NSTX-U Laser Blow-Off impurity Injector
Conceptual Design Review

LLNL LBO team:

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Introduction:
The NSTX-U Laser Blow-Off impurity Injector

Physics needs driving the LBO system

- **Time-dependent ion transport measurements**
  - **Transport-code development and testing (LDRD at LLNL; PI Tom Rognlien)**
  - **Study of edge and core ion transport in NSTX-U (OFES-supported project; PI Vlad Soukhanovskii)**
  - **Time-dependent ionization studies for astrophysics (OFES-supported project; PI Peter Beiersdorfer)**
  - **Johns Hopkins impurity studies (Kevin Tritz et al.)**
- **Laser blow-off system has been in the NSTX general plan for over a decade**
  - **Multiple physics studies have called for an LBO system**

The LBO will be a "user facility" that is available to anyone needing the controlled injection of solid material for NSTX-U physics studies

Introduction:
The NSTX-U Laser Blow-Off impurity Injector

Design based on

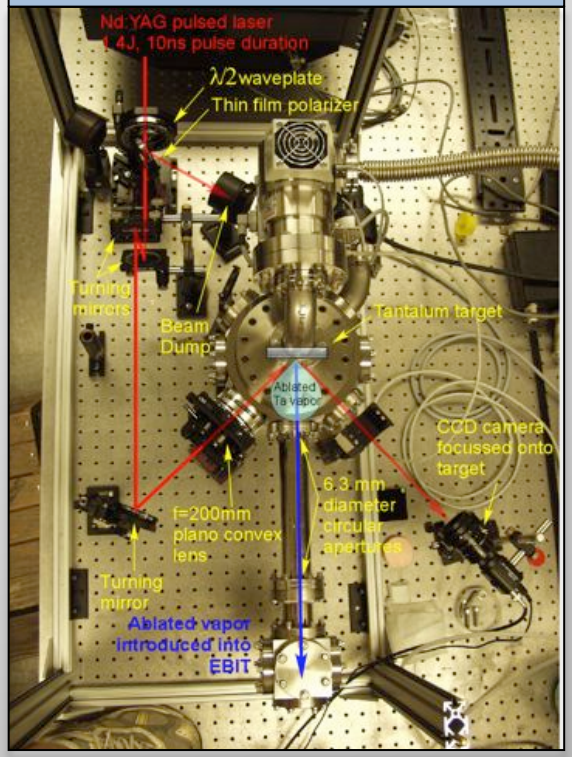
- **Experience with the PLT impurity injector**
- **The laser blow-off system on the electron beam ion trap facility (EBIT) at Livermore**
- **The Alcator C-mod LBO system**

REVIEW OF SCIENTIFIC INSTRUMENTS **77**, 10F106 (2006)

Laser ablation system for the injection of neutral materials into an electron beam ion trap

A. M. Niles, E. W. Magee, D. B. Thorn, G. V. Brown, H. Chen, and P. Beiersdorfer
Lawrence Livermore National Laboratory, University of California, Livermore, California 94550

LBO system on EBIT



The laser and much ancillary equipment will come directly from the EBIT LBO system, which has been moth-balled about 5 years ago

General design properties of the NSTX-U LBO system

- Injection material is evaporated from glass slide
- Injection amount per shot is variable
- 10 Hz laser, allowing single and multiple injections $\Delta t \geq 100$ ms between injections
- Target positioning and laser timing remotely controlled from control room
- Laser beam totally enclosed (except during initial alignment)
- Target chamber is small and can be removed and reinstalled as needed

Laser parameters

- Q-switched NdYAG laser Continuum model NY82-10
- Infrared beam at 1064 μm
- Measured performance (2006):
  - 16 ns pulse duration
  - 12 mm beam diameter (86% of light)
  - Linearly polarized
  - 1.4 J output energy, continuously adjustable between 0.1–1.1 J with a half-wave plate and polarizer
- Laser and control optics fit on a 8 ft by 2 ft optics table

Laser and control optics will be taken from the existing EBIT LBO system

- EBIT LBO system has recently been taken out of storage and set up at the EBIT lab in Livermore

Side view

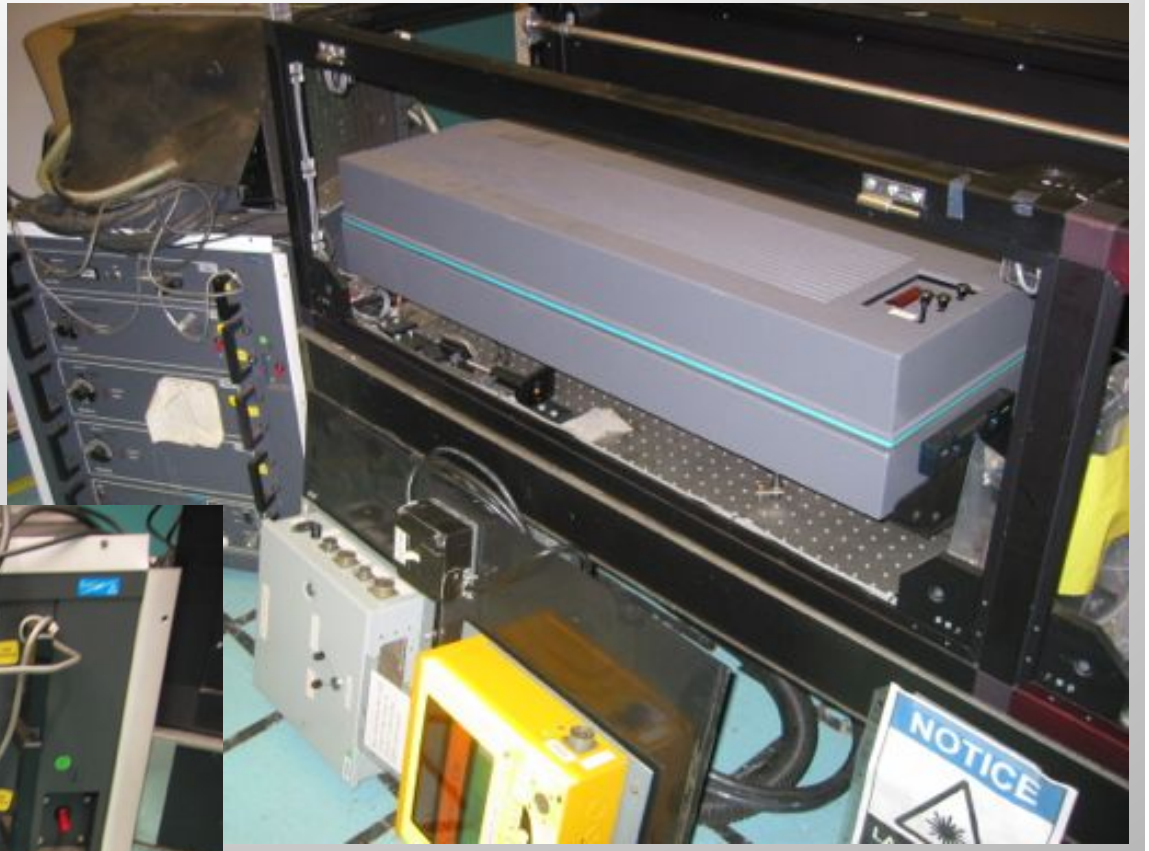
Top view

Laser control optics

- Control optics include:
  - Variable adjustment of laser energy to target
  - Power meter
  - Turning mirrors
- 18 inch high enclosure attaches to the frame and seals off the laser beam
- Enclosure is fully interlocked with the laser power supply

Laser power supplies and control

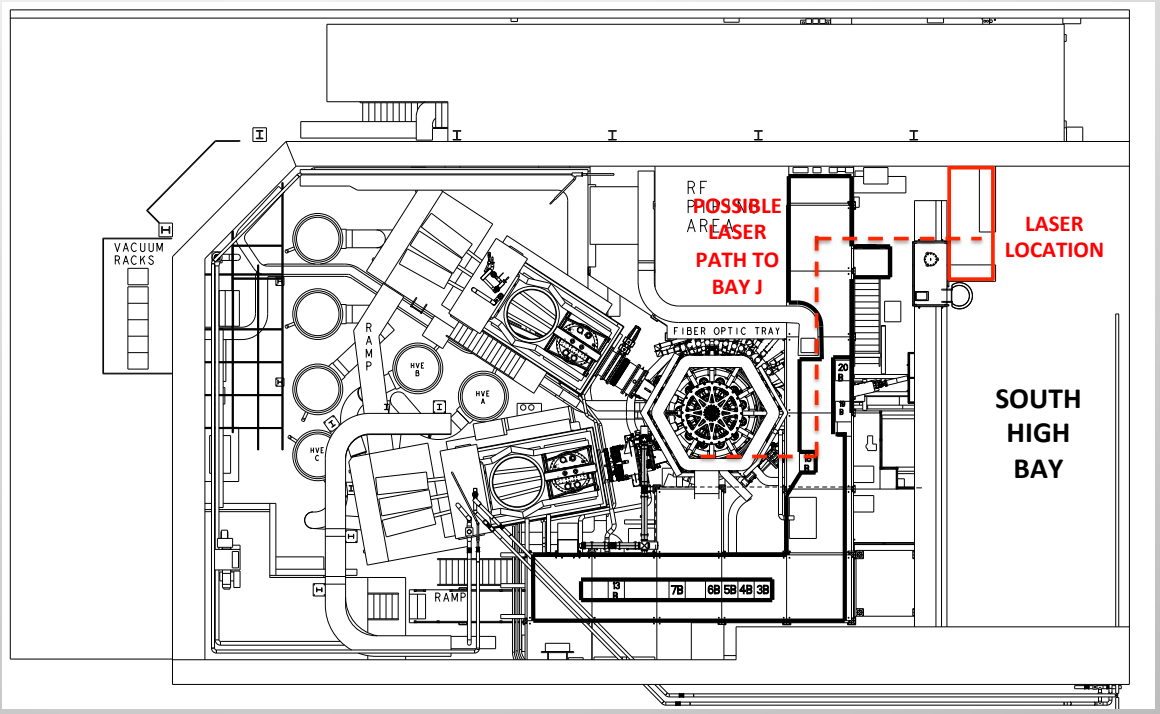
- Rack contains all needed power supplies and controllers
- Controller accepts external trigger and remote programming



- Two 25 ft umbilical chords connect the rack to the laser

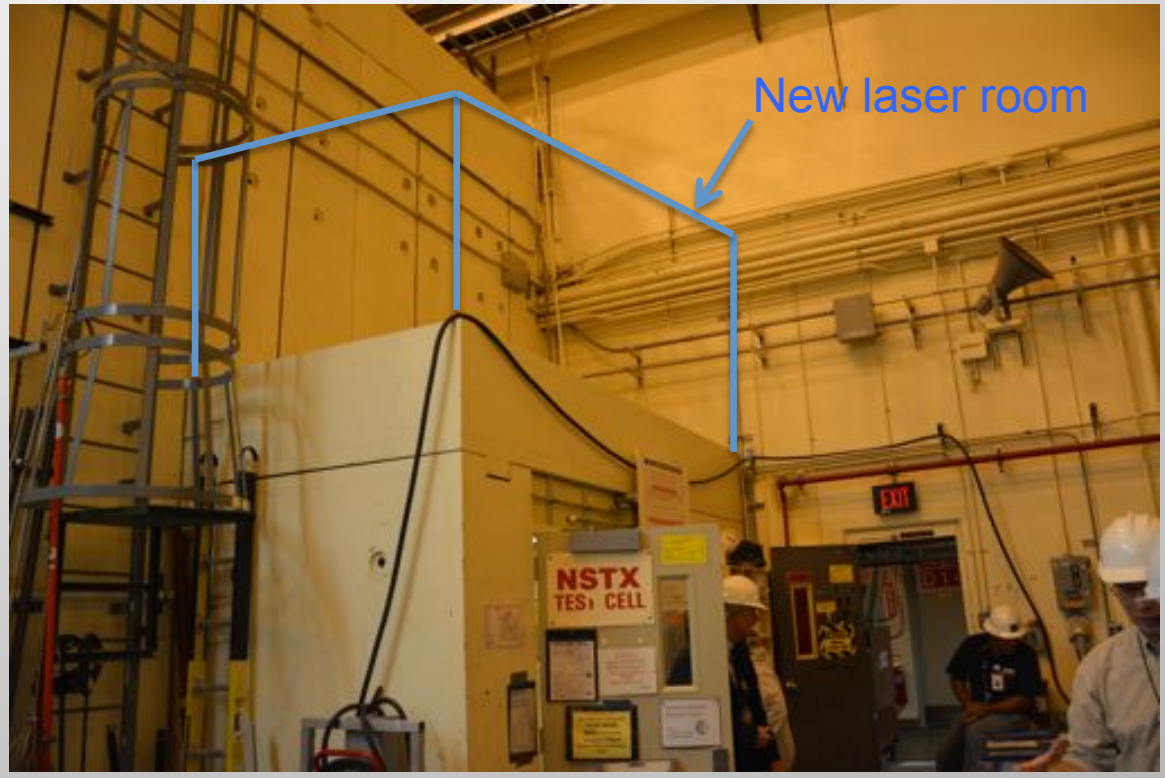
Laser location

- PPPL has the responsibility to locate the laser and build the laser room
- The laser location suggested by PPPL is on the mezzanine above the south bay entrance to NSTX-U
- Location is acceptable for laser operation



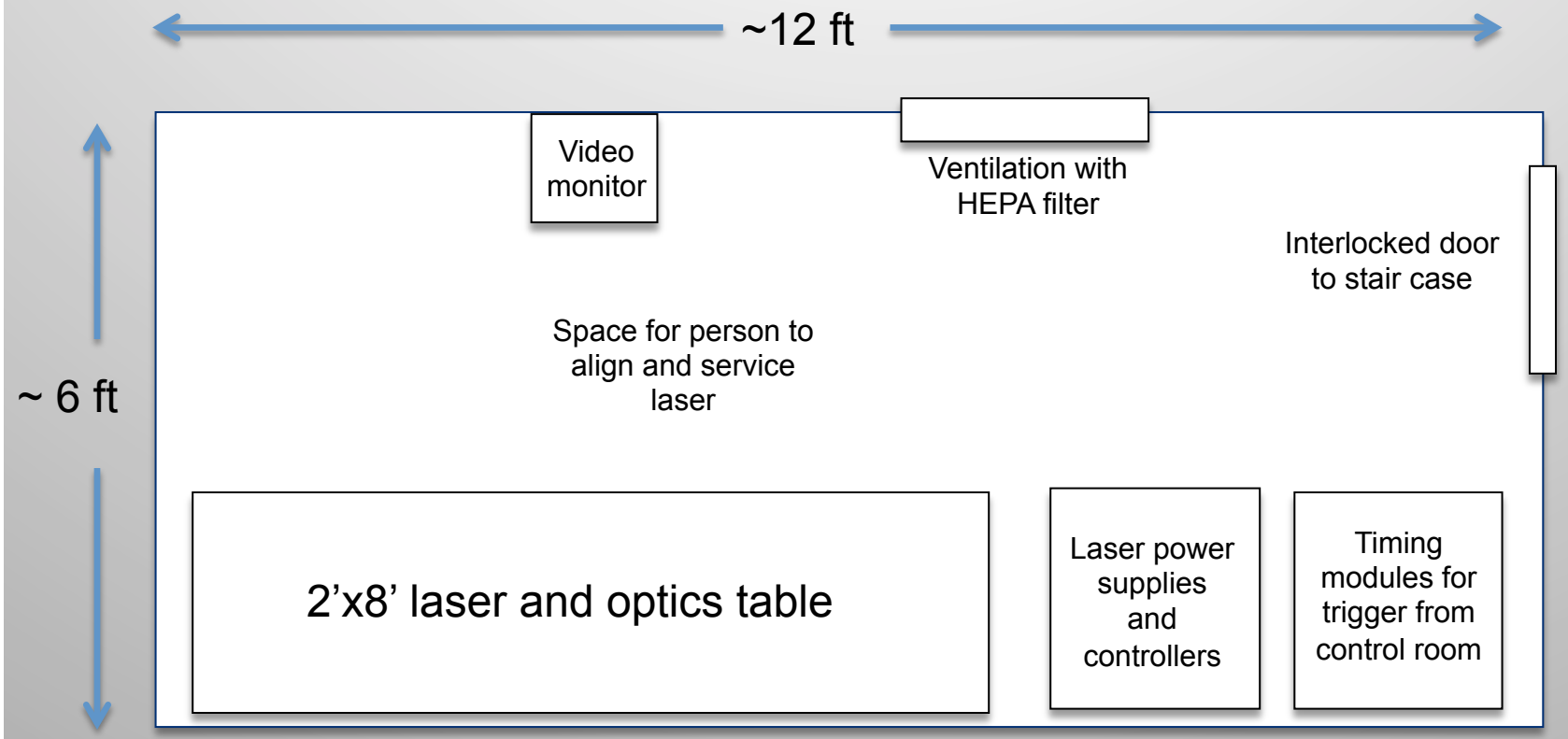
Laser room - specifications

- Room needs to be fully enclosed so as to contain laser beam when being aligned
- Door needs to be interlocked with laser power supply
- Room cooled by air exchange with south bay – needs HEPA air filter to minimize dust
- Power requirements:2 x 4 MO boxes with 110 V, 1 x 208V/ 20A outlet for laser
- LCW for laser cooling
- Staircase



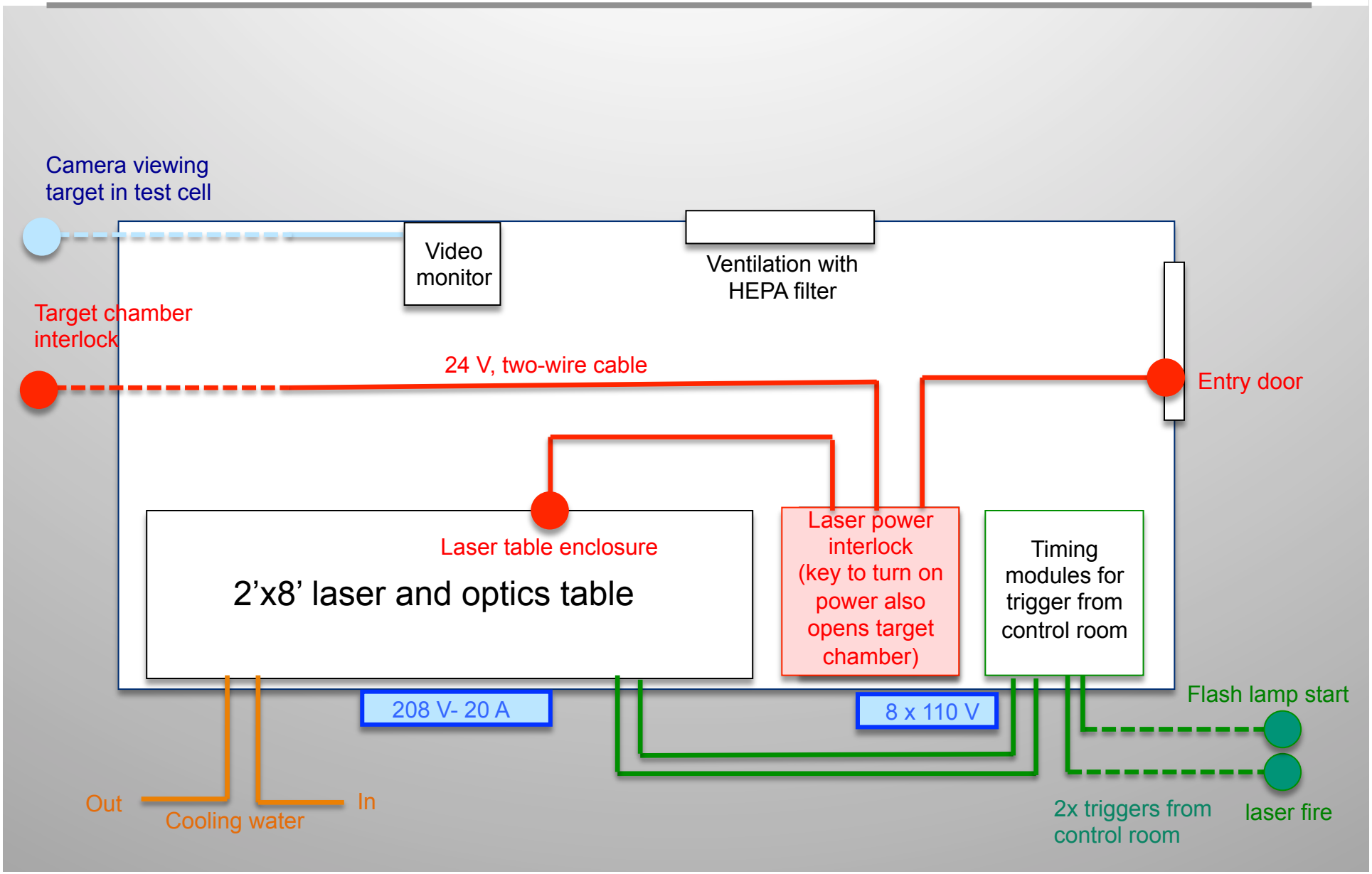
Laser room – possible layout

- **Bare minimum size with 8 ft ceiling:**



- **Room needs to be larger, if it is to house additional lasers for other projects**

Laser room – control and utility connections

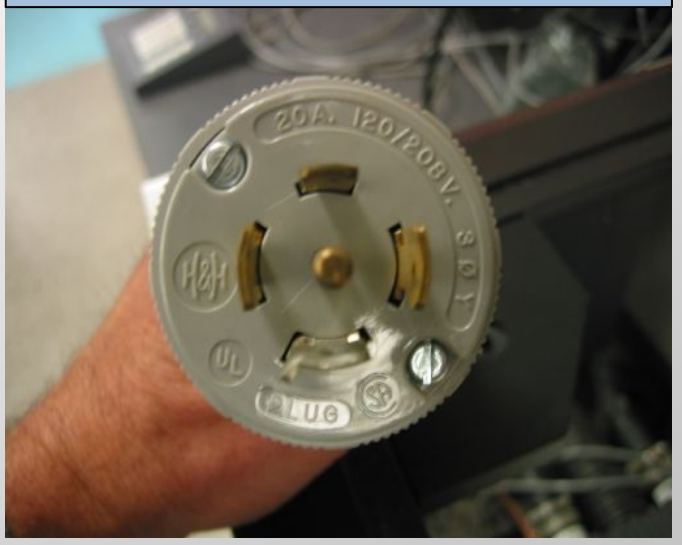


Utility connections - details

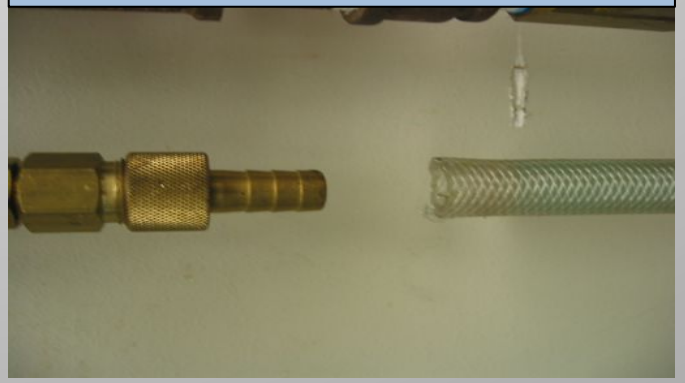
Requirements:

- **208 volts at 20 amperes 3 phase Y**
- **Cooling water (nominal 70°F)**
- **Cooling water flow rate: 1gpm ≤ flow ≤ 5gpm**
- **Cooling hose size (1/2”): 2 each**
- **Visual flow meter**
- **Pressure gages on LCW supply and return**
- **Water pressure regulator**

Power connector

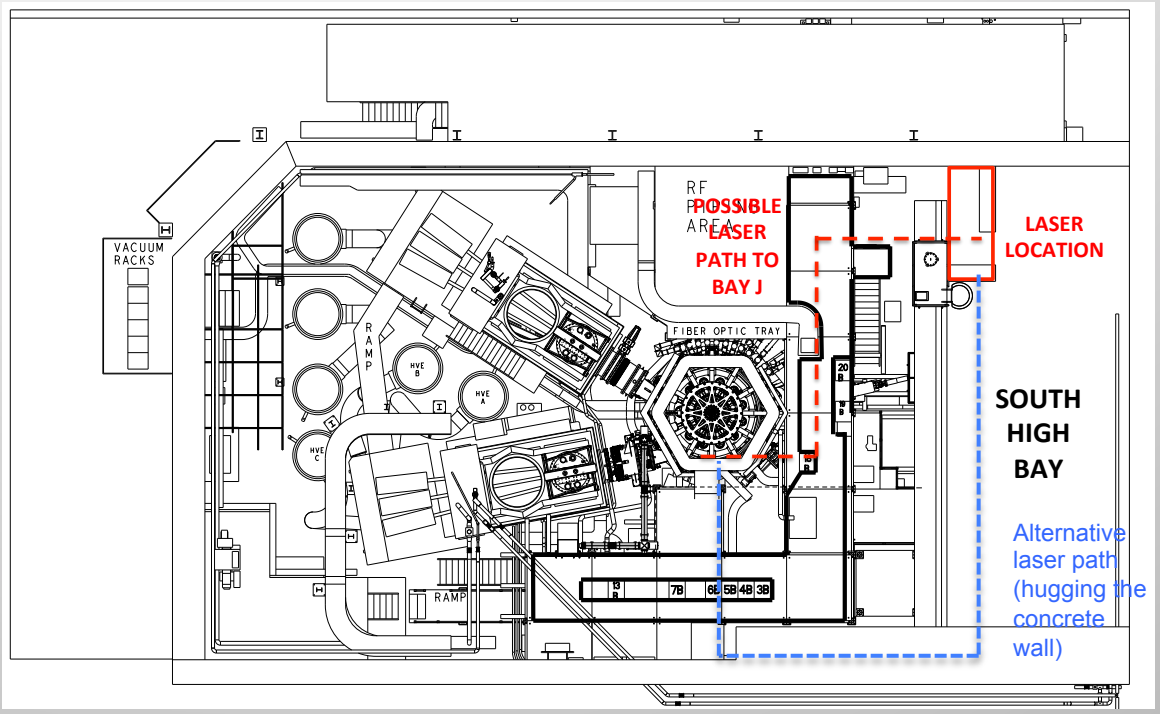


LCW connector



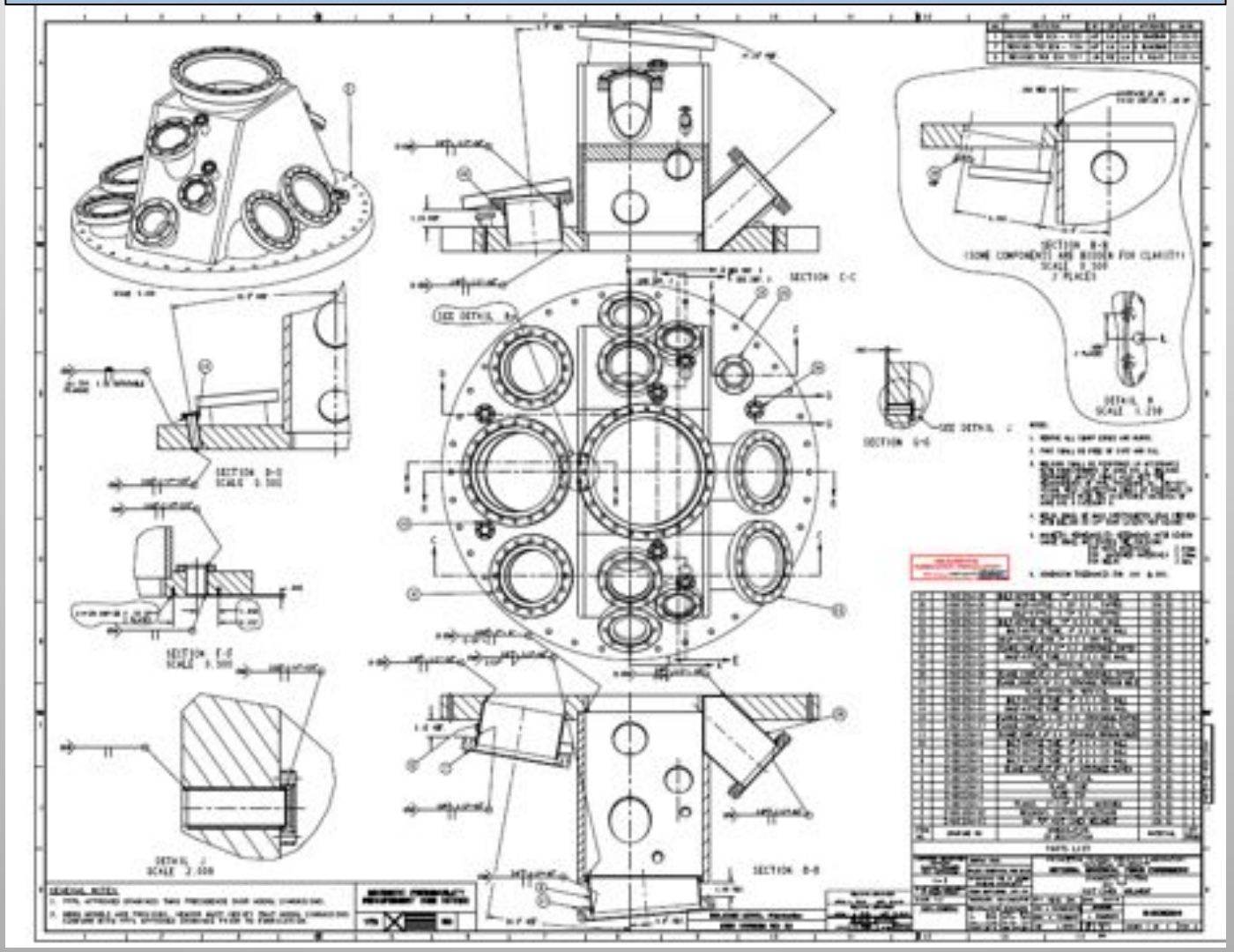
Laser path

- The laser should ideally be along the concrete walls for stability
- PPPL to install the beam duct
- Duct can be 4 inch diameter ABS pipe
- Antireflection optics and dielectric mirrors will be supplied by LLNL

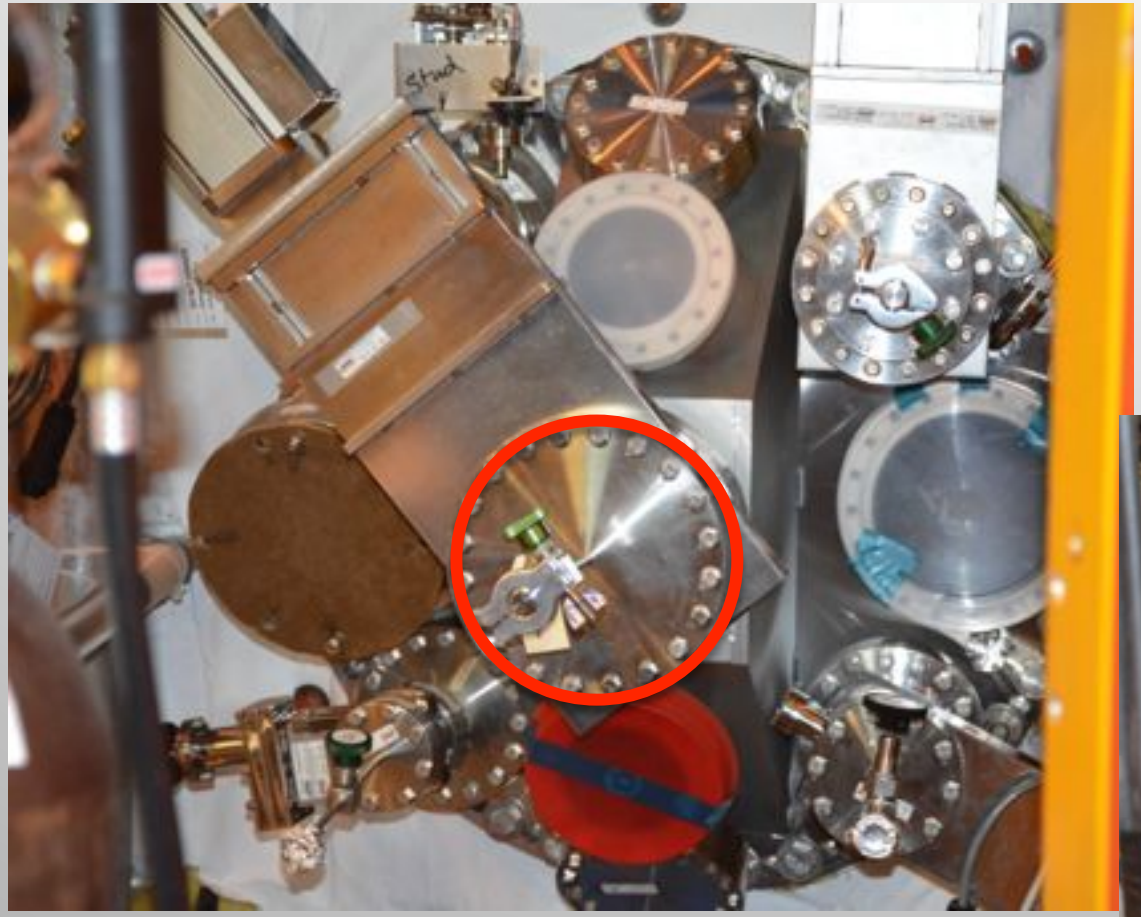


Bay J is the location for the LBO target chamber

Diagnostic systems Bay I port cover weldment (as supplied)

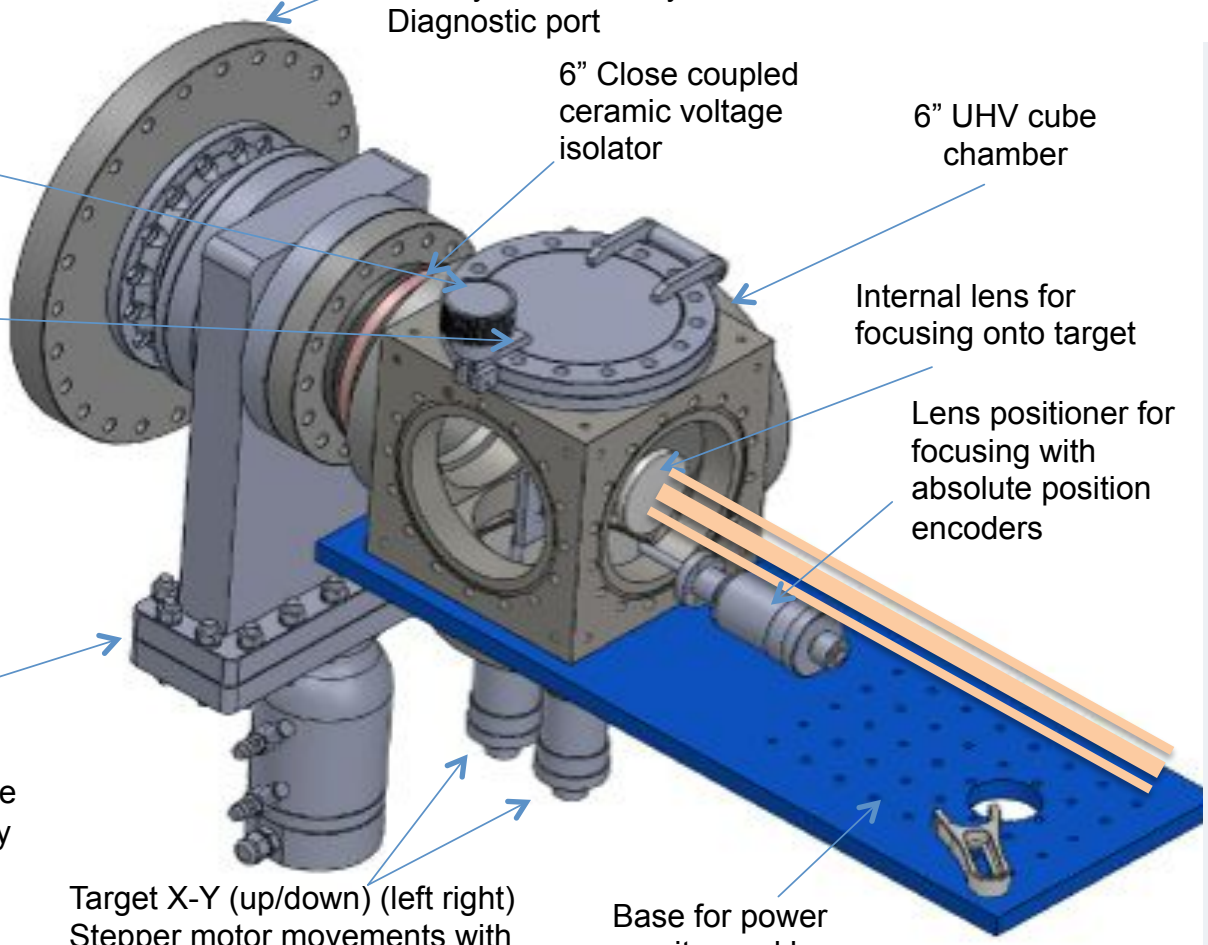


Bay J is the location for the LBO target chamber



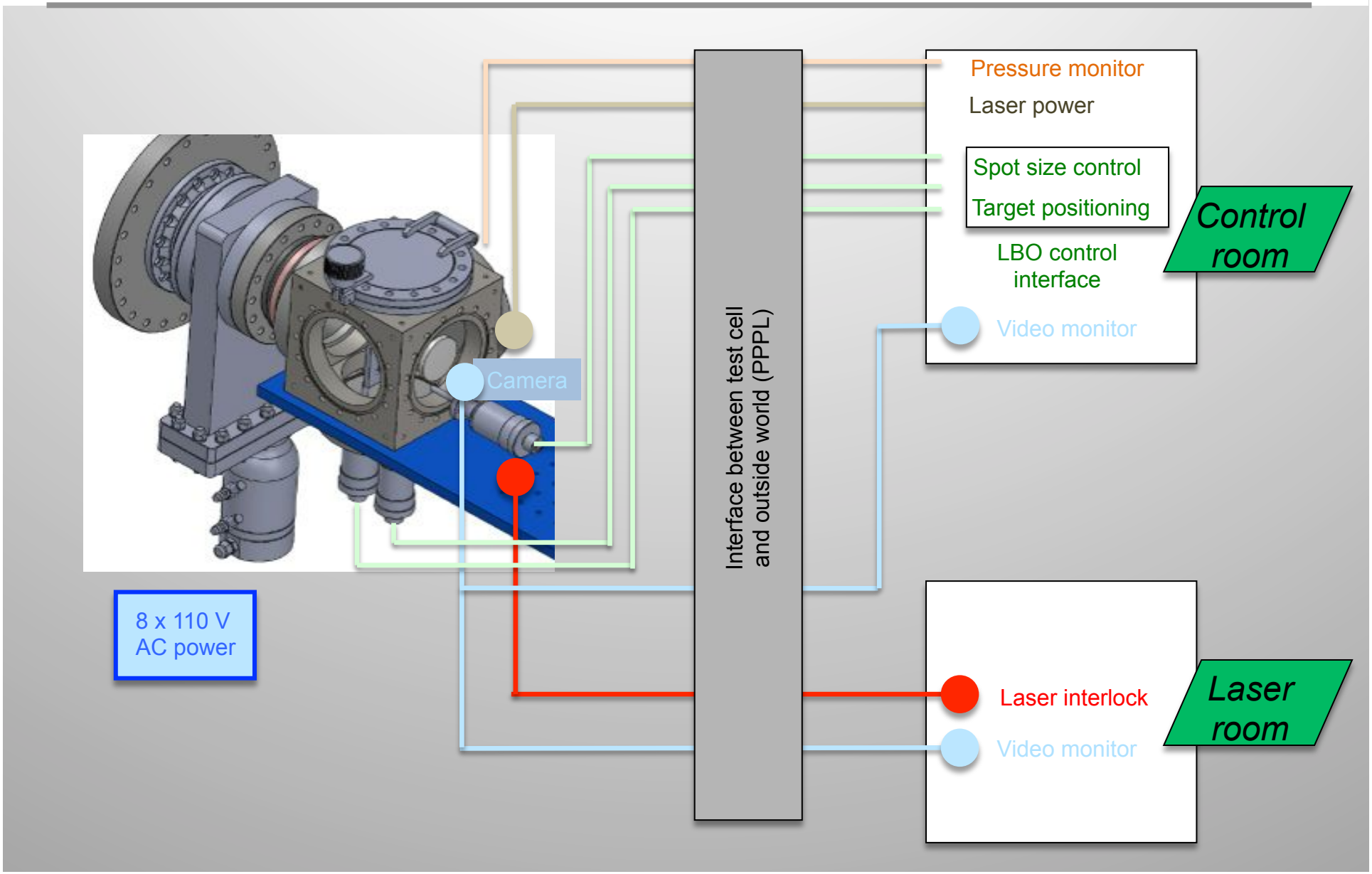
- The bolt pattern indicates a switch in flange size from 10” to 8”
- We designed to 10” flange

Target chamber design

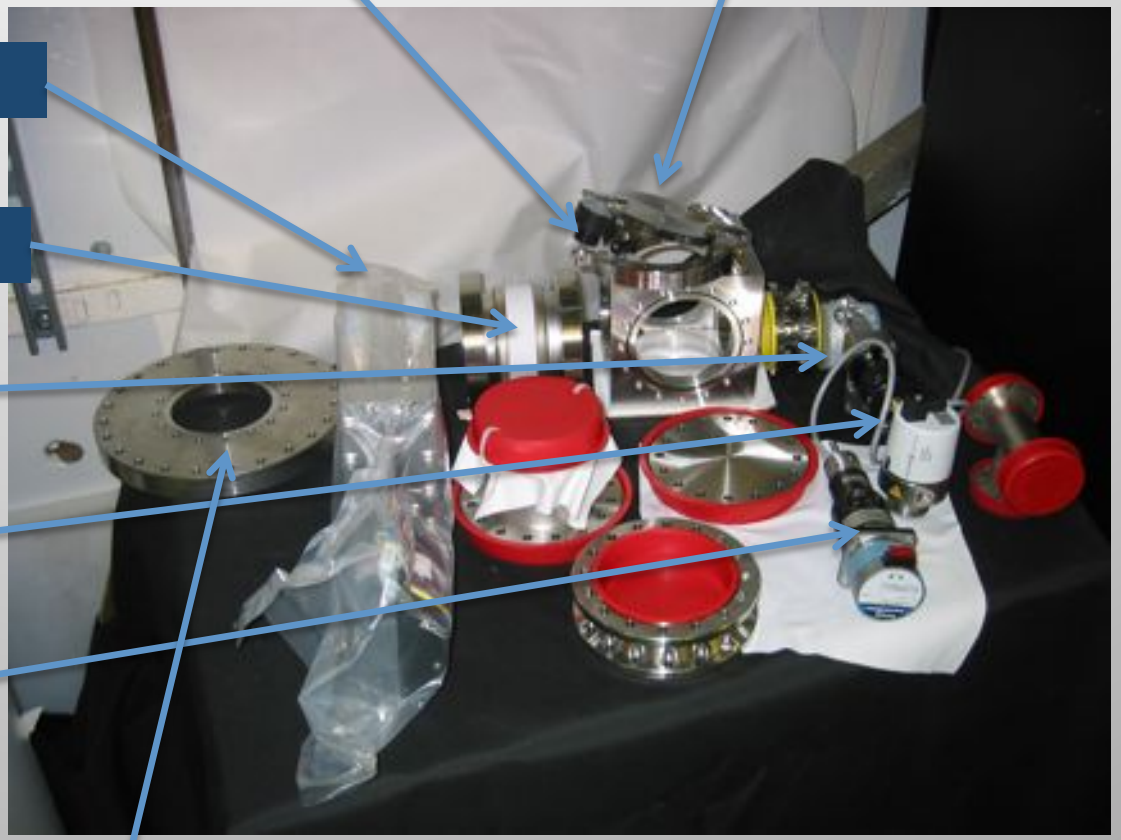


- **Weight of target chamber is less than about 50 lbs**
- **Chamber is supported off port flange**
- **No support stand is needed**
- **Pumping provided by PPPL**

Target chamber controls and utilities



The parts for the target chamber have largely been procured



Time table and tasks

- FDR to be scheduled for March/April 2015
- Tasks to be performed by LLNL and PPPL
  - LLNL tasks and procurements:
    - Laser and laser optics
    - Laser safe operating procedure
    - Procurement of laser beam conduit and optics
    - Target chamber design and assembly
    - Programming of stepper motor computer
    - Operation of LBO system
  - PPPL tasks and procurements:
    - Construction of laser room (including utilities and interlock system)
    - Determine the routing of the laser beam conduit inside the test cell
    - Installation of laser beam conduit and optics
    - Install utilities
    - Lay control and signal cables and provide the interface between test cell and outside areas
    - LBO triggers from control room

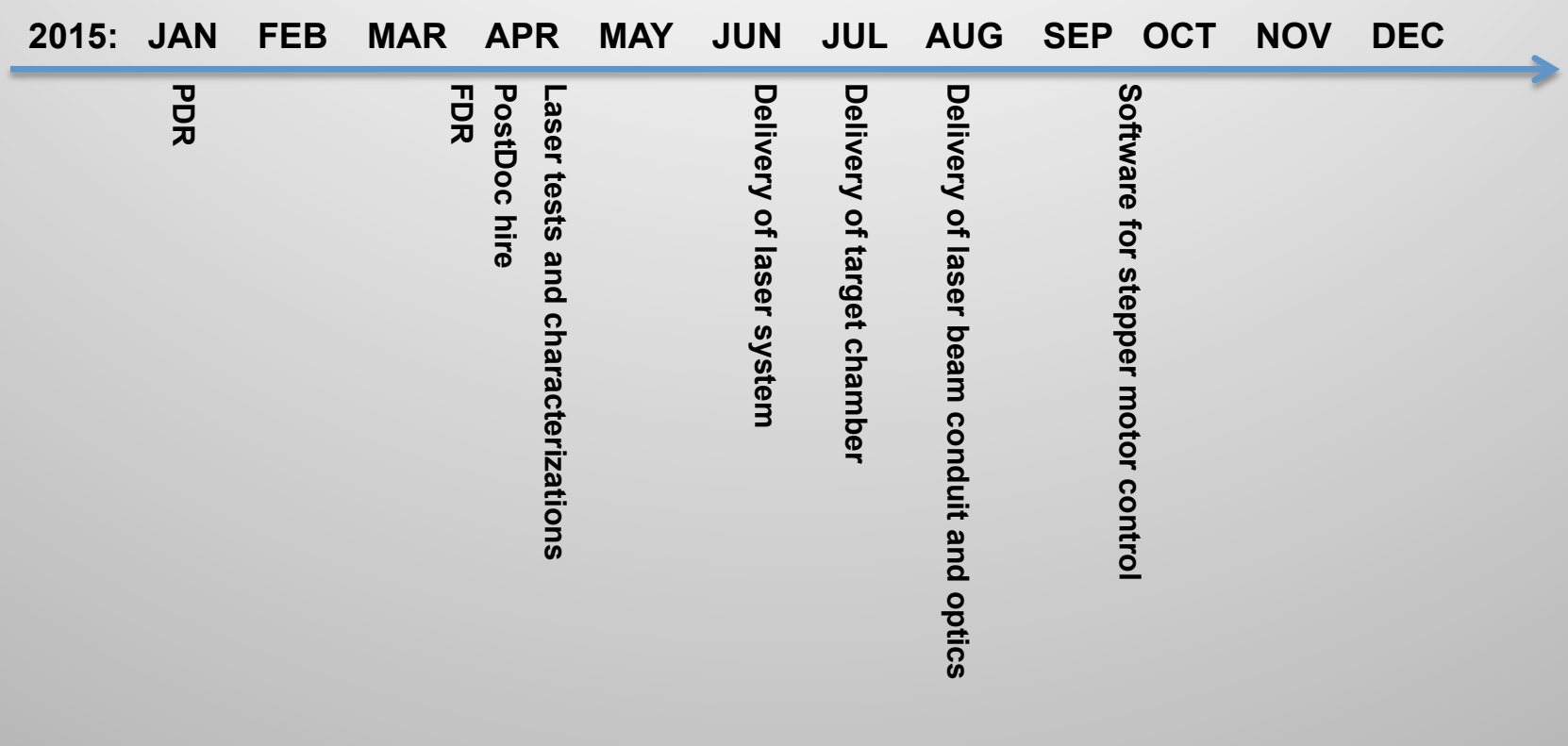
LLNL tasks and procurements - details

- Laser
  - Laser to be tested and operated at LLNL in March–April 2015
    - Measurements of performance characteristics (power, beam diameter, timing, pulse length)
    - Test single-pulse and multi-pulse operation
    - Adjust output power with wave plate/polarizers
  - Laser with optics mounted on table to be shipped to PPPL June 2015 or when laser room is ready
  - Laser beam conduit and optics to be procured once PPPL has finalized the routing
  - Laser safe operating procedure (LSOP) provided to PPPL

LLNL tasks and procurements - details

- Target chamber
  - Design to be completed at the time of the FDR
  - Chamber will be assembled and vacuum tested within three months after completion of FDR (June-July 2015)
  - Chamber will be shipped to PPPL when PPPL gives go ahead
- Stepper motor control
  - Computer code controlling motor operation for spot size control and xy positioning of target will be finalized by September 2015
- Operation of LBO system
  - LLNL is in the process of hiring a post doctoral researcher, who will work at PPPL

LLNL time line summary



LLNL time line will be adjusted to fit the NTSX-U/PPPL time line