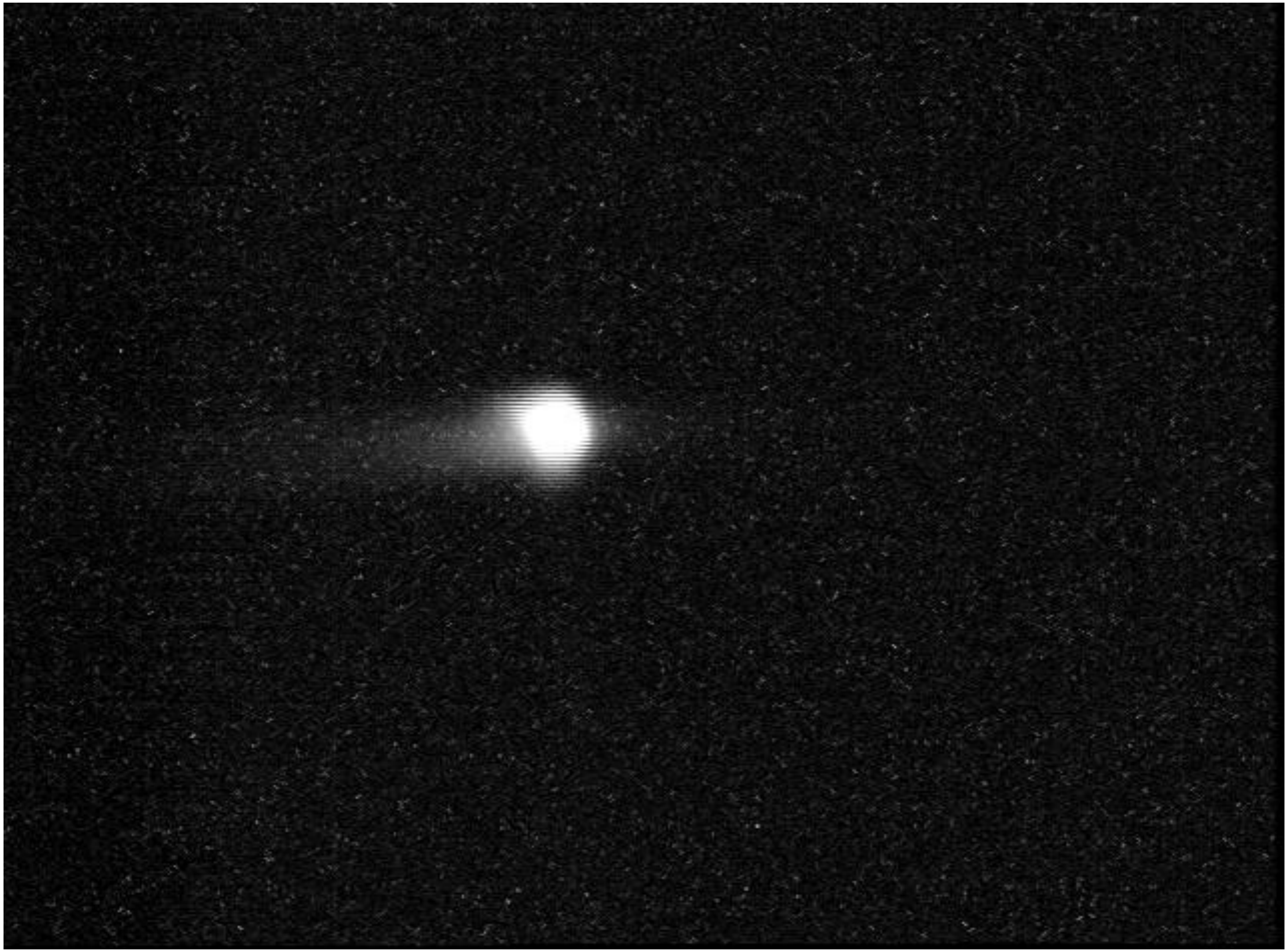
- Operations personnel monitor beam using diagnostic tools like beam position monitors, beam current monitors, beam loss monitors, synchrotron light monitors and etc.

- Energy locks, orbit locks and current locks are used to keep beam stable.

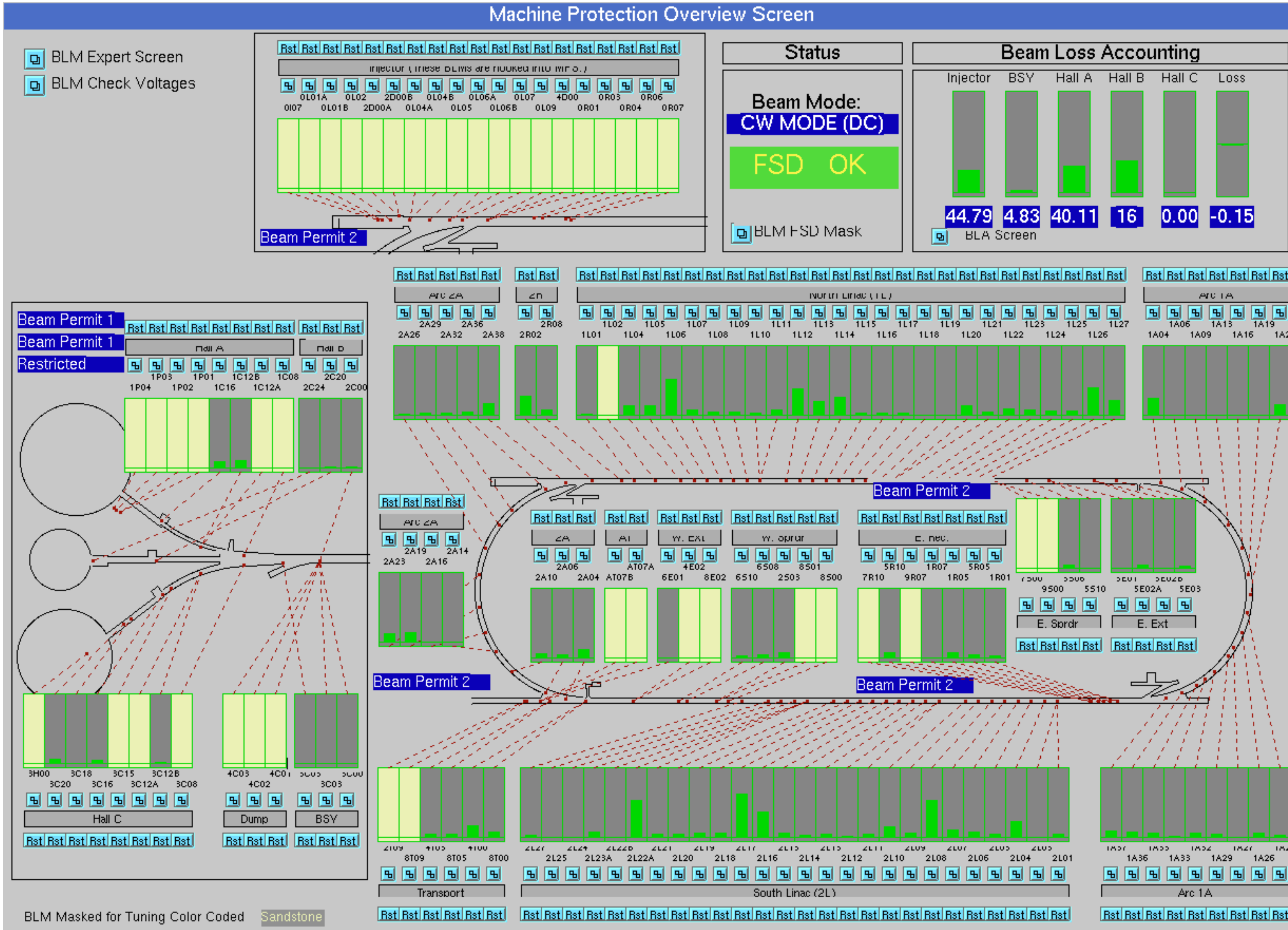
CEFAF Overview   Beam Position Monitors



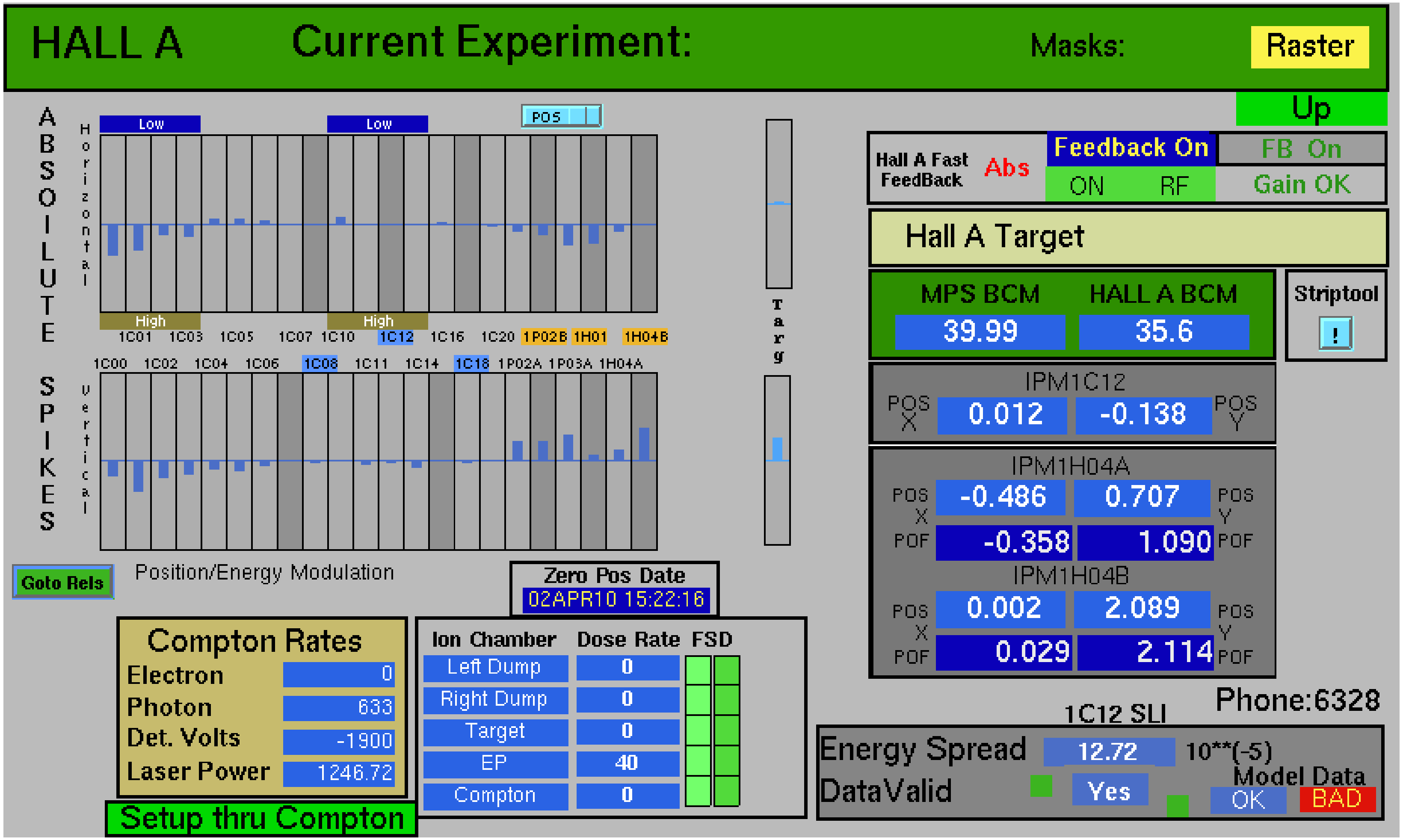
CEFAF Overview   Synchrotron Light Monitor



CEFAF Overview   Beam Loss Monitors

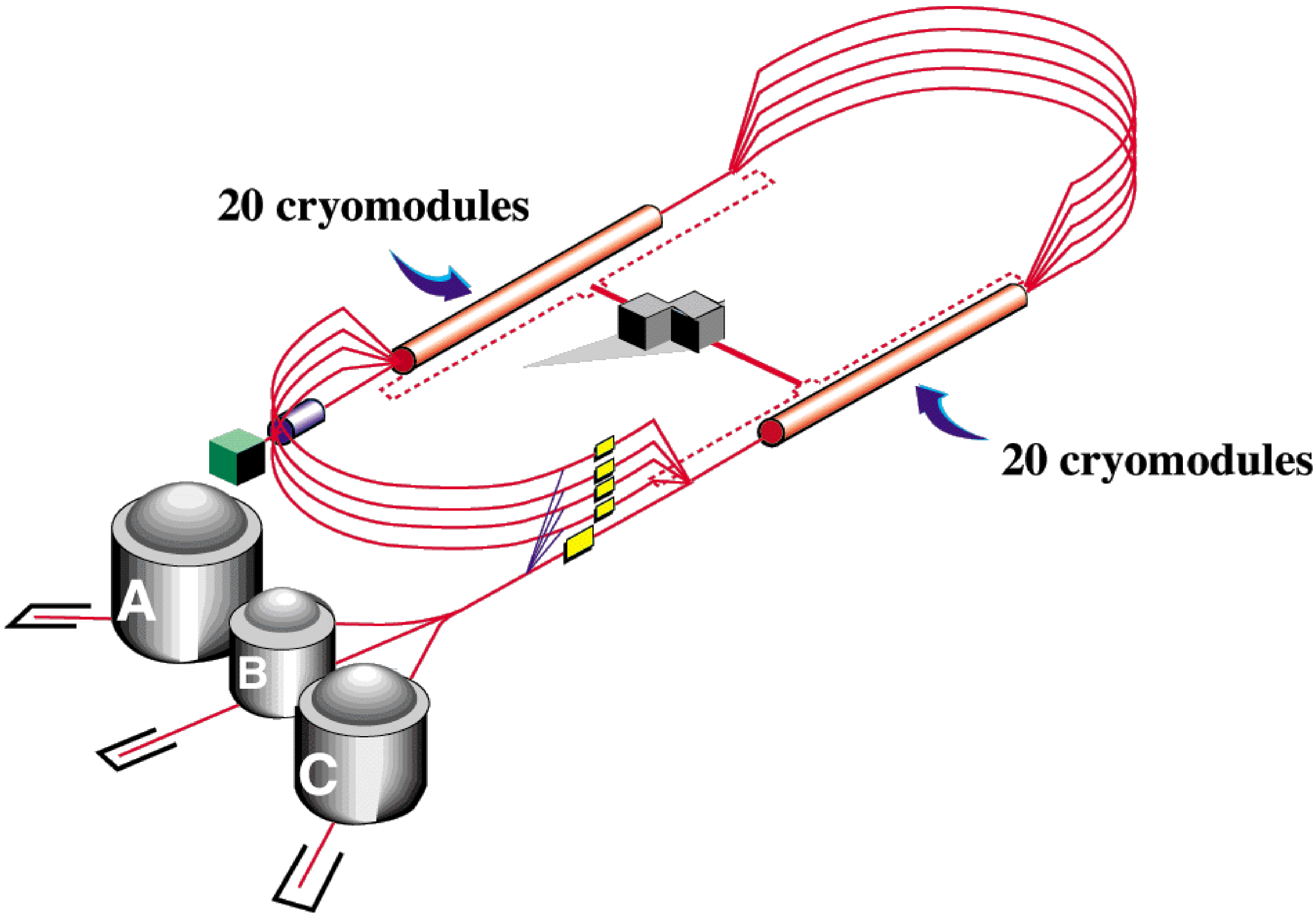


CEFAF Overview   Hall A Beam

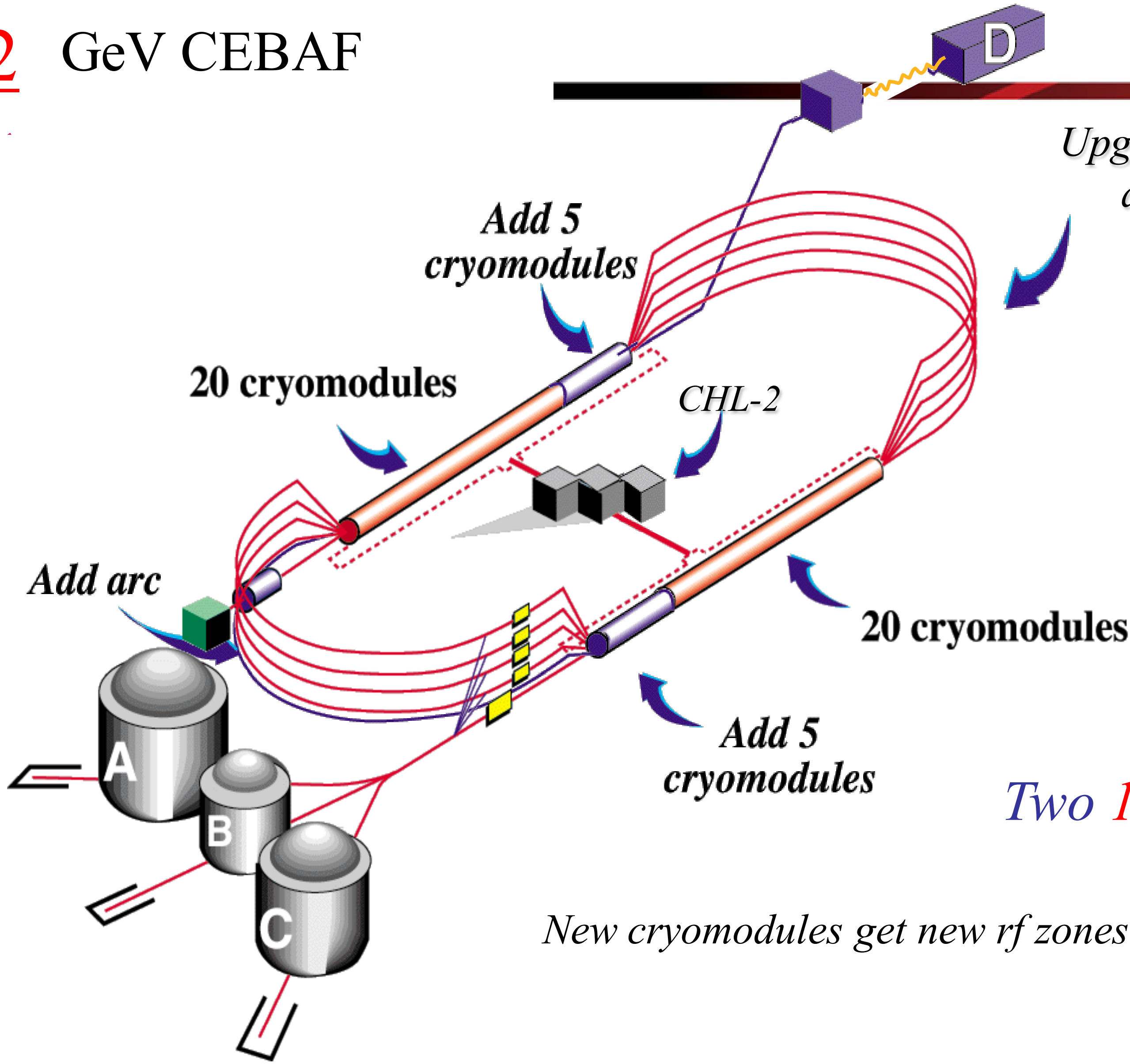


- Safety has two folds: personnel safety and machine safety.
- Personnel safety: radiation hazard, electrical hazard, oxygen deficiency hazard, and etc.
- Machine safety: beam burn-through, beamline component damage, target damage and etc.
- To ensure safe operations we have safety interlocks and strict policies and rules.

CEFAF Overview 12 GeV Upgrade



12 GeV CEBAF



Two 1.1 GV linacs

New cryomodules get new rf zones