TSIB HPT Lab Scope and Requirements

Frederique Pellemoine

TSIB HPT Lab Conceptual Design Review

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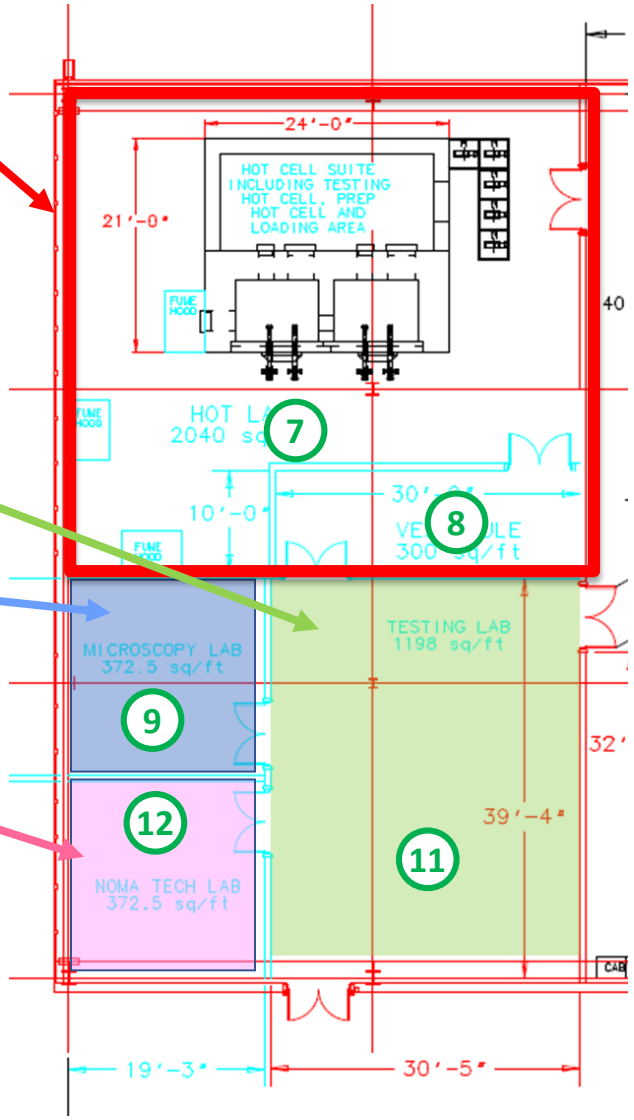
TSIB HPT Lab Scope

- HPT Lab will support material science studies and post investigations for existing and future generation Fermilab Targetry development
  - Materials science studies of non-active materials
    - Targetry materials and materials under consideration for use as Targetry material will be studied and tested to establish baselines and evaluate their potential
  - Development of novel material for use as targetry material and associated fabrication and production technologies
  - Radiation damage studies of irradiated materials
    - Studies and test of previously irradiated materials to determine irradiation damage effect on Targetry material

TSIB HPT Lab to support R&D Program

- Hot Lab Area including Hot Cell Suite
- Cold testing Lab
- Microscopy Lab
- Novel material and technology development area (NOMATech lab)



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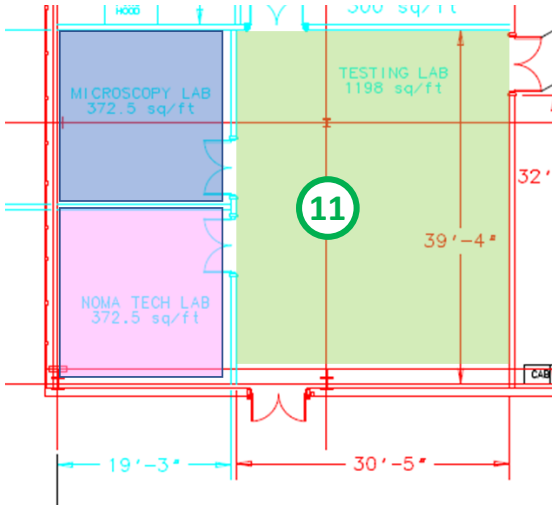
Cold testing area for thermo-mechanical testing on material



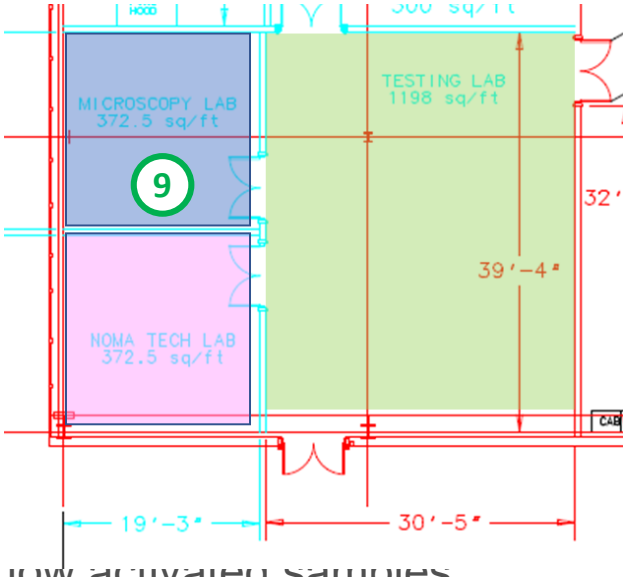
- Scope
  - The Testing Lab (11) will be used to evaluate mechanical and physical properties of non-activated material
  - An area of the Testing Lab (North / East corner) will be equipped with a grinding/polishing station to prepare samples for microscopy study
- Requirements
  - Space for equipment and for two workstations/desks with computer
  - Electrical requirements (125V/20A, 280V/20A 1 phase, 480V/60A 3 phases)
  - Compressed air (2 lines)
  - A polishing station with a sink (with domestic water),
  - Storage cabinets for tolls, small equipment, samples, …
  - Fire protection system to be determined by Fermilab ES&H/FESS life safety
  - Chemical protection plan to be evaluated by Fermilab ES&H team

Cold testing area for thermo-mechanical testing on material

- Equipment list

List of existing equipment	Dimension [WxDxH, ft]	Electrical requirements		
		phase	Voltage (V)	Nominal Current Draw / unit (A)
Commercial grinder/polisher	1.3x 2.3x2.1	1	100-240	5
dilatometer	8x3x4	1	208	16
Fermilab Fatigue Machine	5x3x4	1	208-240	2
Mechanical load frame (Mecmesin 5kN existing)	5x3x7	1	208-240	10
Mechanical load frame (Shimadzu)	8x6x7	1	120	10
List of future potential equipment				
diamond wheel saw	1.1x1.3x1.1	1	100-240	1
Fatigue/tensile testing Machine Instron 8801	3.5x2x8.5	1	110	10
Furnace for load frame	To be fitted inside the load frame	1	220	16
thermal bench test				
Vibration test stand				
laser flash diffusivity				
profilometer				
Split Hopkinson pressure bar				
hardness tester				
DIC system				

Microscopy Lab



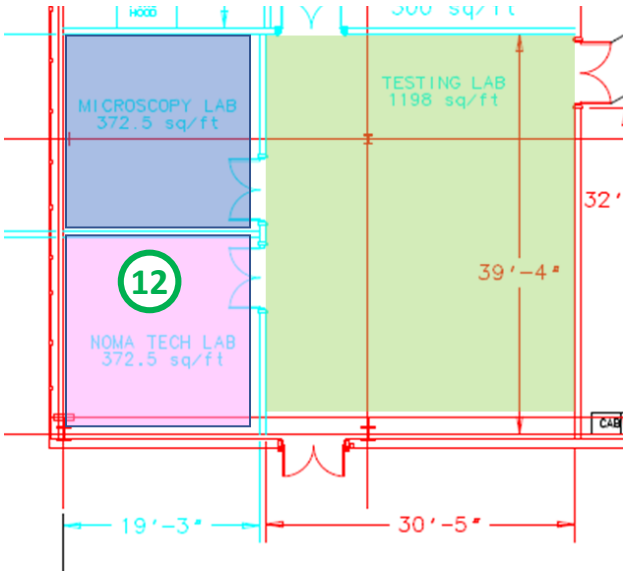
- Scope
  - Microstructural analysis of specimens (mostly Optical) but it will accommodate future upgrades in microscopy equipment (e.g. SEM/EBSD)
    - During initial operations, only non-activated samples will be tested and a space will be reserved in the Hot Lab (South/East corner) to set up a digital microscope or other inspection instruments to allow examination and analysis of low activated samples.
  - The Microscopy Lab will initially have a nano-indenter, a high-resolution Digital microscope
    - microstructure, surface roughness, fractography, various other 3D measurements such as grain size, precipitates % age and to some extent contact less profilometry.
- Requirements
  - Space for equipment and for one workstation/desk with computer
  - Electrical requirements (125V/20A+30A, 280V/20A 1 phase)
  - Faucet and drain for SEM
  - Storage cabinet for tools, and samples

Microscopy Lab

- Equipment list

List of existing equipment	Dimension [WxDxH, ft]	Electrical requirements		
		phase	Voltage (V)	Nominal Current Draw / unit (A)
High resolution digital microscope (Keyence VHX-7000)	6x3x6	1	120	1.5
Nano-indenter	6x3x6	1	120	4
List of future potential equipment				
Desktop SEM	5x2.5	1	100-240	4
Differential Scanning Calorimetry	5x2			

Novel material and technology development area (NOMATech lab)



- Scope
  - Develop and manufacture various novel materials which have potential to be used as future high-power targets and beam intercepting devices.
    - High Entropy Alloy (HEA), ceramic and metallic nanofiber samples
- Requirements
  - Space for equipment including a fume hood
  - Electrical requirements (125V/20A, 280V/20A 1 phase)
  - Fireproof cabinet for flammable chemicals (45 gallons capacity)
  - Storage cabinet for other chemicals
  - Storage cabinet for tools, and samples
  - Fire protection system to be determined by Fermilab ES&H/FESS life safety
  - Chemical protection plan to be evaluated by Fermilab ES&H team

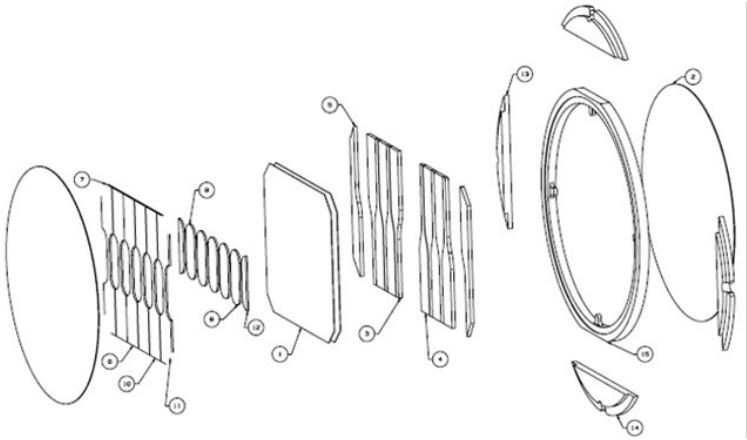
Novel material and technology development area (NOMATech lab)

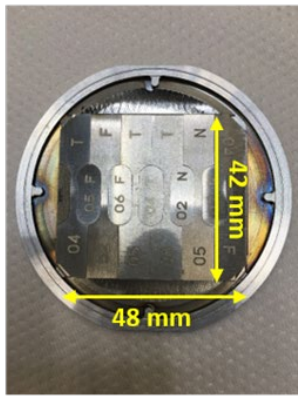
- List of equipment

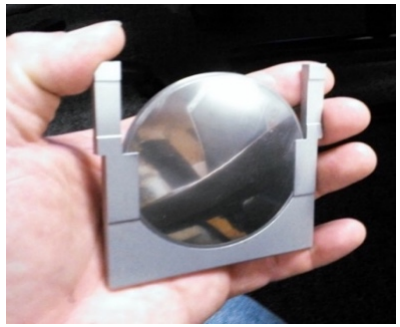
List of potential equipment	Dimension [WxDxH, ft]	Electrical requirements		
		phase	Voltage (V)	Nominal Current Draw / unit (A)
fume hood for chemical mixing	8 x 3x5	1	120	6
High temperature furnace	3x3x4	1	208-240	15
Nanofiber electro-spinning machine	8x6x8	1	120	10

Activated Material Sources

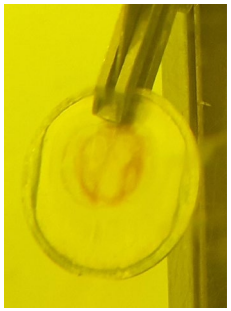
- The activated materials will come from several sources:
  - The primary sources will be samples extracted from the current and future targetry components in the C0 hot cell.
    - Small material samples can be extracted from horn, production target, beam windows, collimators or any other Fermilab beam intercepting devices
  - The second source of activated samples will come from specimen fabricated for dedicated irradiation in support of the Fermilab HPT R&D program.
    - These specimens will be small in size (order of an inch or smaller) for specific mechanical and thermal testing of activated materials (so-called R&D samples).
    - These samples may be irradiated in facilities outside of Fermilab, or irradiated at Fermilab; however, Fermilab currently does not have dedicated and high-dose relevant irradiation stations on-site



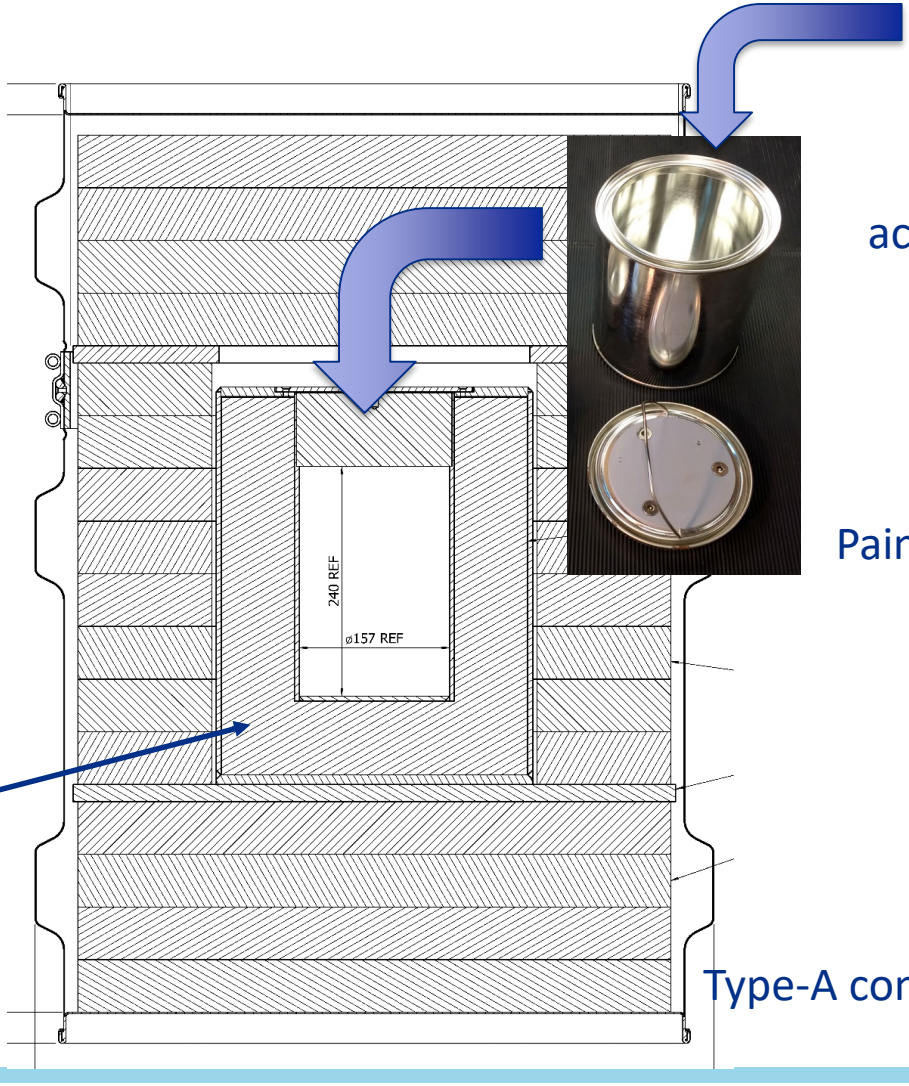




R&D Activated Material Packaging



Capsule with activated materials



Paint can / inner pot

Lead pot

Type-A container drum

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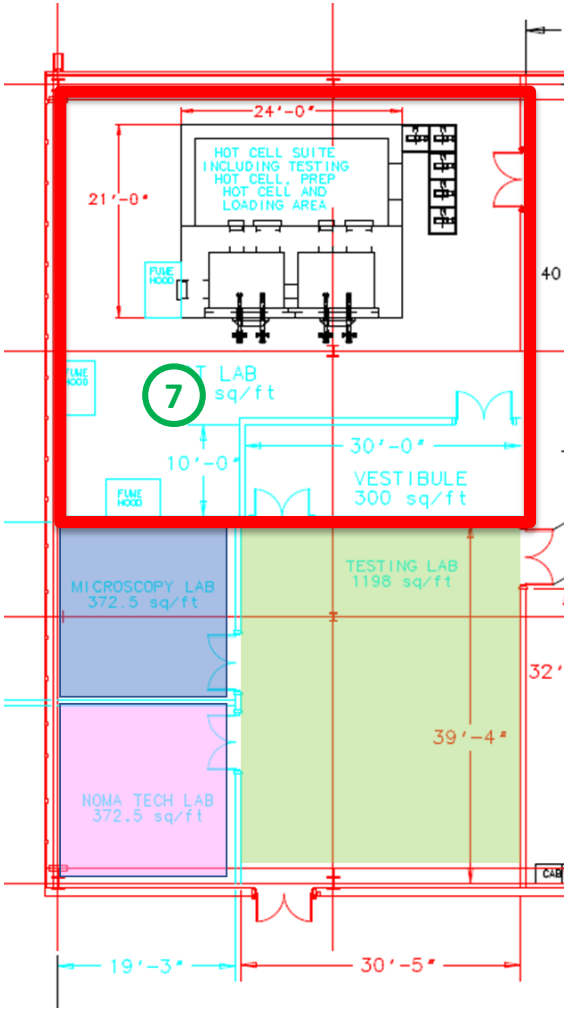
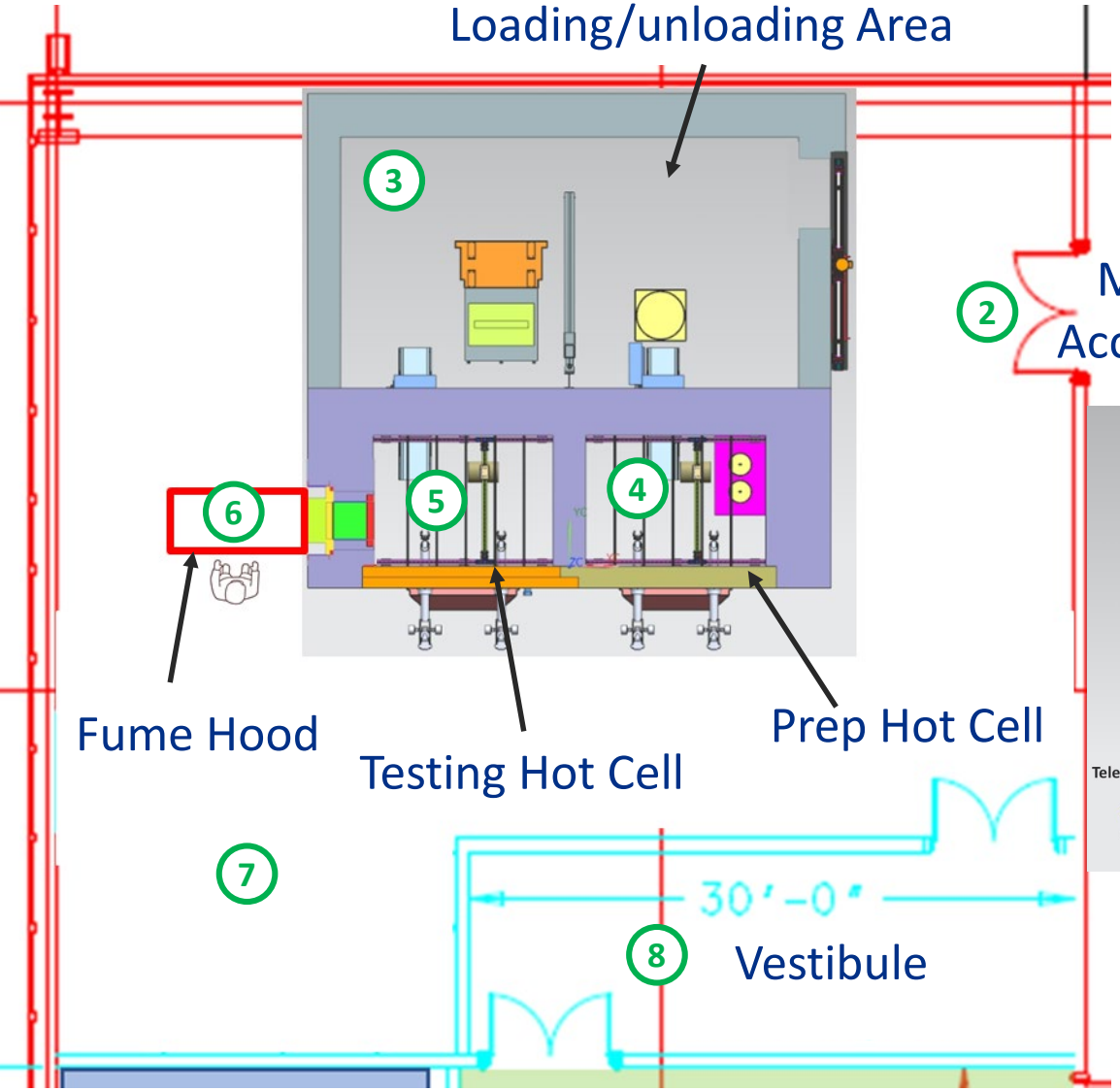
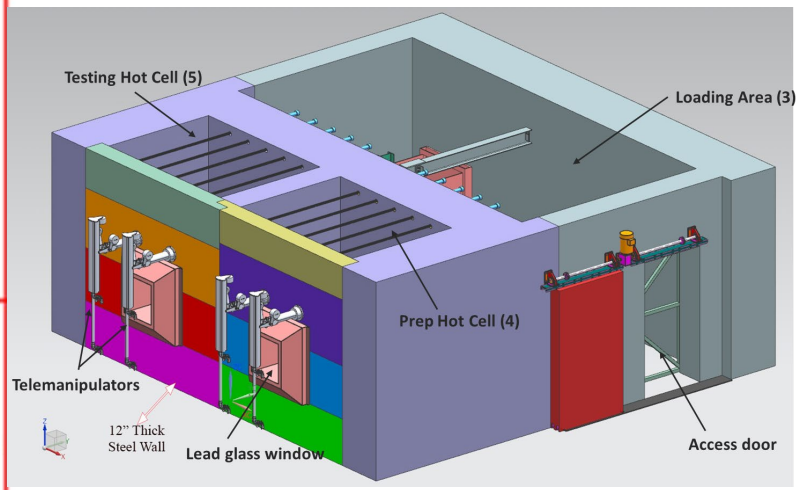
Hot Lab Area Scope

- The Hot Lab area includes a hot-cell suite and fume hood for mechanical and physical property testing of activated materials
- The hot cells will be dedicated to analyze and perform Post-Irradiation Examination on small samples only (1 mm to 100 mm scale).
- Low activated samples can be tested in the fume hood or the Hot lab after being prepared in the hot cell suite and surveyed (and decontaminated, if necessary) in the fume hood



Hot Lab Area Layout





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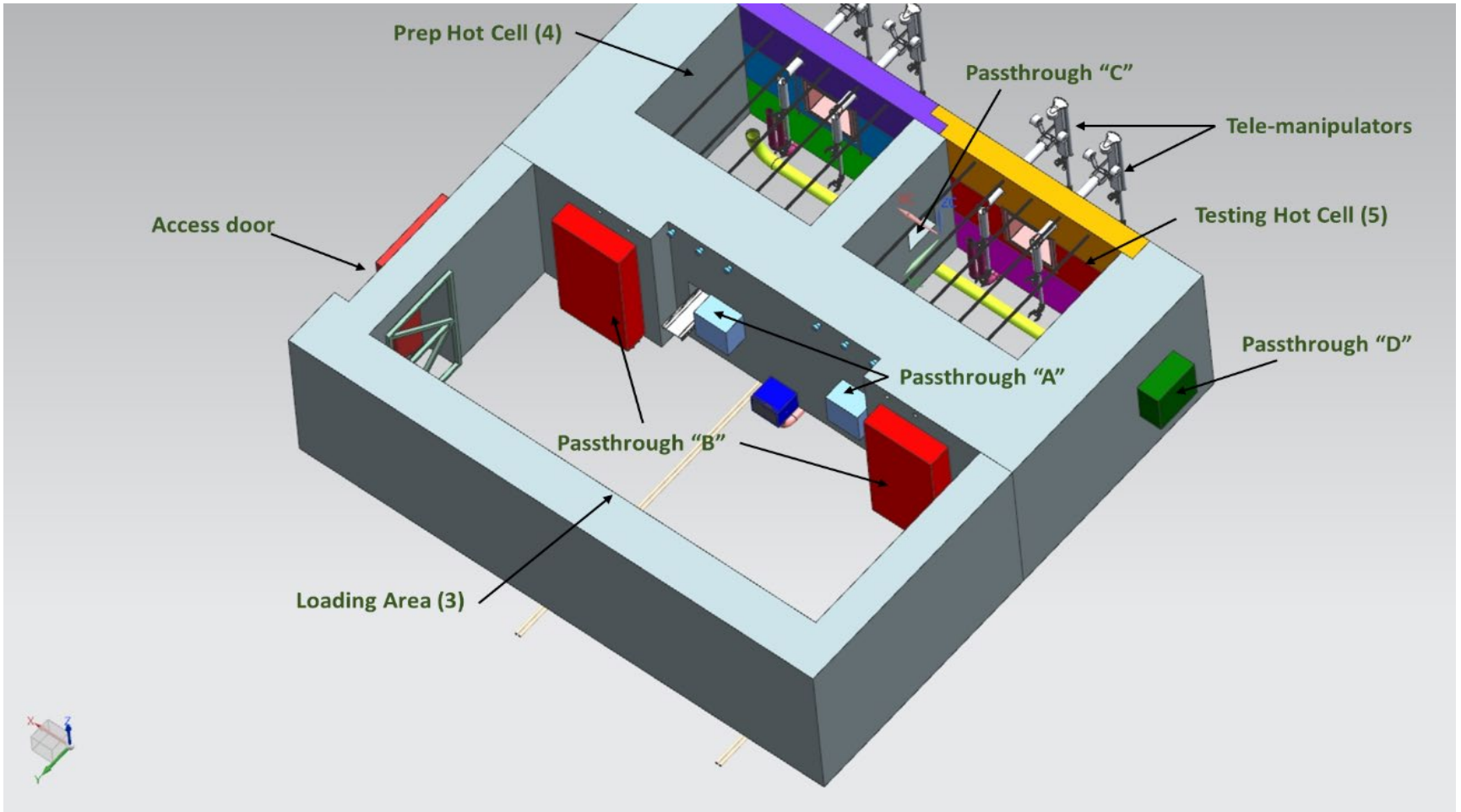
Passthrough in the Hot Cell Suite

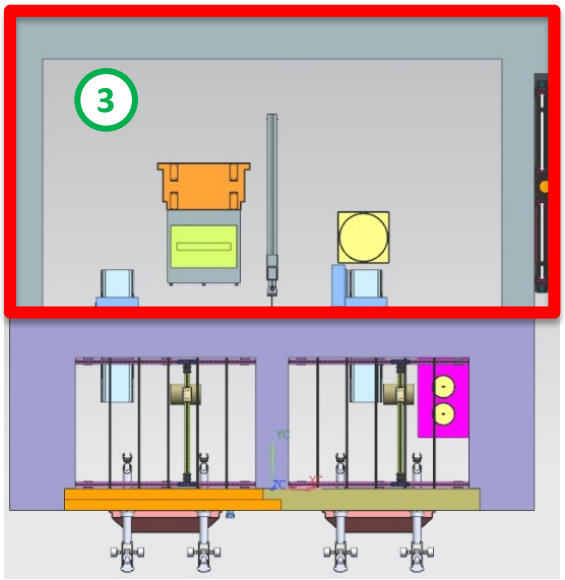


Loading/unloading Area Scope

- Receive the type-A container, and transfer the inner pot containing the activated material to the Prep hot cell
- Install and transfer equipment in and out of hot cells
- Control, decontaminate and temporarily store as needed, the testing equipment from the two hot cells to the hot lab
- Prepare the large equipment on a shield plug
- Extract waste from the hot cells to the appropriate disposal/storage container/cask
- House the HVAC Ventilation filtration unit of the 2 hot cells for controlled maintenance of the filters

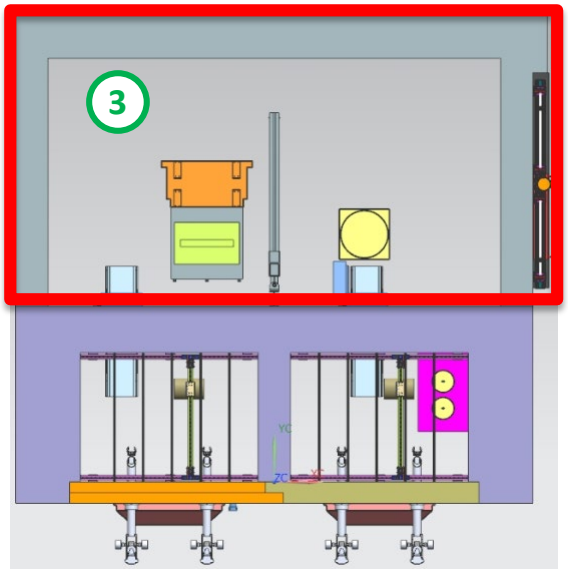
Loading/unloading Area Requirements

- Have a negative pressure compared to the Hot Lab area
- The access door is controlled by Radiation Physics Operations Department.
  - It will only be opened, and personnel access into the Loading Area (3) permitted, during the activities described by the scope.
  - The door is large enough to have pallet jack (or similar) with large equipment to access the Loading Area
  - a frisker station and designated step-off are at the exit of the loading area in the Hot Lab
- Passthroughs for moving equipment and materials in and out of cells
- Penetration for electrical utilities (125V/20A, 280V/20A 1 phase)
- Fire protection system to be determined by Fermilab ES&H team/FESS life safety
- Shield wall thick enough to mitigate the exposure of workers in the Hot lab (< 0.25 mrem/hr)



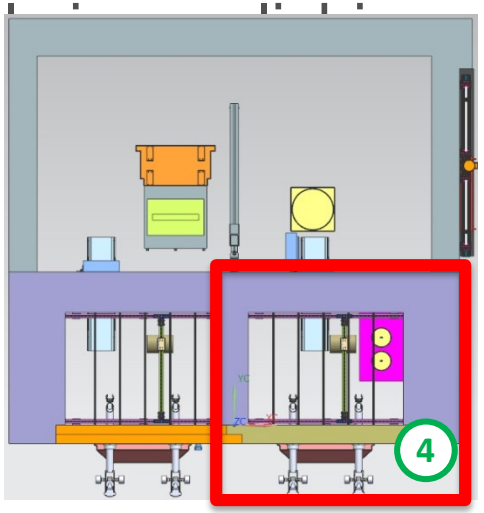
Loading/unloading Area Space Requirements

- The loading/unloading area needs to have enough space :
  - To set up the Hot Cell HVAC unit with access to the bag-in bag-out filter exchange system
  - To allow access and workspace around the Type-A container during preparations for transfer activities
  - To accept a lifting devices with mobile shielding panel enabling transfer of activated materials from/to the Type-A container
  - To accept and maneuver a pallet truck (or similar) when transferring the Type-A container from the truck bay via the Hot Lab
  - To install a permanent jib crane (1 ton load)
  - To prepare a large equipment and cabling
  - To be able to temporarily store equipment removed from the Testing Hot Cell for later use in the Hot Cells



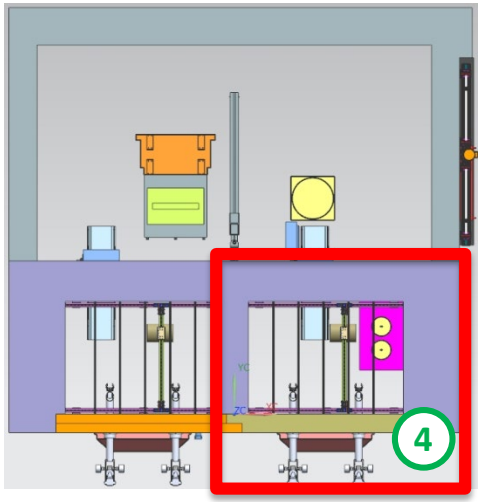
Prep Hot Cell Scope

- Paint can / inner pot with activated samples is transferred to the prep hot cell from a type-A container
- The Prep Hot Cell will be primarily used to open and remove sample capsules/containers from the inner pot, to open the capsules containing the activated samples, to extract and sort the individual samples and store them as needed prior to testing
- Activities may include cutting samples in smal samples for microscopy analysis and decontamination (if necessary) of individual sample prior to Post-Irradiation Examination
- All activities in prep hot cell that need worker operation will be done remotely using telemanipulators



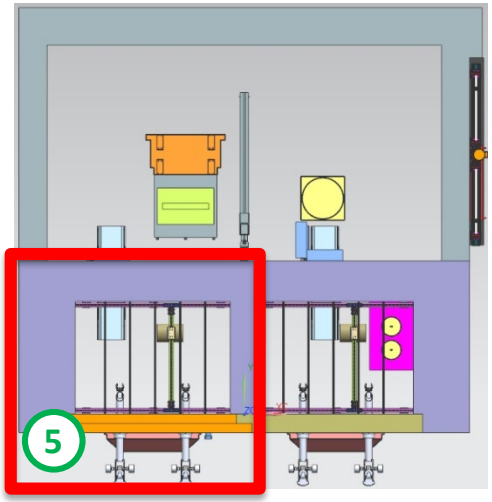
Prep Hot Cell Requirements

- 2 telemanipulators , have enough space in front of the cell to remove the arms for repair
- one viewport
- Pass throughs for moving equipment and materials in and out of cells and between cells
- Proper ventilation to ensure a negative pressure inside the hot cells and proper filtration to contain contamination to the interior of the hot cell suite
- Penetrations for HVAC system
- Replaceable feed-through penetration ports for 125V/20A, 280V, 20 A, 1 phase, signal cables, utilities (fluid, compressed air)
- All the switches ON/OFF, control valves (for fluids), for utilities will be controlled outside of the hot cell near the workstation (front wall) for rapid access to the worker.
- In-cell lifting capability of 1000 lbs
- Long term storages for lower activated samples and for high dose samples
- Walls/floor of the hot cell should be finished/sealed with surface treatment to improve lighting and for easier decontamination
- Fire protection system to be determined by Fermilab ES&H team/FESS life safety
- Shield wall and view port thick enough to mitigate the exposure of workers in the Hot lab (< 0.25 mrem/hr)



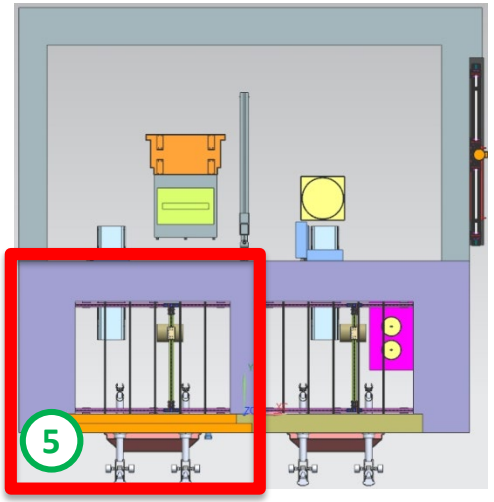
Testing Hot Cell Scope

- Individual specimens (typically 1 mm to 100 mm scale) will be tested
- Material tests will include mechanical tests (e.g. tensile, bend, fatigue) and physical property tests (e.g. dilatometry, thermal diffusivity, and ultrasonic)
- The Testing Hot Cell will be prepared each time for a specific course of studies. Prior to the test of the sample, any needed testing instruments not already installed in the Testing Hot Cell will be transferred into the cell via passthrough doors
- All activities in Testing hot cell that need worker operation will be done remotely using telemanipulators



Testing Hot Cell Requirements

- 2 telemanipulators , have enough space in front of the cell to remove the arms for repair
- one viewport
- Pass throughs for moving equipment and materials in and out of cells and between cells
- Proper ventilation to ensure a negative pressure inside the hot cells and proper filtration to contain contamination to the interior of the hot cell suite
- Penetration for HVAC system, cables and controls
- Replaceable feed-through penetration ports for 125V/20A, 280V, 20 A, 1 phase, signal cables, utilities (fluid, compressed air)
- All the switches ON/OFF, control valves (for fluids), for utilities will be controlled outside of the hot cell near the workstation (front wall) for rapid access to the worker
- Walls/floor of the hot cell should be finished/sealed with surface treatment to improve lighting and for easier decontamination
- In-cell lifting capability of 1000 lbs
- Long term storages for lower activated samples
- Space to accept several testing equipment (at least 2 smalls and 1 large at the same time)
- Fire protection system to be determined by Fermilab ES&H team / FESS life safety
- Shield wall and view port thick enough to mitigate the exposure of workers in the Hot lab (< 0.25 mrem/hr)



Shielding Requirements

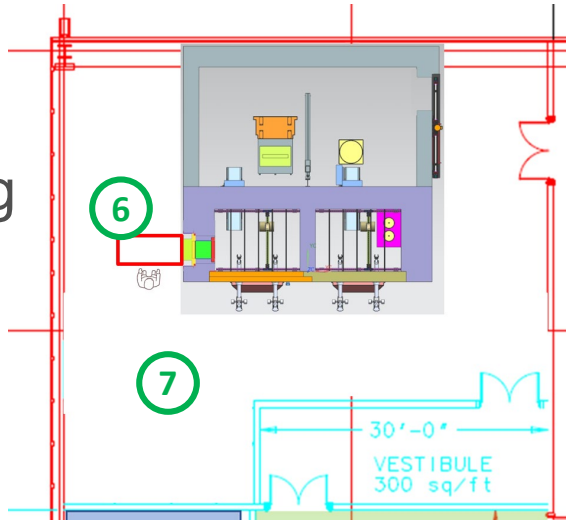
- Worst case scenario based on previous irradiation campaigns at BNL-BLIP facility
  - Proton up to 200 MeV on Ti-capsule containing 56 samples during 55 days, accumulating a total of up to 4.6 x 10^{21} protons
  - The maximum dose rate after 3 months of cooling down was calculated to be ~40 R/hr
  - In future irradiations, we do not anticipate irradiating higher atomic number materials for longer irradiation time at BLIP facility
- Hot cell shielding must provide sufficient shielding to reduce a 40R/hr source at 1 foot down to 0.25mrem/h
  - Approximately 1ft of steel or 3 ft of concrete will provide the necessary shielding required

	Distance from external wall of work cell [ft]									
[mrem/h]	0	0.33	0.417	0.5	1	2	3	4	6	6.67
1 ft iron (source against inside wall)	1.18	0.66	0.59	0.52	0.29	0.13	0.073	0.046	0.024	0.02
1 ft iron (source 1ft from inside wall)	0.43	0.32	0.29	0.27	0.19	0.11	0.068	0.047	0.027	0.023
2 ft concrete (source 1 ft from inside wall)	10.6	8.6	8.2	7.8	6	3.8	2.7	1.9	1.2	1
2 ft concrete (source against inside wall)	20.1	14.7	13.7	12.8	8.9	5	3.2	2.2	1.2	1.1
3 ft concrete (source against inside wall)	0.26	0.2	0.19	0.187	0.14	0.09	0.06	0.05	0.03	0.02

- Lead glass thickness for the viewing windows has been calculated to be between 22” and 28” depending on density on combinations of density

Fume Hood and Hot Lab Scope

- Fume hood (6) adjacent to the Testing Hot Cell and Hot Lab (7) will be able to accept low-activated material via a passthrough
- Different thermal/mechanical tests will be handled in the fume hood or the hot lab
  - Specific dose rate and activity limits for samples in the fume hood and the hot lab is being determined by the Radiation Physics Operations department, taking into consideration the types of tests being performed and how personnel will be handling the material (I.e., by hands or use of tools), and how long samples may be handled by hand
- The fume hood will serve as a point of control for samples transferring out of the Hot Cell Suite



Fume Hood Requirements

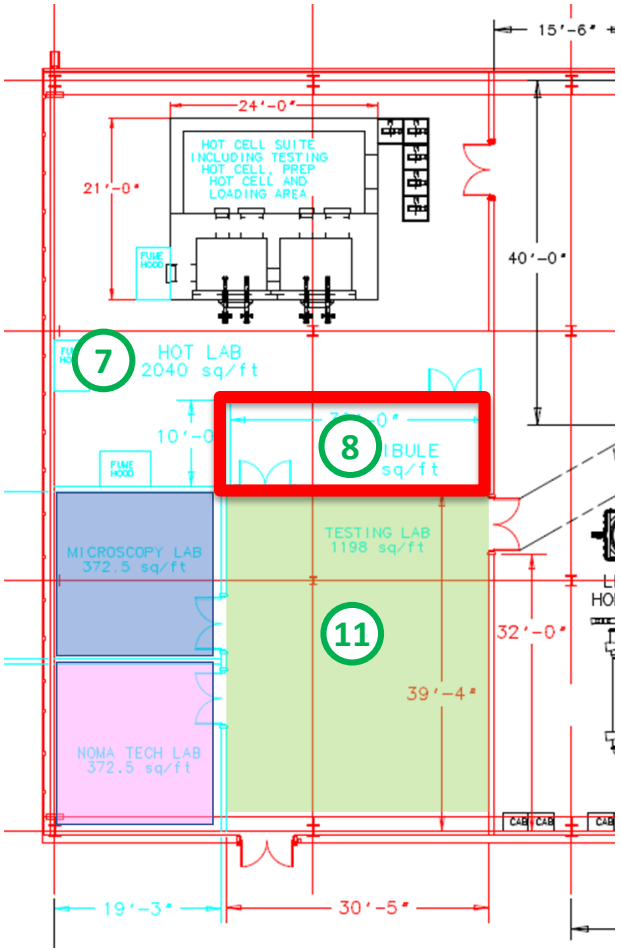
- The fume hood needs
  - To be adjacent to the testing hot cell with a direct access via the passthrough
  - To be large enough to accept the few large testing equipment such as dilatometer or compact tensile test machine
  - An independent ventilation to assure a negative pressure compared to the Hot Lab and maintain the required face air velocity as per ANSI/AIHA/ASSE Z9.5 and ANSI/ASHRAE 110 – Laboratory Ventilation Package (or applicable standard)
    - A bag-in/bag-out system for fume hood will be determined
  - Electrical requirements (125V/20A, 280V/20A 1 phase) inside the fume hood for equipment

Hot Lab Requirements

- Proper ventilation to ensure a negative pressure inside the hot lab compared to the vestibule and the rest of the TSIB building
- Access doors for material and for personnel need
  - To be sealed (material door (2) and door between Hot Lab (7) and vestibule (8))
  - Material access door to the hot lab is controlled by Radiation Physics Operations Department and will only be opened when a container is received into the hot lab (7).
  - Access doors for personnel through the vestibule will be limited with a control system.
- Electrical requirements (125V/20A, 280V/20A 1 phase, 480V/60A 3 phases)
- Compressed air (2 lines)
- Space for
  - Few testing and inspection equipment
  - Test bench with outlet panels
  - Fireproof cabinet for flammable chemicals (~20-30 gallons)
  - Storage cabinet for other chemicals/hazardous products
  - Shielded storage to store the low activated material accepted for test in the hot lab and the fume hood
  - Storage cabinets for tools and small equipment
  - Workstations/desks with computer
- An independent floor drain system separated from the general TSIB building drain and sump system as determined necessary by Fermilab Radiation Safety group.
- Fire protection system to be determined by Fermilab ES&H/FESS life safety
- Chemical protection plan to be evaluated by Fermilab ES&H team

Vestibule

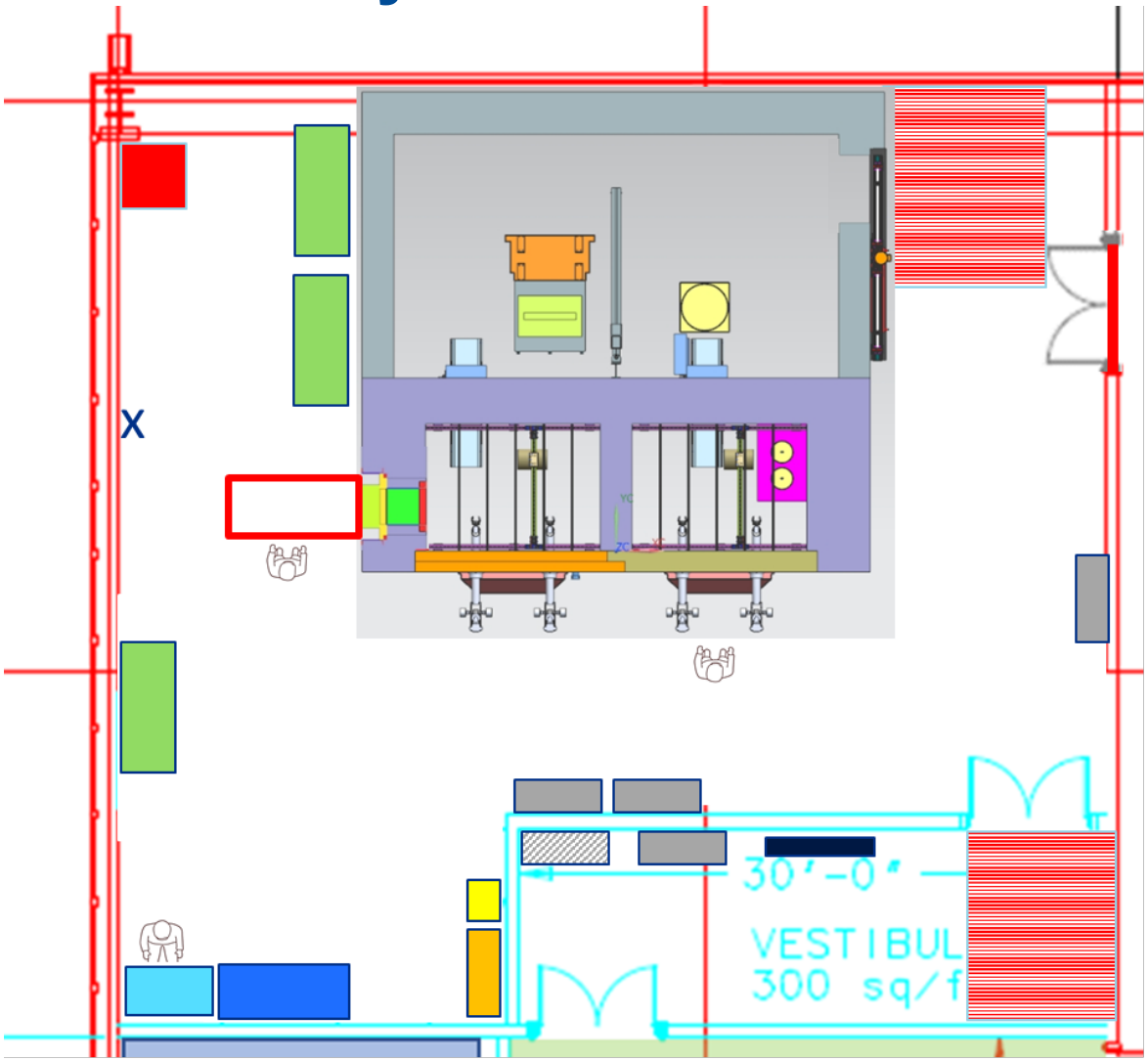
- Scope
  - This room serve as an entrance to the Hot Lab and as a point of control at the exit of the Hot Lab
  - Only qualified personnel will be allowed to enter the ‘vestibule’ room adjacent to access the Hot Lab
- Requirement
  - Access through its entrance door will be limited with a control system
  - Access door between the hot lab and the vestibule needs to be sealed to maintain a negative pressure in the hot lab area
  - Space for
    - a frisker station and designated step-off area near the door to exit the hot lab
    - at least one bench and one cabinet for booties / PPE if needed
  - Electrical requirements (125V/20A, 280V/20A 1 phase)



HPT Lab Requirements

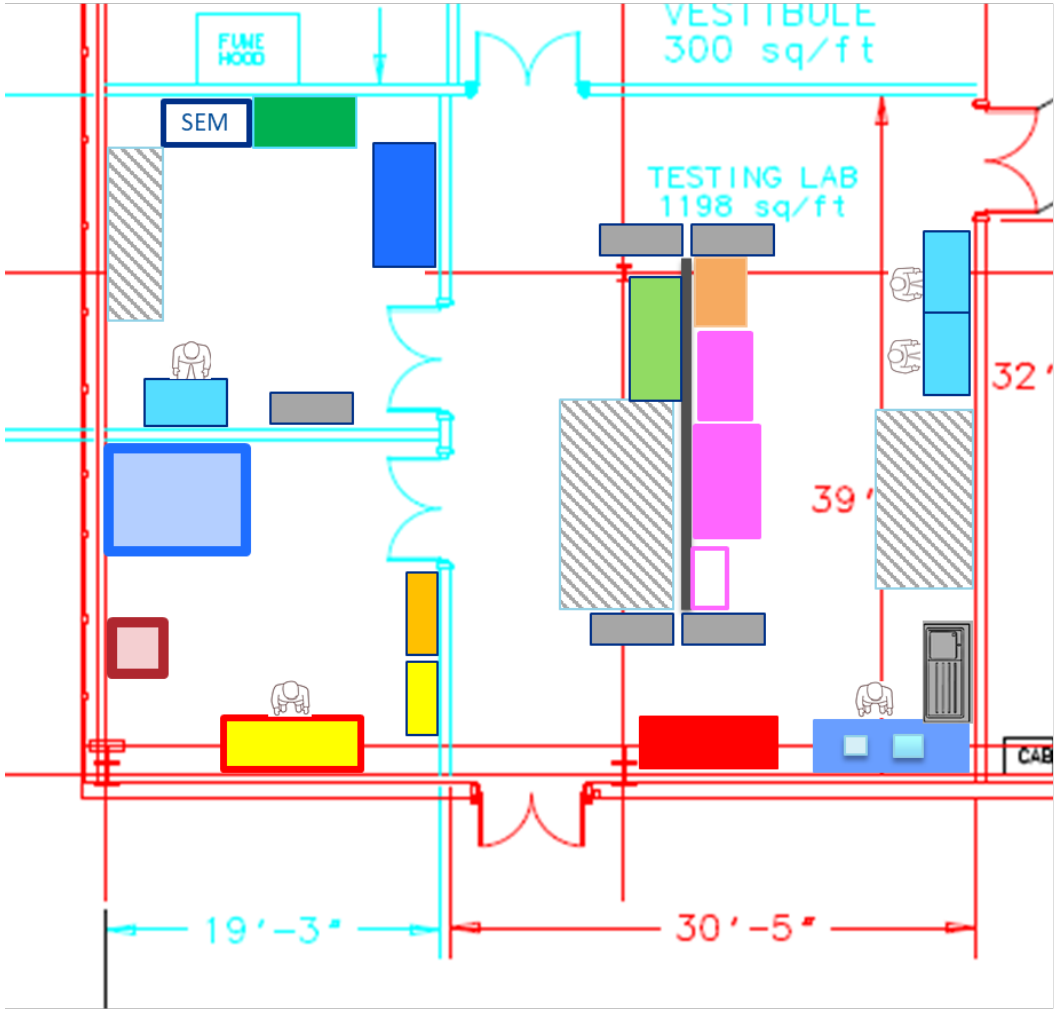
- Wireless network
- Wire network in the different rooms with a minimum of 4 LAN plug per room, more in the largest room (Hot Lab and Testing Lab)
- Room Temperature/climate control in each area
- Dry walls to keep cleanness in the Labs
- Floor needs to have a surface treatment (epoxy) for easy maintenance and cleaning
- Windows to outside should be high level windows to allow any instrumentation installation

Hot Lab Layout



- Fume hood
- fireproof cabinet for flammable chemicals (~24 gallons)
- storage cabinet for other chemicals / hazardous products
- storage cabinet
- Test bench w/ outlets
- Keyence microscope on test bench
- Workstation/desk with computer
- Low activated sample shielded storage
- Locker bench
- Locker
- Frisker station and designated step-off area

Non – Activated Material Area Layout



Space for future equipment

SEM

- Dilatometer
- Grinding/Polishing and sectioning station
- Sink
- FNAL Fatigue Machine
- Mechanical load frame
- Workstation/desk with computer
- Keyence microscope on test bench
- Nano-indenter
- Fume Hood
- HT furnace
- Nanofiber electro-spinner
- storage cabinet
- fireproof cabinet for flammable chemicals
- storage cabinet for other chemicals / hazardous products
- Test bench w/ outlets

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Backup Slides

Prep Hot Cell Requirement

- 2 telemanipulators and one lead glass window (thickness defined by the vendor depending on layer density used)
- Several Passthrough: one small and one large to communicate with loading area, one small to communicate with Testing hot cell
- Proper ventilation to ensure a negative pressure inside the hot cells.
  - Since potential generation of contamination is greatest in the Prep Hot Cell, a negative air pressure, relative to the other Hot Cell Suite areas and the surrounding Hot Lab, will be maintained with the Hot Cell Suite Ventilation system.
  - the ventilation system needs to keep negative pressure in the testing hot cell (4) and (5) when any passthrough is open
  - Penetration for HVAC system, cables and controls
- All the switches ON/OFF, control valves (for fluids), for utilities will be controlled outside of the hot cell near the workstation (front wall) for rapid access to the worker.
- Fire protection system to be determined by Fermilab ES&H team/FESS life safety
- In-cell lifting capability of 1000 lbs
- Several storages to accept several paint cans/inner pots with lower activated samples (number of cans/pots to be defined depending on the space available below the worktable) and for high dose samples
- Walls/floor of the hot cell should be finished/sealed with surface treatment (epoxy?) to improve lighting and for easier decontamination
- 5 replaceable feed-through penetration ports for 125V/20A, 280V, 20 A, 1 phase, signal cables, utilities (fluid, compressed air)

Testing Hot Cell Requirement

- 2 telemanipulators
- one lead glass window (thickness defined by the vendor depending on layer density used)
- Several Passthrough: one small and one large to communicate with loading area, one small to communicate with Prep hot cell and one small to communicate with the adjacent fume hood
- Proper ventilation to ensure a negative pressure inside the hot cells.
  - Since potential generation of contamination is greatest in the Prep Hot Cell, a negative air pressure, relative to the other Hot Cell Suite areas and the surrounding Hot Lab, will be maintained with the Hot Cell Suite Ventilation system.
  - the ventilation system needs to keep negative pressure in the testing hot cell (4) and (5) when any passthrough is open
  - Penetration for HVAC system, cables and controls
- All the switches ON/OFF, control valves (for fluids), for utilities will be controlled outside of the hot cell near the workstation (front wall) for rapid access to the worker.
- Fire protection system to be determined by Fermilab ES&H team/FESS life safety
- In-cell lifting capability of 1000 lbs
- Several storages to accept several paint cans/inner pots with lower activated samples (number of cans/pots to be defined depending on the space available below the worktable) and for high dose samples
- Walls/floor of the hot cell should be finished/sealed with surface treatment (epoxy?) to improve lighting and for easier decontamination
- 5 replaceable feed-through penetration ports for 125V/20A, 280V, 20 A, 1 phase, signal cables, utilities (fluid, compressed air)
- Space to accept several testing equipment (at least 2 smalls and 1 large at the same time)

Shielding Requirement

- Worst case scenario based on previous irradiation campaigns at BNL-BLIP facility
  - Proton up to 200 MeV on Ti-capsule containing 56 samples during 55 days, accumulating a total of up to 4.6 x 10^{21} protons
  - The maximum dose rate after 3 months of cooling down was calculated to be ~40 R/hr
  - In future irradiations, we do not anticipate irradiating higher atomic number materials for longer irradiation time at BLIP facility
- Hot cell shielding must provide sufficient shielding to reduce a 40R/hr source at 1 foot down to 0.25mrem/h
  - Assumption
    - Iron ((7.87 g/cc), concrete (2.35 g/cc), Source of unspecified material
    - an irradiated aluminum sample measuring 40 rad/hour @ 1 foot, which corresponds to a 3.14 Ci point-source of Na-22 and an average photon energy of about 1 MeV

	Distance from external wall of work cell [ft]									
[mrem/h]	0	0.33	0.417	0.5	1	2	3	4	6	6.67
1 ft iron (source against inside wall)	1.18	0.66	0.59	0.52	0.29	0.13	0.073	0.046	0.024	0.02
1 ft iron (source 1ft from inside wall)	0.43	0.32	0.29	0.27	0.19	0.11	0.068	0.047	0.027	0.023
2 ft concrete (source 1 ft from inside wall)	10.6	8.6	8.2	7.8	6	3.8	2.7	1.9	1.2	1
2 ft concrete (source against inside wall)	20.1	14.7	13.7	12.8	8.9	5	3.2	2.2	1.2	1.1
3 ft concrete (source against inside wall)	0.26	0.2	0.19	0.187	0.14	0.09	0.06	0.05	0.03	0.02

- 1ft of steel and 3ft of concrete will provide the necessary shielding required
- Lead glass thickness for the viewing windows has been calculated to be between 22” and 28” depending on density on combinations of density

Fume hood Requirement

- The fume hood needs
  - to be large enough to accept the few large testing equipment such as dilatometer or compact tensile test machine
  - an independent ventilation to assure a negative pressure compare to the hot lab (but pressure higher than the Hot Cell Suite) and maintain the required face air velocity as per ANSI/AIHA/ASSE Z9.5 and ANSI/ASHRAE 110 – Laboratory Ventilation Package (or applicable standard).
  - to be adjacent to the testing hot cell with a direct access via the passthrough
  - The exhaust (ductless or not) needs to be determined by FESS/AE.
    - a bag-in/bag-out system for fume hood will be determined/developed.
  - Electrical requirements (125V/20A, 280V/20A 1 phase) inside the fume hood

Hot Lab Requirement

- Proper ventilation to ensure a negative pressure inside the hot lab compared to the vestibule and the rest of the TSIB building
- Access doors need
  - To be sealed (material door (2) and door between Hot Lab (7) and vestibule (8))
  - Material access door to the hot lab is controlled by Radiation Physics Operations Department and will only be opened when a container is received into the hot lab (7).
  - Access doors for personnel through the vestibule will be limited with a control system.
- Electrical requirements (125V/20A, 280V/20A 1 phase, 480V/60A 3 phases)
- Two compressed air lines (120 psi): one near the hot cell suite to “feed” hydraulic testing equipment installed in the Testing Hot cell via feedthrough, and one compressed air along the south wall of the Hot Lab
- Fire protection system to be determined by Fermilab ES&H/FESS life safety
- Chemical protection plan to be evaluated by Fermilab ES&H team.
- one fireproof cabinet for flammable chemicals (~20-30 gallons)
- One storage cabinet for other chemicals/hazardous products
- One shielded storage to store the low activated material accepted for test in the hot lab and the fume hood
- An independent floor drain system separated from the general TSIB building drain and sump system as determined necessary by Fermilab Radiation Safety group.
- 2 to 3 jumbo heavy-duty metal storage cabinets (48x 18 x 78”)
- at least 1 test benches with outlet panels