

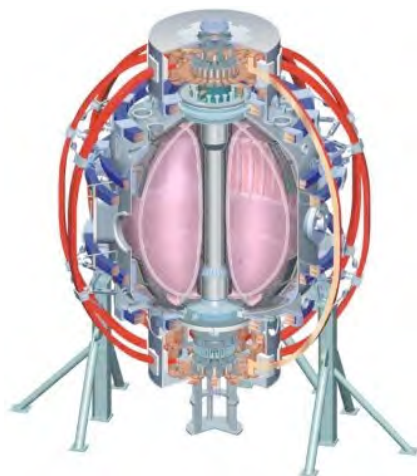
NSTX NBI Upgrade Overview

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**Princeton Plasma Physics Laboratory
NSTX Upgrade Project
Office of Science Review
LSB B318
December 15-16, 2009**

College W&M
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KBSI
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ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec



NBI BL2 Upgrade Overview - *Introduction*

- *NSTXU NBI General Requirements*
- *NSTXU Test Cell General Arrangement Drawing*
- *NSTXU Test Cell Equipment Relocations*
- *BL Decontamination Status and Progress*
- *NBI Project Overview:*
 - *BL2 Relocation and Mechanical ServicesMartin Denault*
 - *Duct, Torus Vacuum Pumping System, Vacuum Vessel Mod ...Craig Priniski*
 - *NBI ArmorKelsey Tresemer*
 - *Power & Control SystemsRaki Ramakrishnan, Mark Cropper*
- *Cost and Schedule comments*
- *Conclusion*

NBI BL2 Upgrade Overview - *Main Requirements*

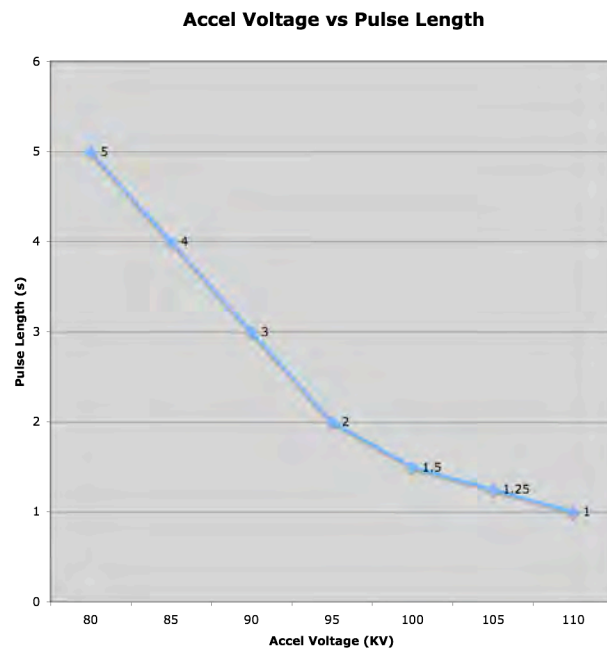
- *Disassemble & evaluate a TFTR BL*
- *Decon a TFTR DT BL*
- *Refurbish BL for reuse*
- *Lift BL over wall*
- *Add second NBI & Services in NTC*
- *Connect Power & Controls*
- *Aim wider*
- *Rearrange NTC to fit*
- *Capability to run either or both*
- *NBI Power x 2 for NSTX!*



NSTX Beamline 1 operating since 2000

NBI BL2 Upgrade Overview - Operating Parameters & Aiming in keeping with GRD

- *NSTX NBI typically operates up to 100 keV now*
- *Approx. 3 MW per source in deuterium at 110 keV available (TFTR operating experience)*
- *NSTX NBI original spec of 80 keV 5 MW for 5 seconds retained*
- *Ion dump operating limits retained based on TFTR & NSTX operating experience...*
- *Existing BL1 Tangency radii [C=50; B=60; A=70] cm unchanged*
- *BL2 Tangency radii designed to be [C=110; B=120; A=130] cm per GRD*



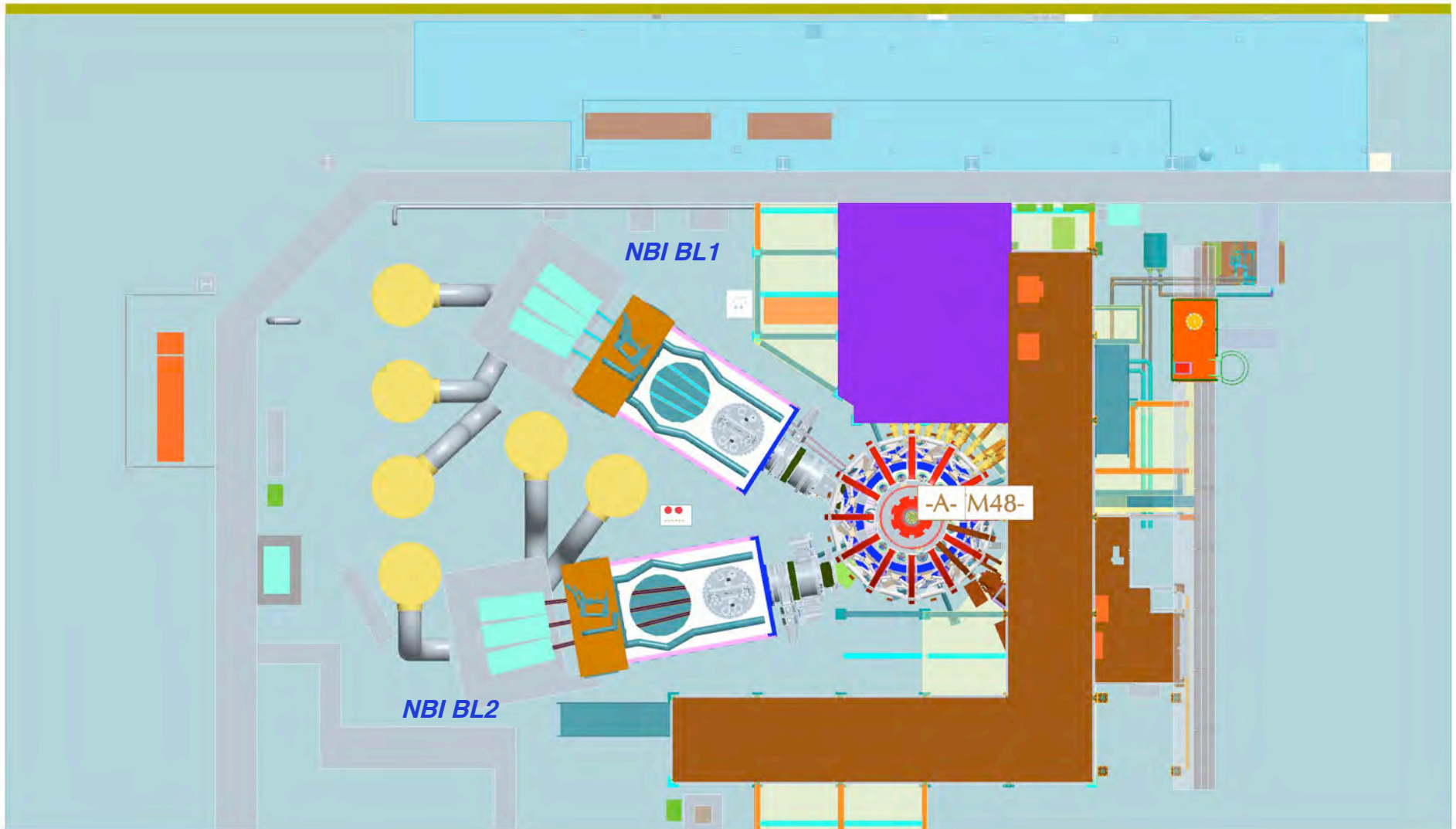
1.75 MW/source

2 MW/source

3 MW/source

2 BL 6 sources 18 MW possible...

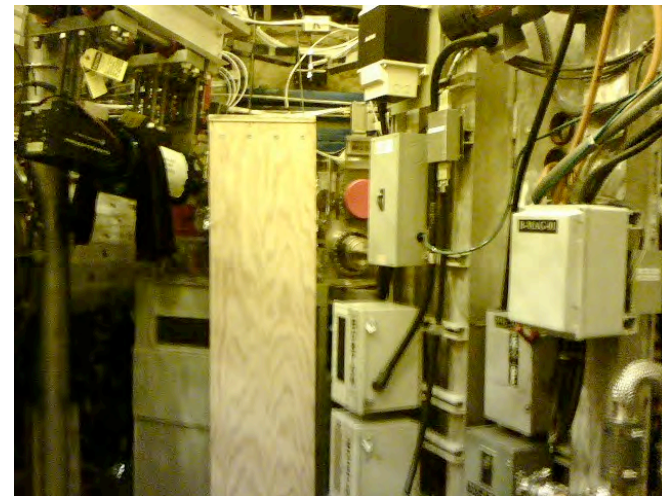
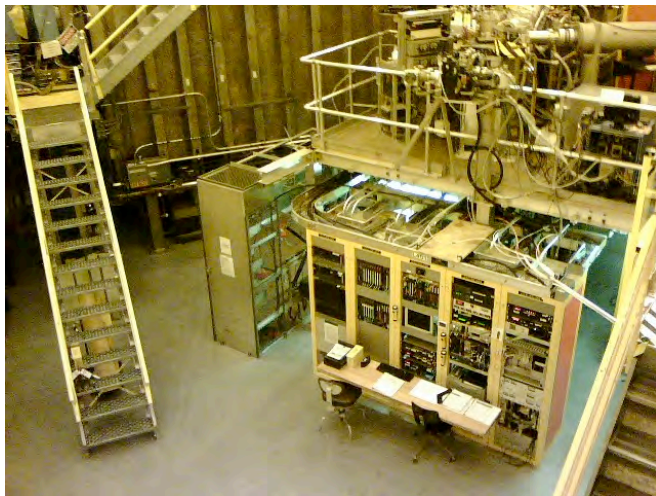
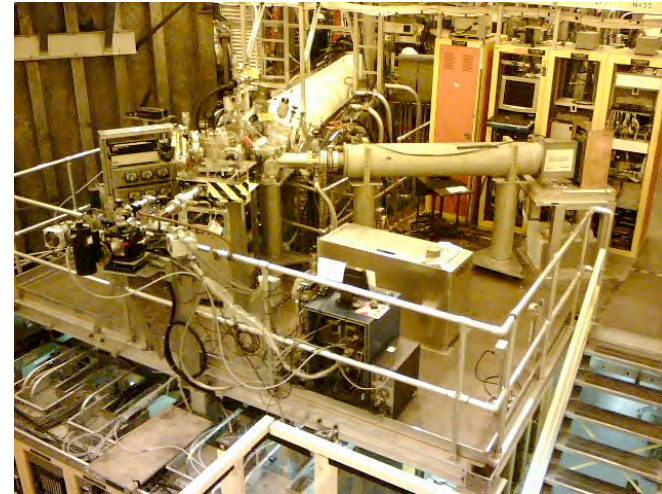
NBI BL2 Upgrade Overview - *General Arrangement Drawing*



NBI BL2 Upgrade Overview - *Rearrange NTC for BL2*

NTC Relocations

- Delete Pump Duct @ Bay L
- Move Diagnostics - many
- Change & add platforms
- Remove denizens of Bay K
- Move Diagnostic Racks
- Move Vacuum System Racks
- Move Gas Injection System bottles



NBI BL2 Upgrade Overview - *Normal outage work*

NTC Relocations are a major portion of the upgrade but constitute normal work for an NSTX outage...

- *Diagnostics and Equipment Relocation considered on a case by case basis*
- *Project agreement for Diagnostics set installed Day 1 after the upgrade*
- *Bays G, J, K, L impacted and still others due to floor space*
- *Racks evaluated for contents and consolidation*
- *Procedures for removal and reinstallation drafted to contribute to cost estimates*
- *Platforms added at 118' elev. on West side for additional rack space*
- *TVPS racks go to North gallery outside NTC*
- *Beam racks go to East gallery outside NTC*
- *Removals slated to start after the NSTX run period has been completed...*

NBI BL2 Upgrade Overview - *BL Recon and Decon*

Evaluation, Decontamination, & Refurbishment of TFTR BL4

- BL operating on TFTR DT campaign and shut down in 1997
- BL operated in deuterium to heat surfaces and remove tritium
- Air purged to stack for 12 years
- Sampled in 1997 and 1998 to determine feasibility of decon - *airborne and surface levels OK*
- Pump and purge BL - *done*
- Remove calorimeter, dump, magnet, and 90 inch flange - *done*
- Remove lid and panels and place in stand - *done*
- Evaluate for reuse - *BL and components are in very good shape*
- Decon calorimeter, dump, magnet, 90 inch flange, lid, box *<=== WE ARE HERE*
- Replace full energy ion dump copper plate
- Refurbish seals and TCs
- Leakcheck
- Move each piece to NTC South High Bay

Note: HP & ERWM required for duration of project and into future NSTX operations just as they are now...

NBI BL2 Upgrade Overview - *Decon in progress...*

- *BL has been fully disassembled*
- *HP Surveys done regularly*
- *Levels in range of PPPL experience*
- *Progress has been steady - levels decreasing*
- *Uptakes have been detectable but very low*
- *Goal: minimize impact on NSTX maintenance*



Lid and cryo panels sitting in new stand



BL4 Magnet and 90 inch flange



Calorimeter decon in progress...

NBI BL2 Upgrade Overview - *Decon Ops in full swing*



We make this look good...

NBI BL2 Upgrade Overview - *Decon Ops in full swing*



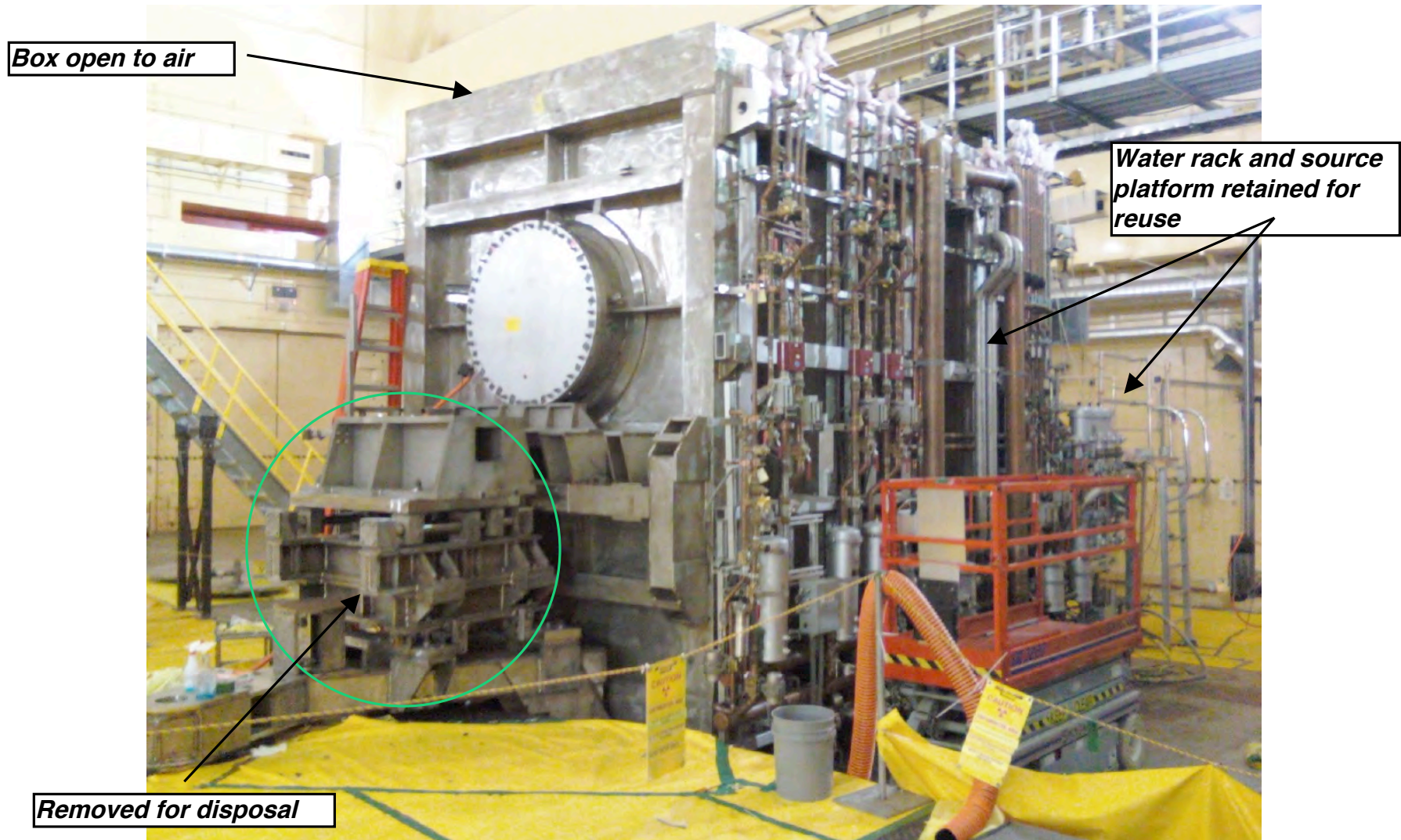
Hoods work well - cooler & cleaner

NBI BL2 Upgrade Overview - *Decon Ops in full swing*



Multiple teams & steady progress

NBI BL2 Upgrade Overview - *Decon Ops in full swing*



The Beam Box is NEXT!

NBI BL2 Upgrade Overview - *Decon Results*

- No detectable acute stack releases during line breaks
- Chronic background stack releases are higher but well below limits
- Initial BL contamination levels have varied from 5 to 100 million dpm / 100 cm²
- Decon crew using double PC suits, triple gloves, quadruple boots, & masks or hoods
- Uptakes @ 0.1-0.5% of daily allowable dose but always seeking continuous improvement
- Wipedowns with H₂O₂, Windex, Swiffer products, deionized water, and rags
- Significant progress on areas that have received decon
- No detectable regrowth has been noticed

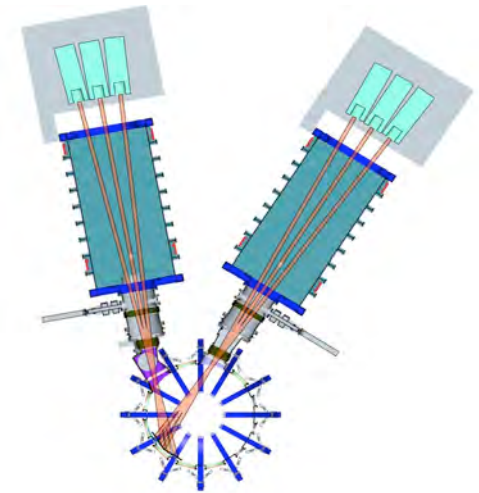
Decon by component - million dpm/100 cm²
results have been generalized from detailed HP surveys

	Start - high	Recent - low	cycles
PrecCal Scraper	18	<1	>20
Calorimeter Vee	20	<2	>20
Exit Flange	45	4	>20
Heat Shield	3	0.3	>20
Magnet	40	<2	>10
90 inch flange	50	<2	>10
Cryo panels out	10	<1	>5
Cryo panels in	80	20	1
Beam Box	TBD		0

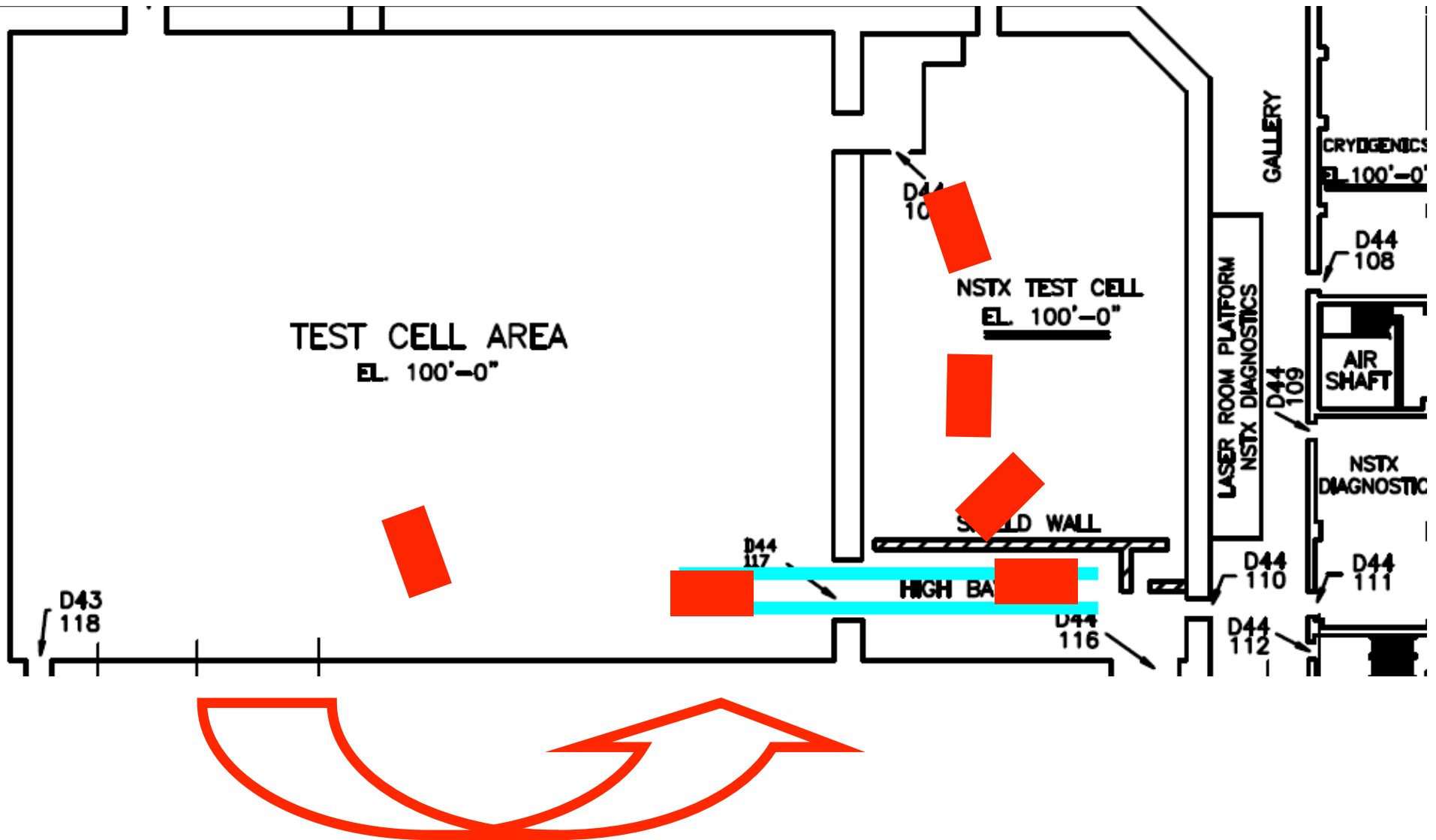
NBI BL2 Upgrade Overview - *NBI Mechanical*

BL Relocation and Services

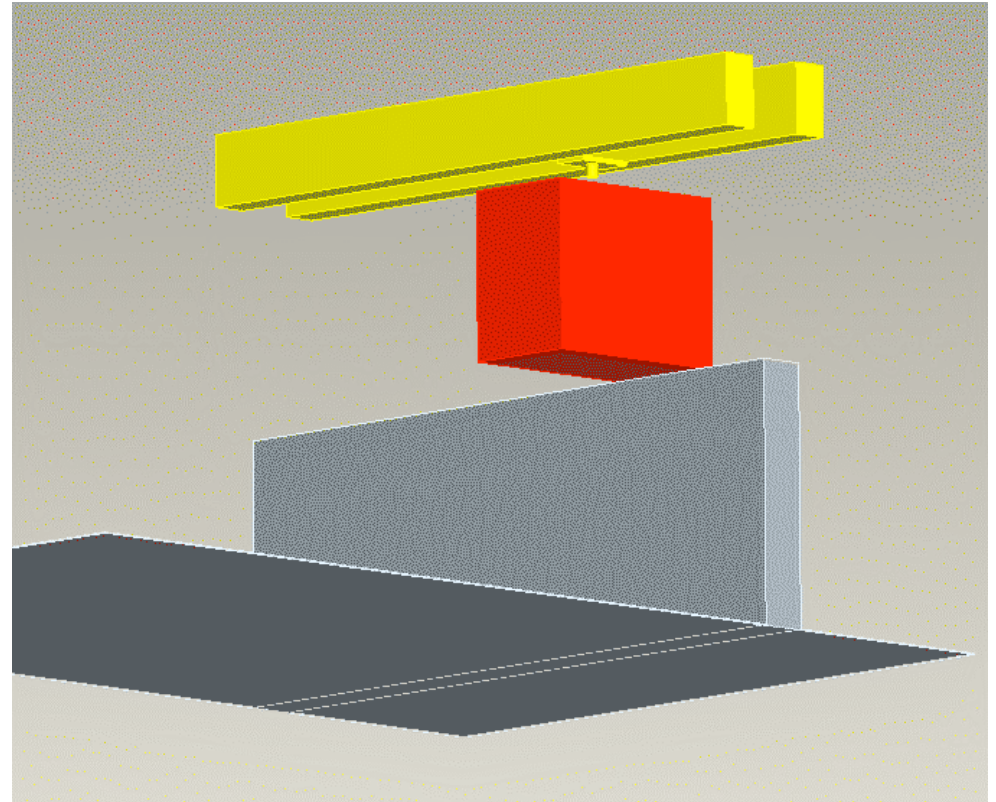
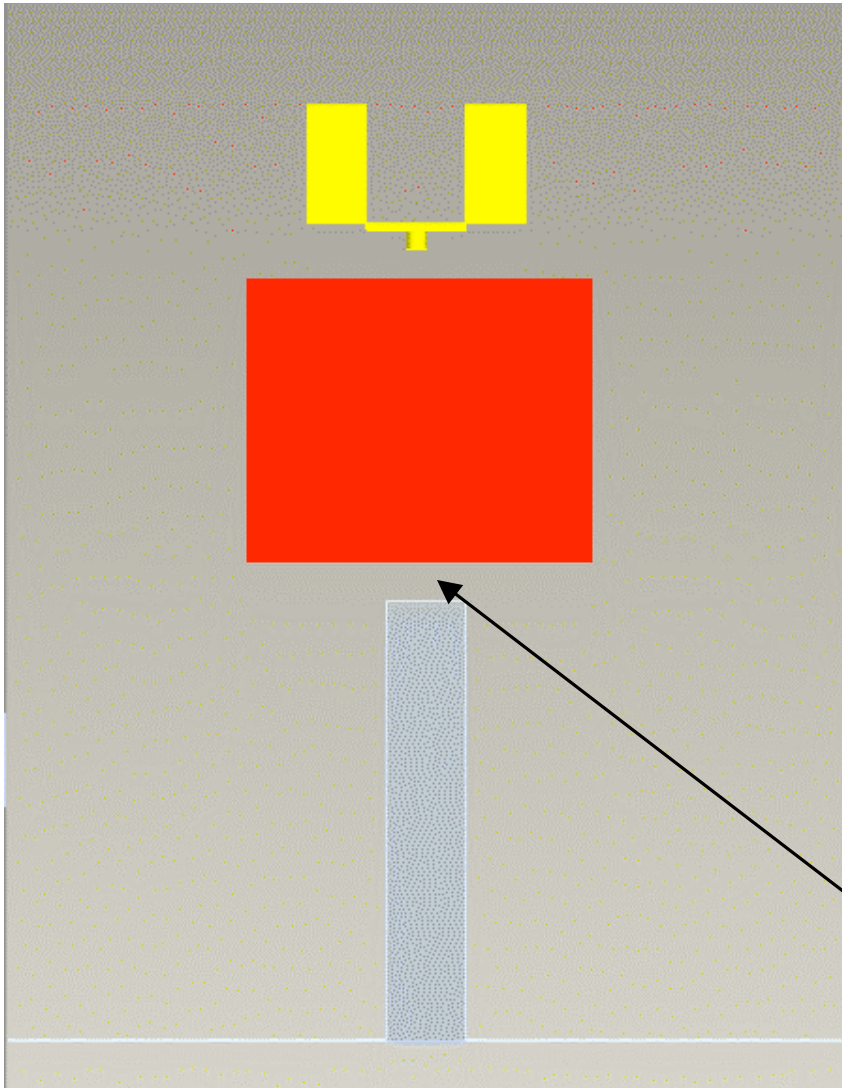
- Relocate beam box, lid, & components to NTC - everything goes over the shield wall
- Refurbish sources for BL2 - (normal NBI operations work)
- Reactivate stack vent connections in NTC
- Build BL support structure similar to existing NSTX NBI
- Align box, lid, components in NTC
- Salvage water rack and source platform
- Modify and connect DI ion source, ion dump, & HVE DI water
- Modify and connect vacuum, cryogenics LHe & LN, gas, SF6, pneumatic services
- Attach platforms
- Install refurbished sources



BL Relocation Path



Model of NBI box lifted over shield wall



Two feet of clearance

NBI BL2 Upgrade Overview - BL2 Services

- ⌋ High Voltage Enclosure Cooling Water
- ⌋ Ion Dump Cooling Water
- ⌋ Ion Source Cooling Water
- ⌋ SF6
- ⌋ Liquid Nitrogen
- ⌋ Liquid Helium
- ⌋ Vacuum Backing Lines
- ⌋ Gas Injection System



•New pumps for BL IS & ID DI water

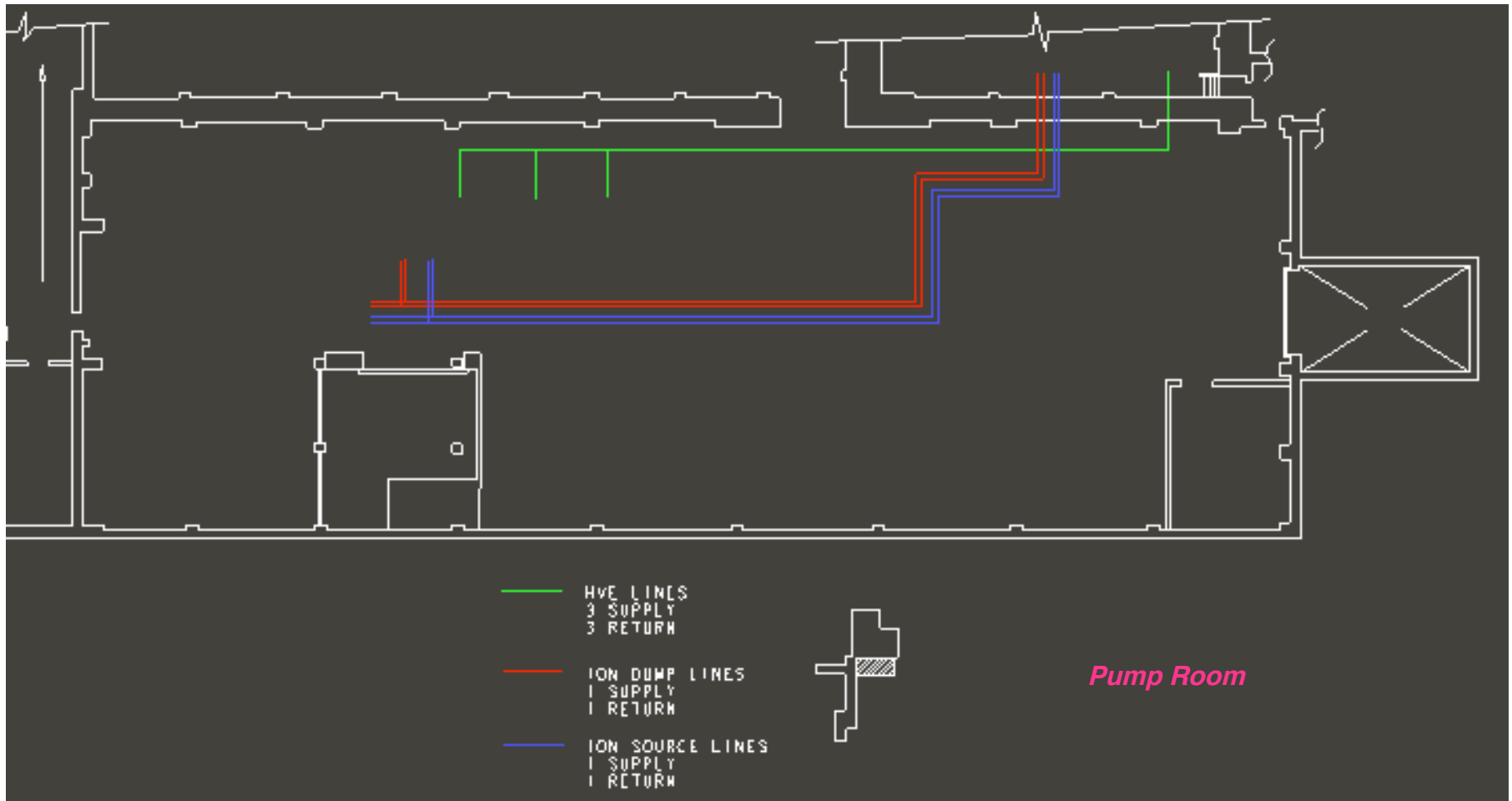


•Reuse NBPS DI Water skids

All services accounted for
All building walk throughs completed, routes mapped
Heat and flow calculations performed for water systems
Pipes, pumps, and runs sized accordingly
Cryogenic loads minimized and acceptable (reuse same frig)
All penetrations identified and locations approved

NBI BL2 Upgrade Overview - BL Services

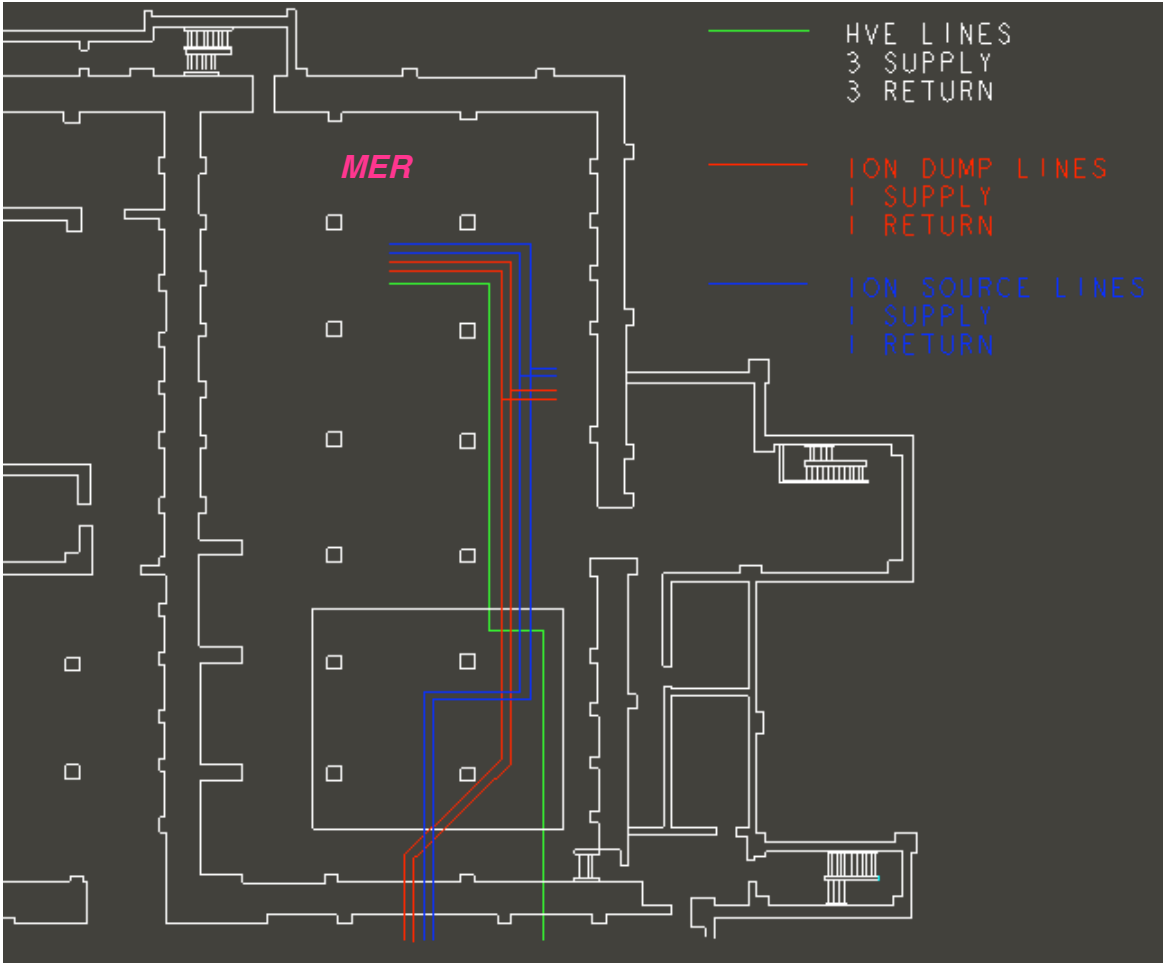
NBI Mechanical: Deionized Water Services



(M. Denault, NBI Peer Review 6/09)

NBI BL2 Upgrade Overview

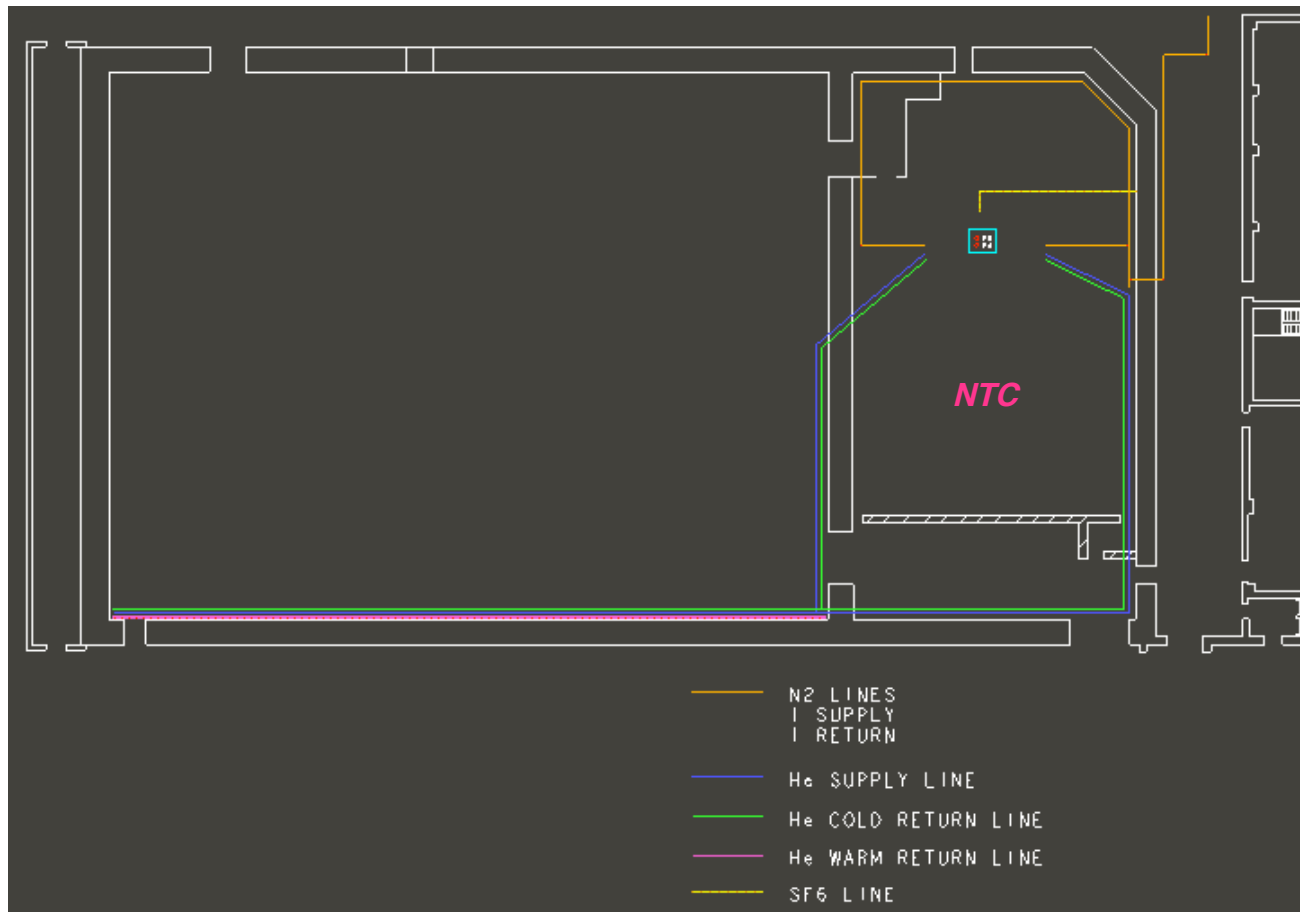
NBI Mechanical: Deionized Water Services



(M. Denault, NBI Peer Review 6/09)

NBI BL2 Upgrade Overview

NBI Mechanical: Cryogenics Services & SF6 line

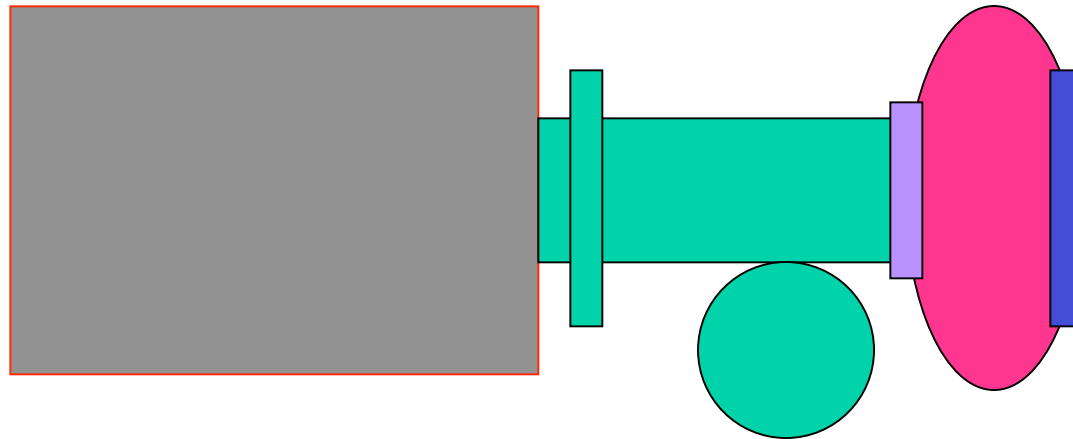


(M. Denault, NBI Peer Review 6/09)

NBI BL2 Upgrade Overview - BL to VV

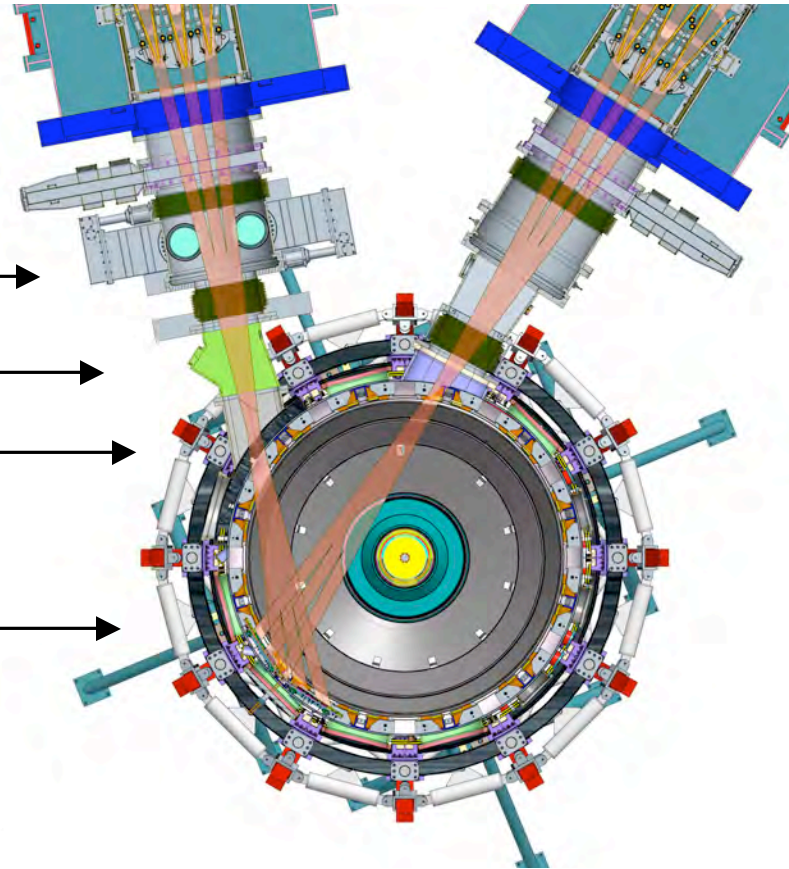
NBI Duct, TVPS, VV, Armor

- Duct design significantly more involved than simply replicating original
- Larger tangency radii require vessel modification to Bay K port
 - New weldment for Bay J-K bay window required
- New circular and rectangular bellows and beam duct parts required
- Torus Vacuum Pump duct location now under and connected to beam duct
- Relocate NBI Armor in vessel to accept 6 source footprint and take a direct hit

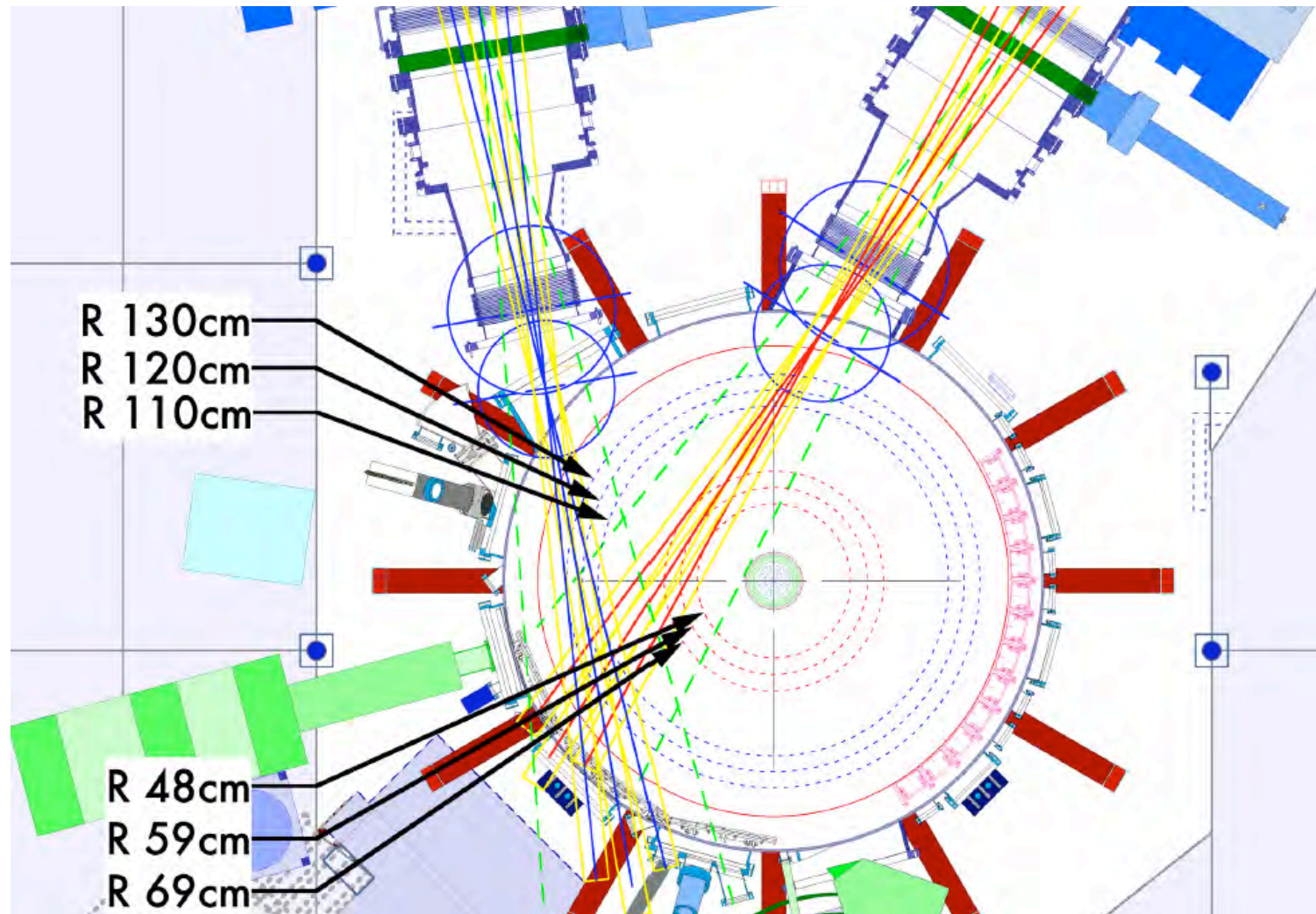


NSTX NBI Duct Overview & Trajectories

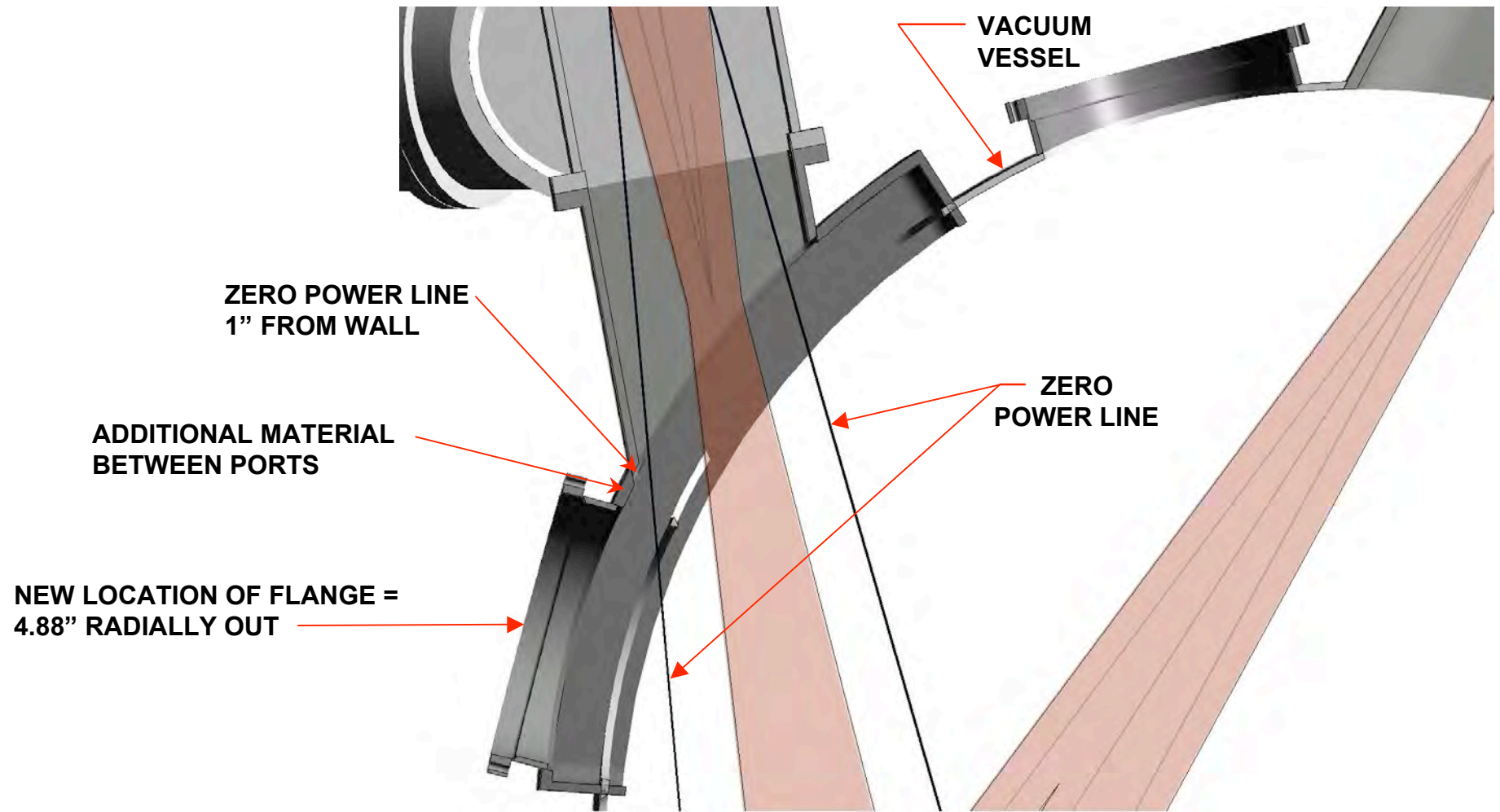
- Aiming angles achieved per GRD
- NBL2 Duct w/ new TIV
- Torus Vessel Pump System Duct
- Port Extension
- Bay J-K Cap
- NSTX Vessel Modification
- NBI Armor relocation



Existing port and TF outer leg pinch points for wider aiming



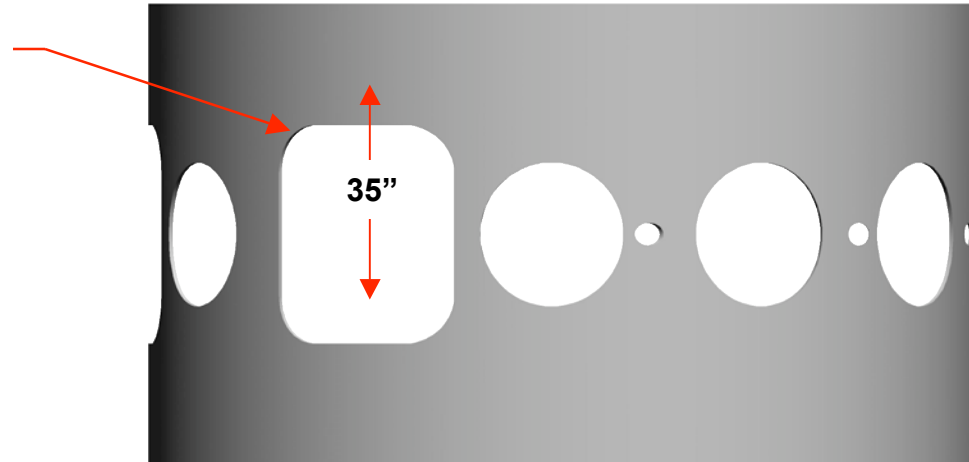
Cap Design Considerations



NSTX Vessel Modification Required

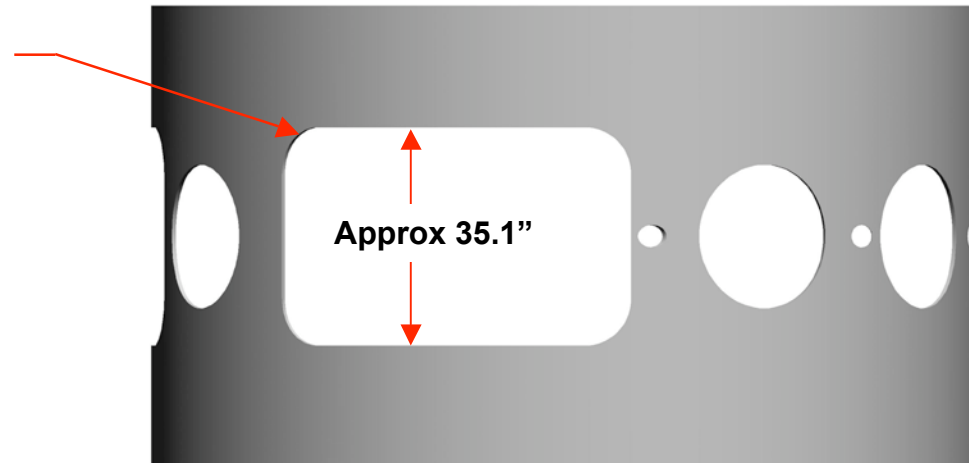
EXISTING CUTOUT ON
THE VACUUM VESSEL
35"H x 32.3"L

EXISTING CUTOUT

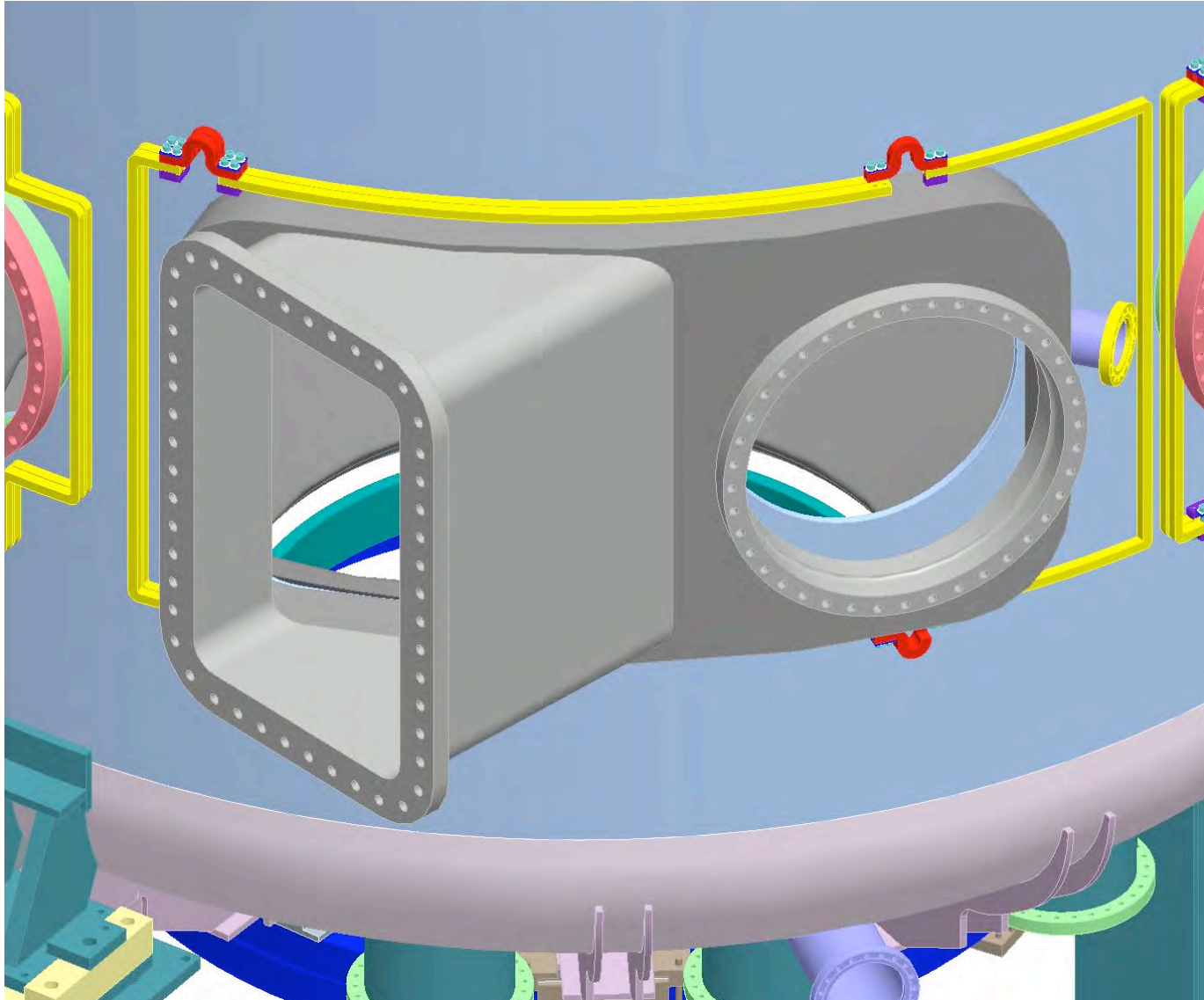


EXISTING CUTOUT WILL
BE EXTENDED AS SHOWN
(Approx. 26.5" Longer)

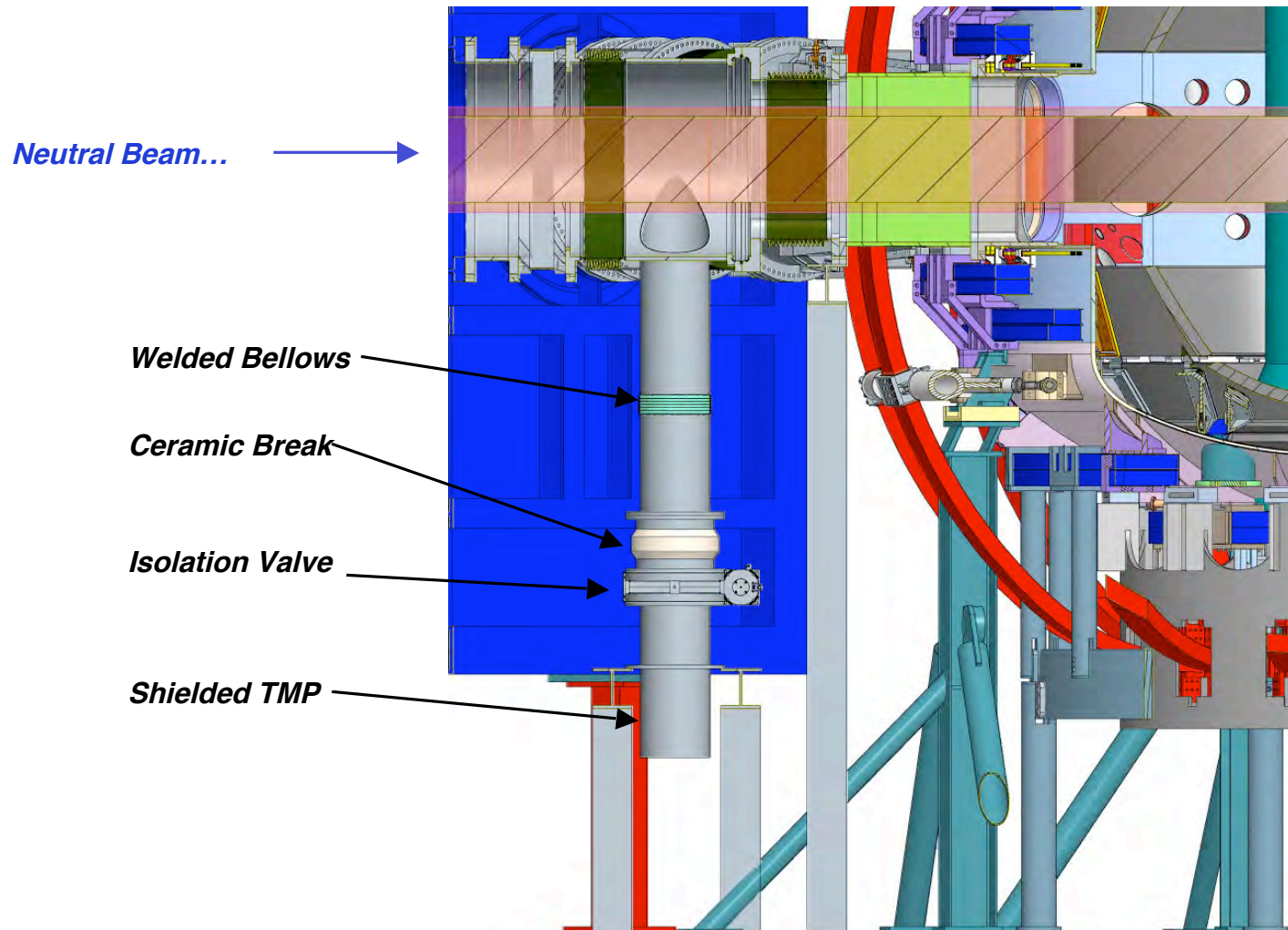
MODIFIED CUTOUT



Cap/Plug Concept



Torus Vessel Pumping System Design



Existing Armor: 3 Beam Footprints



ATJ Carbon tiles

No beam impingement during plasma ops

Ip and Ip redundant interlocks

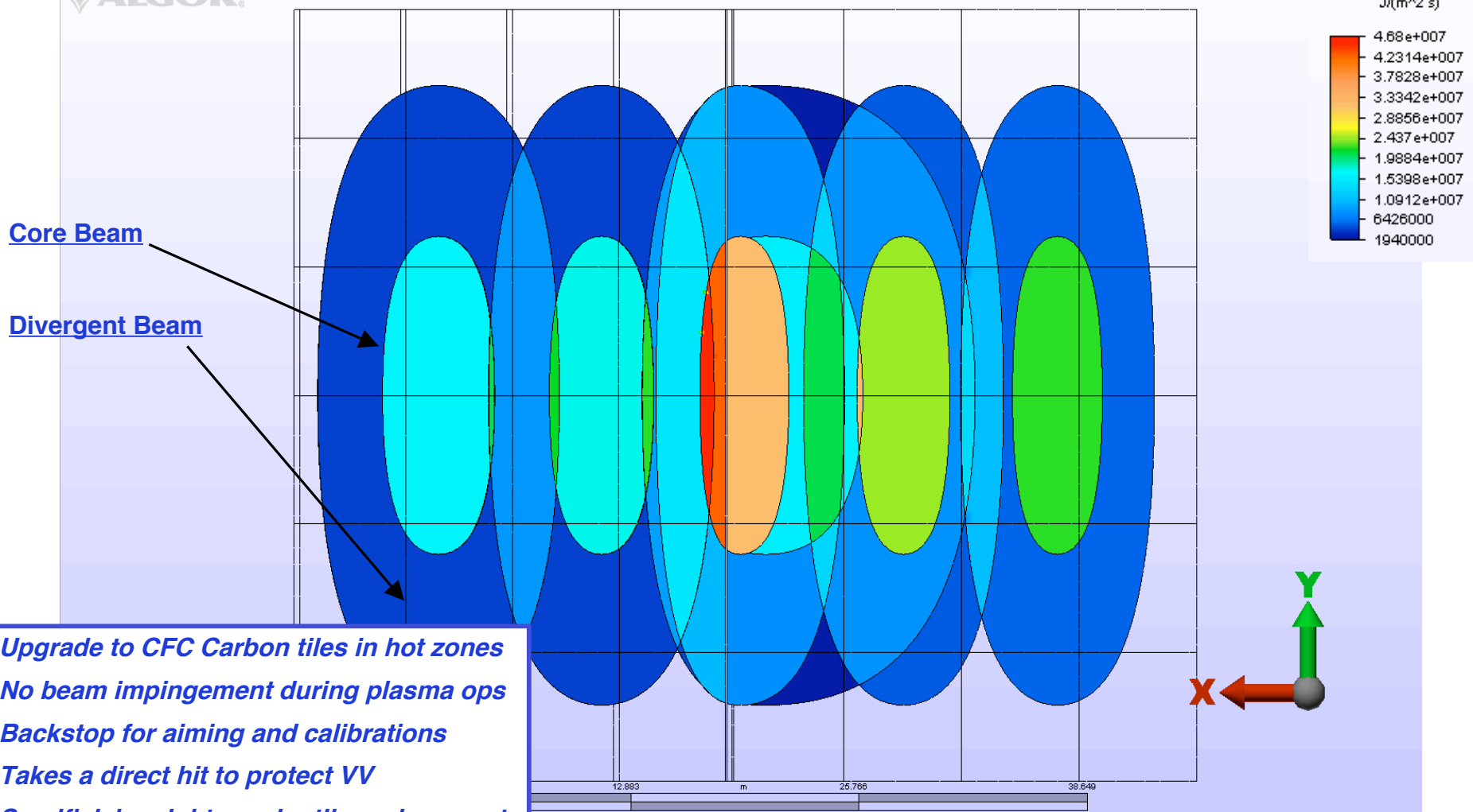
Backstop for aiming and calibrations

Takes a direct hit to protect VV

Sacrificial - might require tile replacements

New Armor Position - 6 Beams

ALGOR.

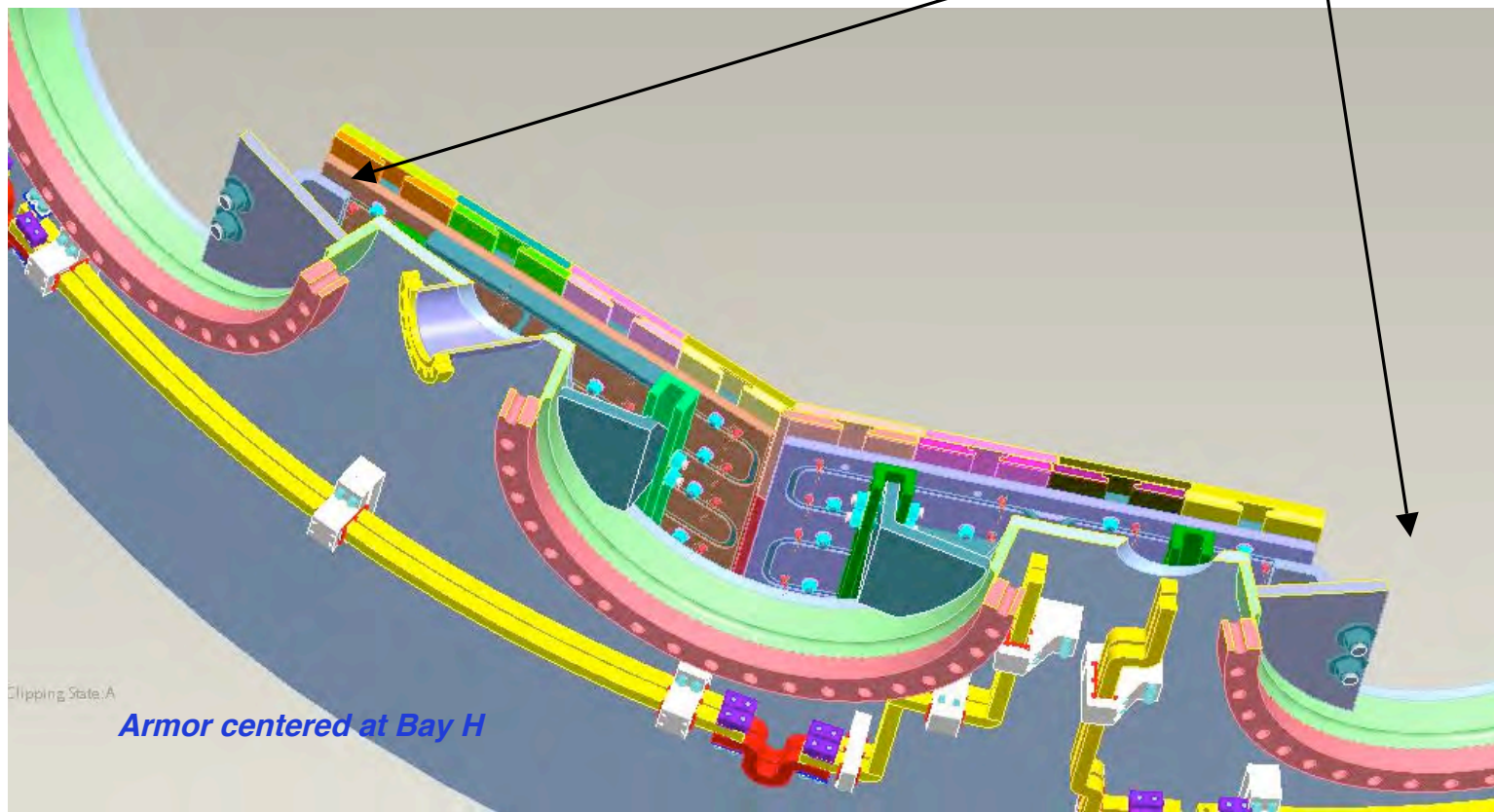


Upgrade to CFC Carbon tiles in hot zones
No beam impingement during plasma ops
Backstop for aiming and calibrations
Takes a direct hit to protect VV
Sacrificial - might require tile replacements
Add additional interlocks to Ip and R Ip

Same idea... better tiles

New Armor: Vacuum Vessel Mounting

- Improving current design for accessibility.
 - Can access sides of backing plates through Bays I and G
 - Improves access to mid-plane mounts



NBI BL2 Upgrade Overview - NBI Power & Controls

Neutral Beam Power System

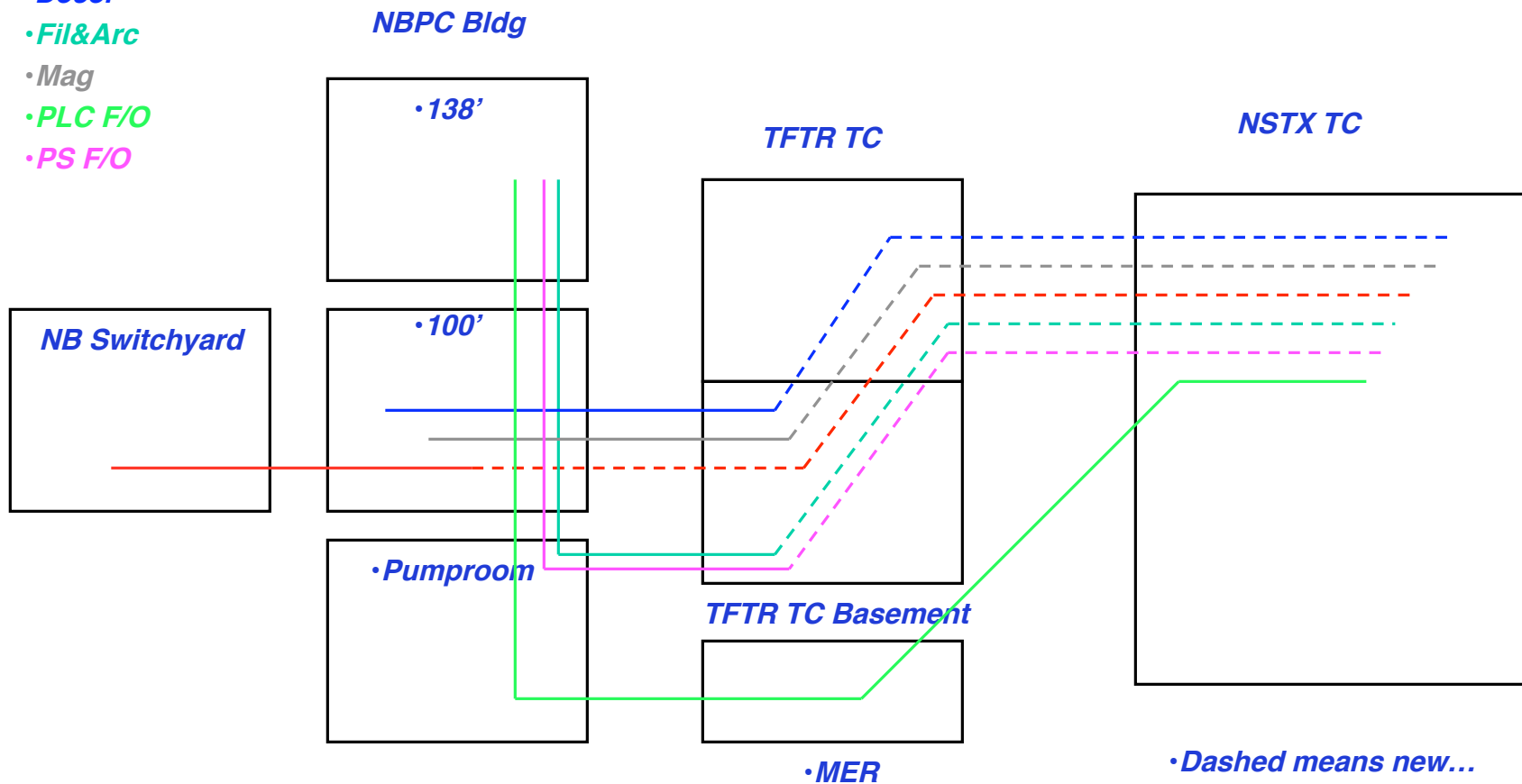
- Same design as original power systems but updated to present BL1 configuration
- Recommission N4 power systems A,B, & C (all still available):
 - } Accel
 - } Gradient Grid (build new air cooled resistive dividers per BL1 design)
 - } Decel
 - } Arc
 - } Filament
 - } Bending Magnet
- Run both beamlines from MG set for 13.8 kV feed (same as we did on TFTR)
- Reuse existing N4 cabling to TFTR TC Basement as is
- Add junction boxes and route new cables from TCB through TC to NTC
- Move N4 HVEs from TCB to NTC
- Reuse transmission lines with clamshell arrangement
- Reuse existing telemetry and fiber optic cables salvaged from TFTR
- Reuse existing NBPS Deionized Water Skids in the pump room (still attached)

New wires...

NBI BL2 Upgrade Power & Controls - Road Map

Routing and Installation

- Accel
- Decel
- Fil&Arc
- Mag
- PLC F/O
- PS F/O

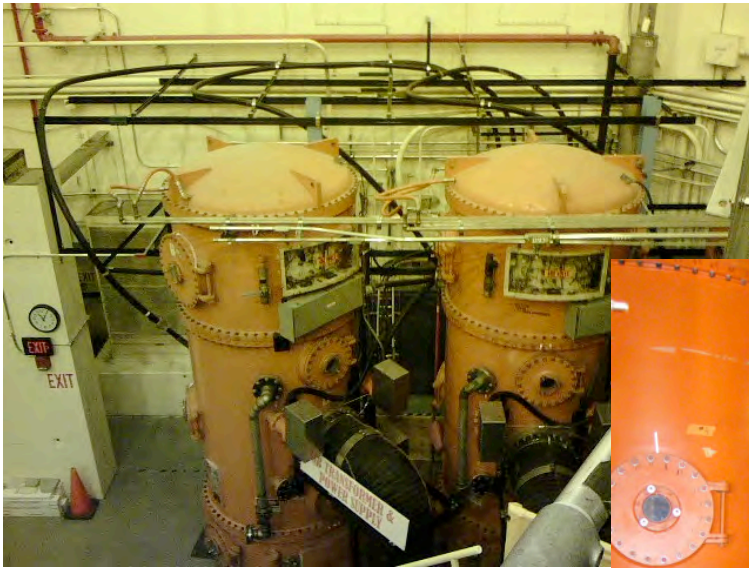


NBI BL2 Upgrade Power & Controls

Routing and Installation

- **TOTAL CABLES TO BE INSTALLED**
 - **THREE TRIAX CABLES – PROJECTED LENGTHS 300*3 FEET**
 - **THREE CABLES 600V 4C/500MCM & GRD WIRE - ARC**
 - **THREE CABLES 600V 4C/500MCM & GRD WIRE - FILAMENT**
 - **THREE CABLES 600V 4C/500MCM & GRD WIRE – MAGNET***
 - ***STANDARDIZE THE CABLES FOR EASE OF PROCUREMENT**
 - **THREE CABLES 600V 4C/#8 & GRD WIRE – 208V FEED**
 - **THREE COAXIAL CABLES RG218U FOR DECEL**
 - **ALL POWER CABLES OF ARMORED CONSTRUCTION**
 - **FIBER-OPTIC CABLES**
 - **6 CABLES WITH 8 FIBERS FOR EACH HVE – TOTAL 18 FOR HVEs**
- **ROUTING PROPOSED**
 - **ROUTE ALL CABLES VIA TFTR TEST CELL BASEMENT, TFTR TEST CELL AND ON TO NSTX TEST CELL VIA PENETRATIONS**
- **INSTALL THE TRANSMISSION LINES**
- **INSTALL AUXILLIARY POWER CIRCUITS**

NBI BL2 Upgrade Overview - HVEs & Xmsn Lines



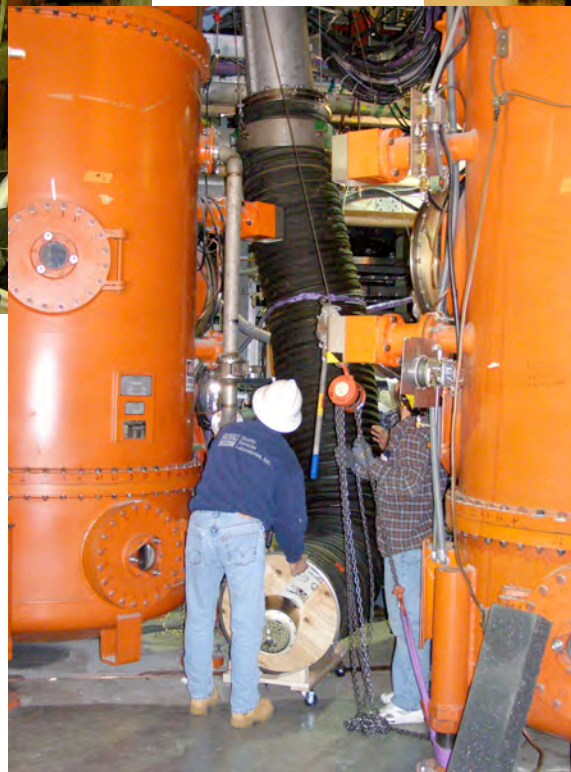
BL1 HVEs and Triax

Decon above in TC
required lowering Xmsn
lines to TCB for
preservation and
storage - completed
prior to decon



BL1 Xmsn lines

Same type HVEs, Triax
Accel cable, and
Transmission lines for
high voltage as on BL1



•Saving N4 Xmsn line for reuse

NBI BL2 Upgrade Overview - *NBI Power & Control*

NB Control Room



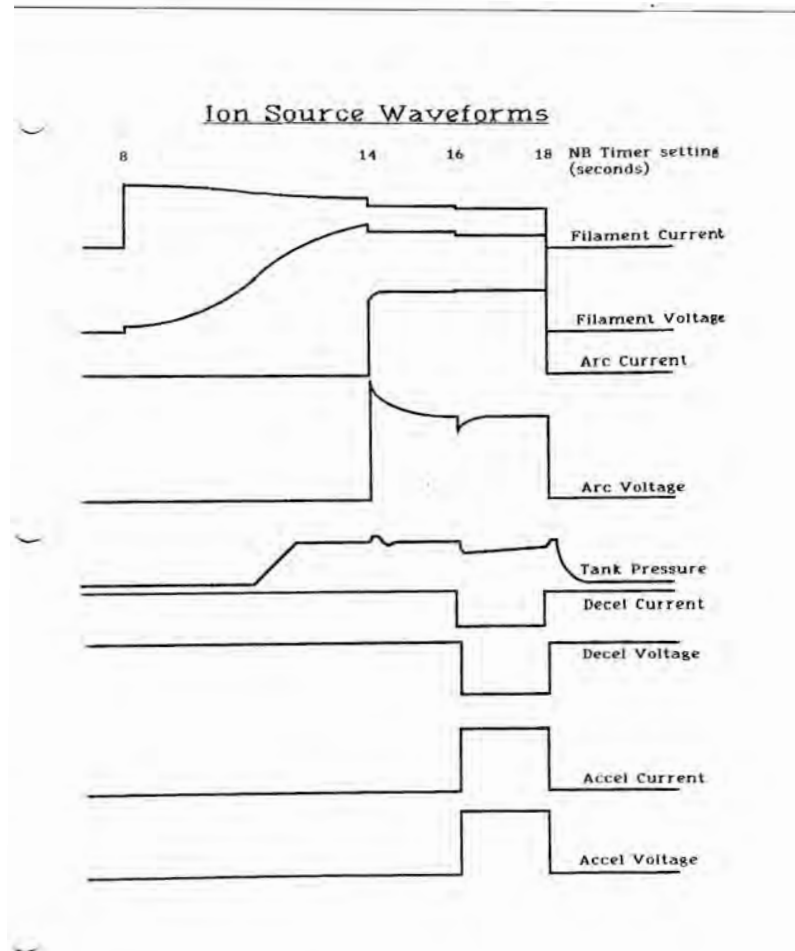
NBI BL2 Upgrade Power & Controls

NBI Controls

- Mimic existing NSTX BL1 Control scheme for BL2
- Reactivate N4 Local Control Centers, CAMAC, Hardwired Interlock System
- Turn BL2 Plasma Current Interlocks on (chassis still in use for BL1)
- Add additional plasma interlock to prevent long pulse into armor
- Expand I/O for PLC control of BL and Services but use existing PLC
- Expand Thermocouple Scanning System to include BL2
- Fold BL2 into EPICS & timing pages
- Update NBOS LabView Operator interface so existing staff can run 2 BLs

More sources, more buttons... but not more operators

NBI BL2 Upgrade Power & Controls - Typical pulse

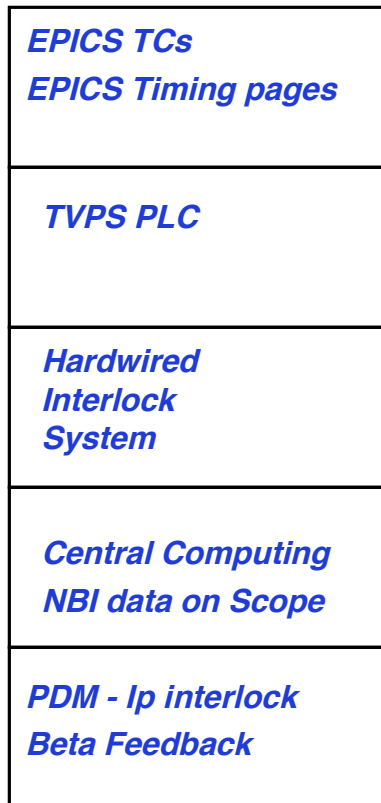
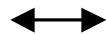
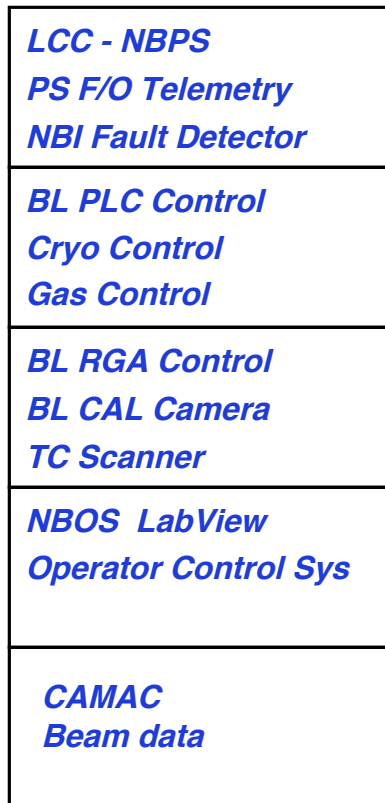


Typical NBI source waveforms for one ion source monitored and adjusted as required every source every shot by NBI Operations staff due to unregulated arc and filament supplies and emission limited ion source design

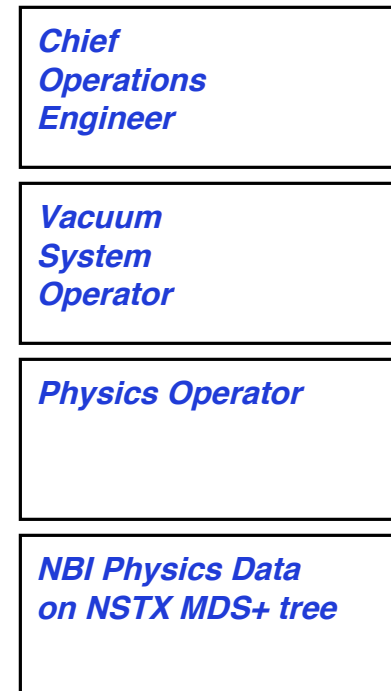
NBI BL2 Upgrade Power & Controls - Handshakes

Neutral Beam Control System & Interfaces to NSTX

NBI Ops Supervisor



NSTX Ops

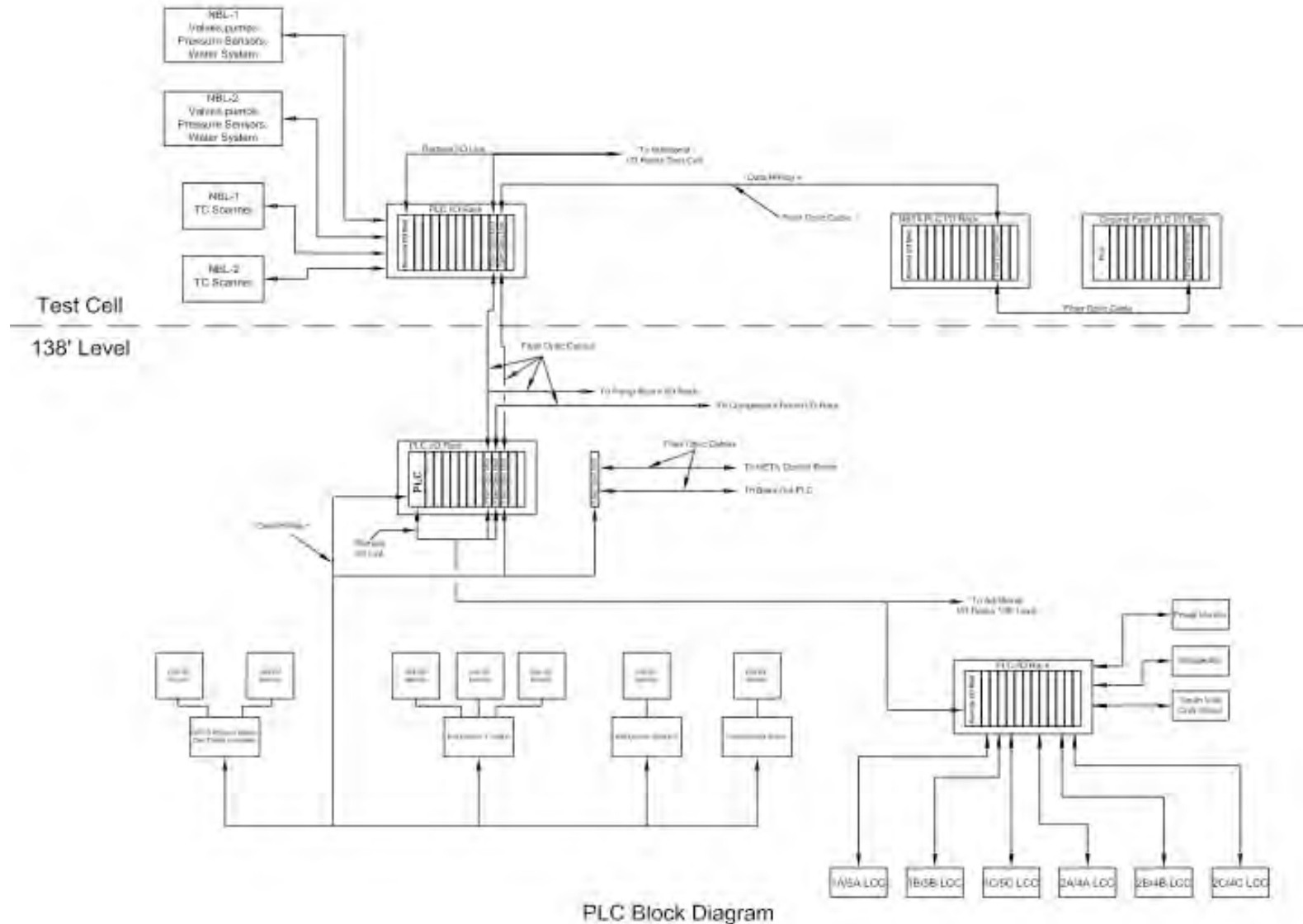


NBI BL2 Upgrade Power & Controls - Progress

- *Block Diagrams of each segment of the control scheme presented at NBI Peer Review 6/24/09*
- *Signal lists have been prepared to determine I/O requirements*
- *Drawing lists have been prepared to determine requirements for new drawings and P&IDs*
- *Rack contents and layouts have been evaluated to determine new space requirements*
- *NBOS LabView Controls will be updated to current technology like BL1*
- *Interfaces are well understood and can be replicated for BL2 control*

Controls design is under control...

NBI BL2 Upgrade Power & Controls - Many block diagrams



NBI BL2 Upgrade Overview - Cost & Schedule

Cost & Schedule comments (detailed elsewhere)

- *NBI BL2 Upgrade cost has direct similarities to original BL1 project for NBI work*
- *Added project components include NTC relocations, Decon, TVPS, and VV mods*
- *Added cost due to HP allocations*
- *Job Work Authorization Forms prepared and reviewed by job engineers*
- *On low end of CD0 cost range expectations*

& On schedule...

- *PDR June 2010*
 - *FDR March 2011*
 - *Start NTC equipment removals after the NSTX run period*
 - *NTC open for upgrade work 2012 and 2013*
 - *Resume NSTX Operations*

NBI BL2 Upgrade Overview - *Conclusion*

- *NBI BL2 Upgrade Requirements - requirements met*
- *NSTX Test Cell General Arrangement Drawing - it fits*
- *NSTX Test Cell Equipment Relocations - moving day*
- *BL Decontamination Status and Progress - so far so good*
- *Project Overview: we have a plan...*
 - *BL2 Relocation and Services*
 - *Duct, Torus Vacuum Pumping System, Vacuum Vessel*
 - *NBI Armor*
 - *NBI Power and Control Systems*
- *Cost and Schedule comments - on track*

Conclusion: *Good to go...*

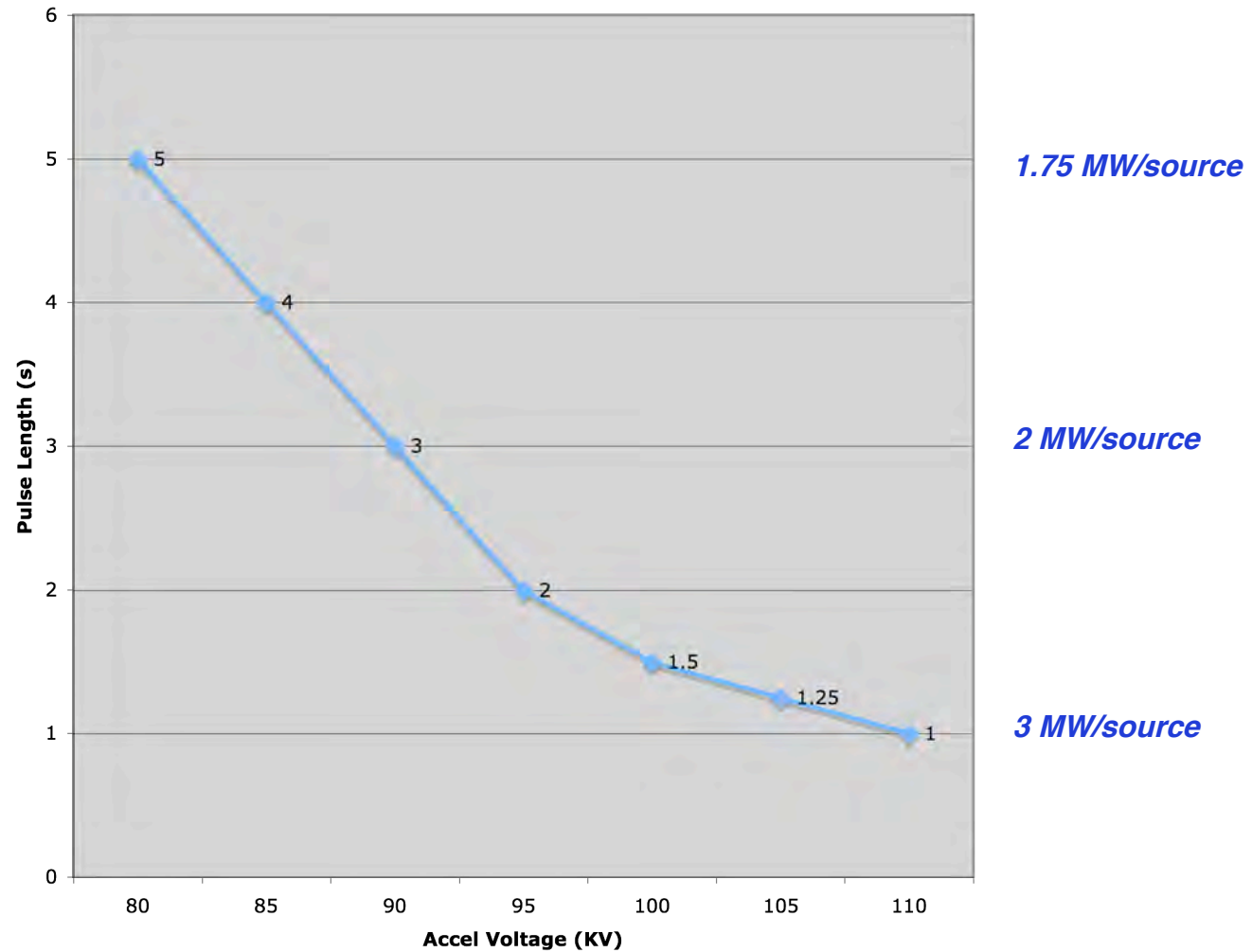
•More field, more Ip, more NBI, more physics, more fusion, more fun...

NBI BL2 Upgrade Overview - *Support Slides*

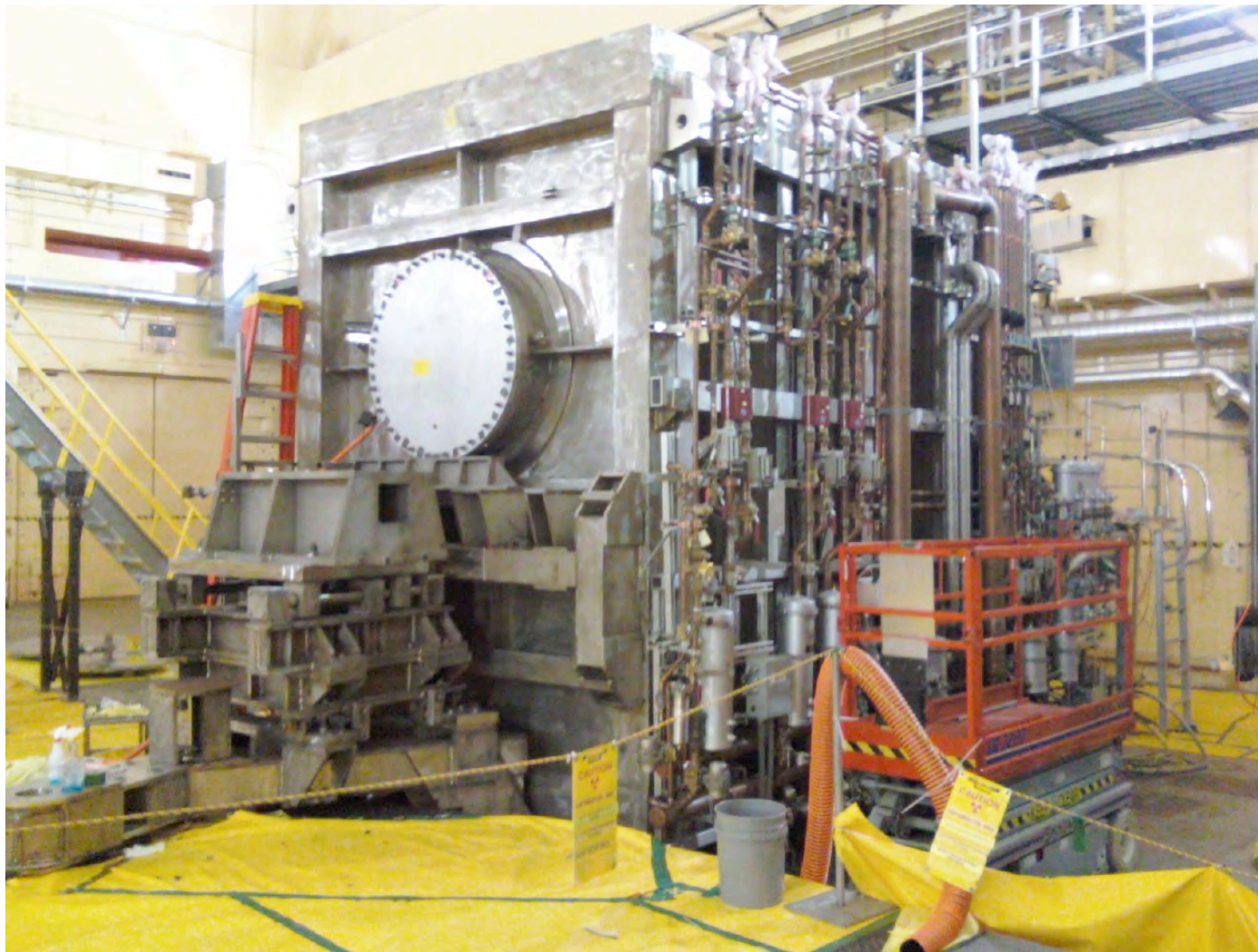
Support Slides

NBI BL2 Upgrade Overview - *keV vs. t & MW*

Accel Voltage vs Pulse Length

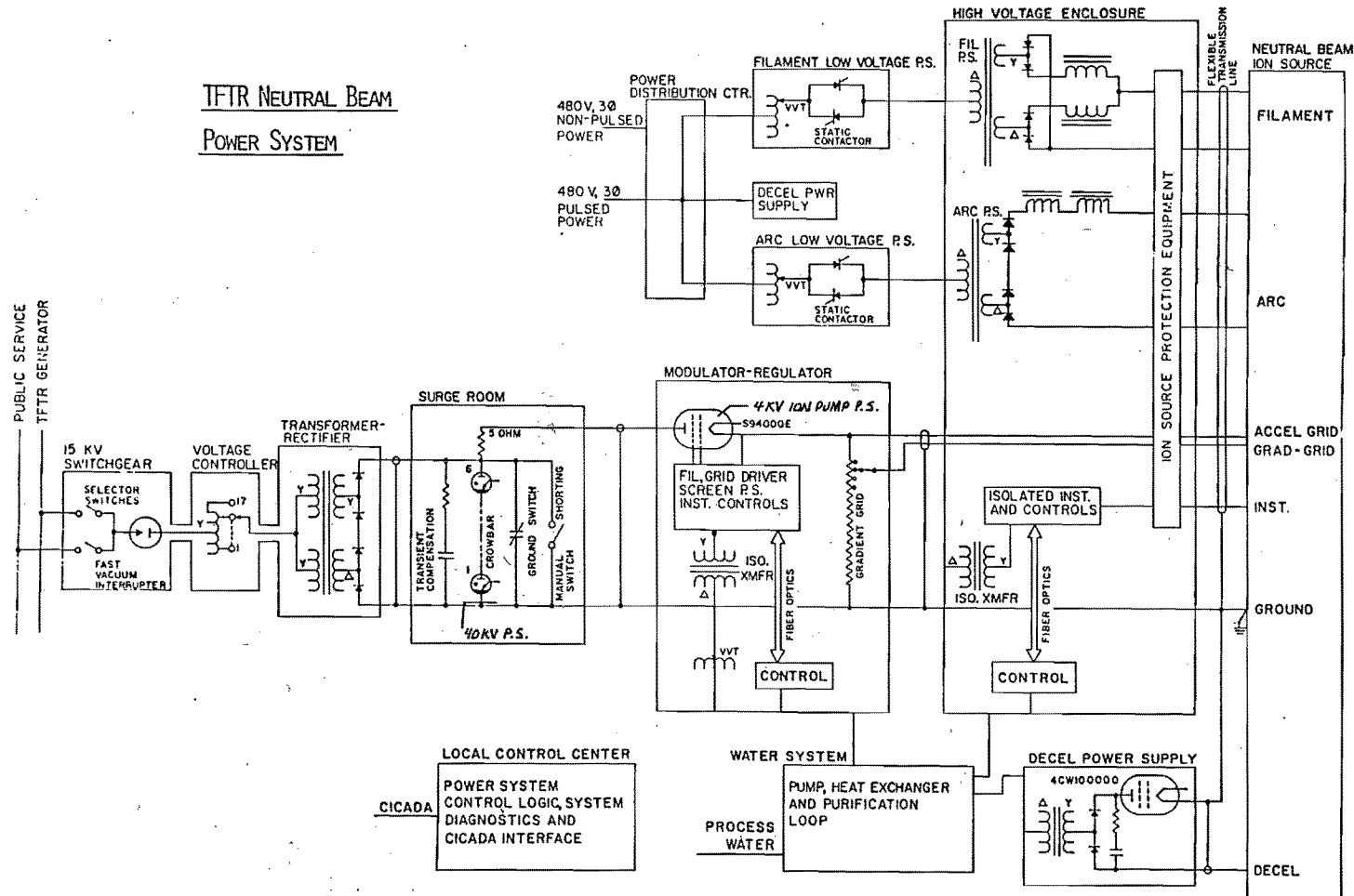


NBI BL2 Upgrade Overview - BL4 Box - *Next!*



Box is open to air and ready for some internal decon...

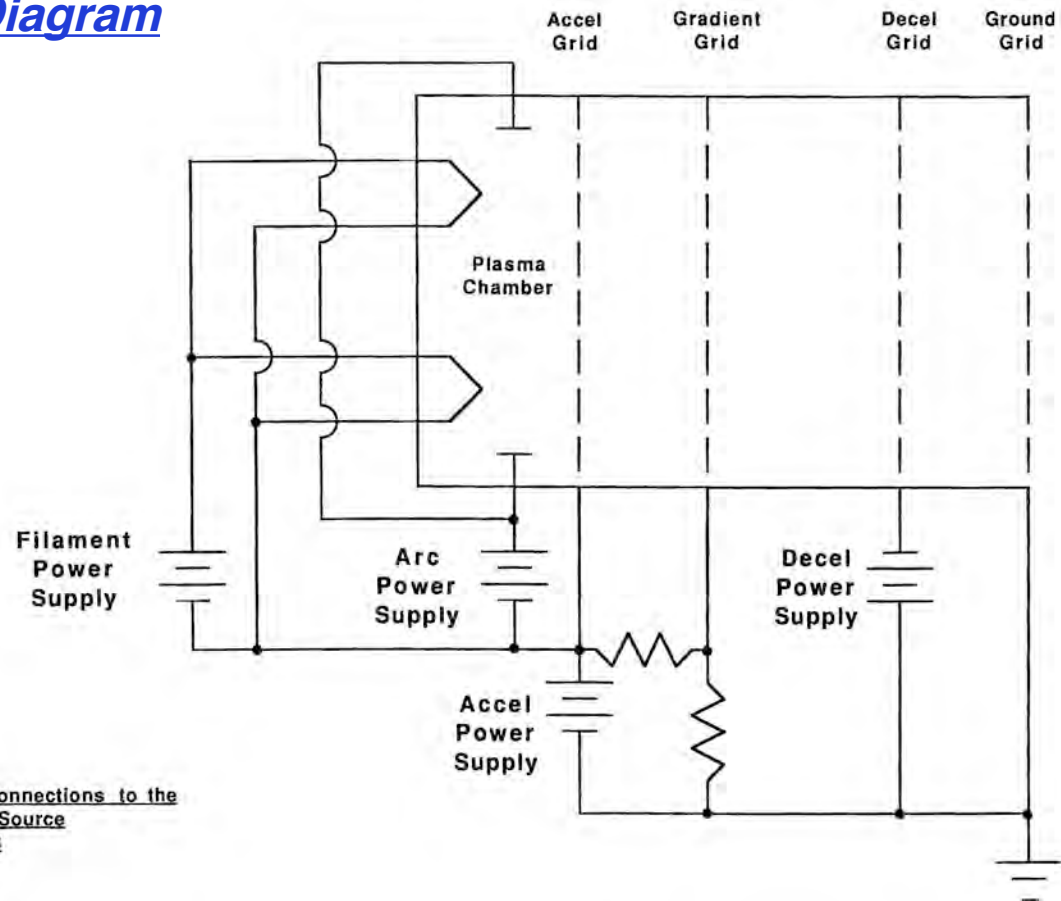
NBI BL2 Upgrade Power & Controls - One Line Diagram



NBI NBPS One Line Diagram

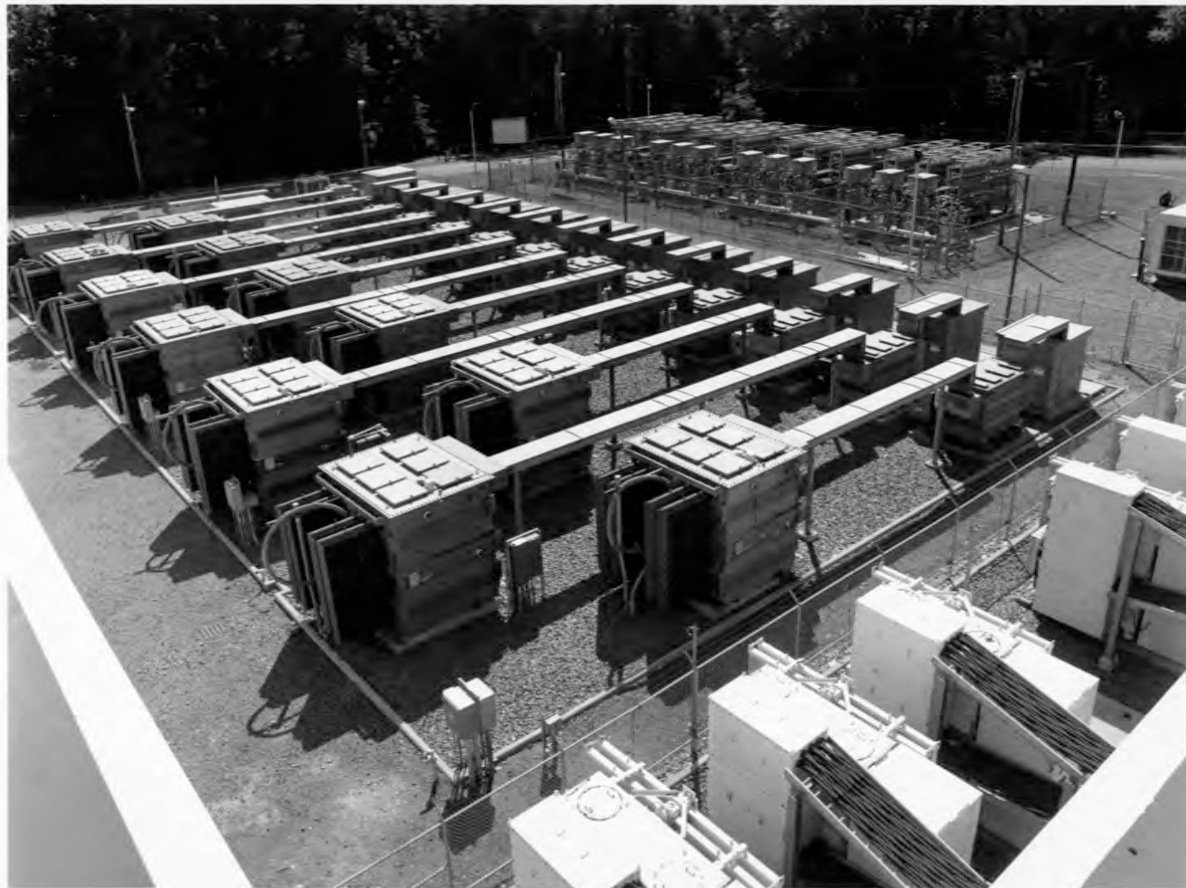
NBI BL2 Upgrade Power & Controls - Battery Diagram

NBI Source Battery Diagram



Power Supply Connections to the
Long Pulse Ion Source
TNS-11/03/88

NBI BL2 Upgrade Power & Controls - NBPS N4 available



NBI NBPS Switchgear and Transformers

NBI BL2 Upgrade Refurbishment - Ion Dump



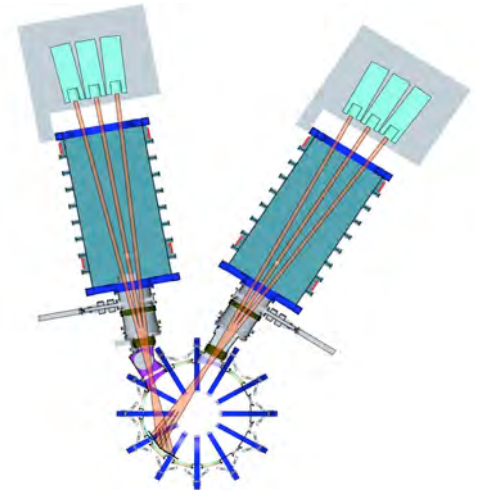
• *Full energy ion dump*

• *Half energy ion dump*

• *Third energy ion dump*

Second Neutral Beam Technical Risks

- Risk: Uncertain of the level of effort required to decontaminate.
 - Decontamination has begun with pumps and purges of the beamline.
 - Decontamination techniques were well tested during the TFTR D&D project
 - Contamination levels in NB4 are similar to levels routinely encountered during the maintenance of TFTR NB sources (100,000 to 350,000 dpm).
 - Plan includes replacing all beam impinged copper surfaces to reduce schedule risk
- Risk: Uncertainty in the commercial availability of High Voltage Switch-Tubes, cabling and terminations for the 100kV Accelerator System.
 - There are sufficient High Voltage Switch Tubes available on site to support a second NB on NSTX
 - Contact with vendors has confirmed that the triax cables and connectors are still available.



Second Neutral Beam Technical Risks

NSTX NB Upgrade Risk Registry				
Number	Affected Job	Job Title	Risk Description	Mitigation Plan (& job where budgeted)
2440a	2440	Beamline Refurbishment	Further inspections may require additional parts and labor	BL OK.
2440b			Existing copper parts may be reusable (except for the dump)	Negative risk - reduce scope of job
2450c			Heat load may be too high	Remake He lines
2460b			May need to build new backing plates	Fabricate on site
2480a	2480	NB2 Duct and VV Mods	Beam too close to bellows/duct	Include molybdenum shielding in estimate
2480b			Difficulty machining vessel	Double estimate for this portion of the job
2480d			Previous fabricators of rectangular bellows not available	Locate alternate vendors
2490a	2490	Relocations to Support NB2 Installation	SPRED re-design and re-installation may require more effort than estimated due to the physical constraints in the area of bay L	Start design work immediately so potential schedule impact can be accomodated if necessary.
2490b			LOWEUS re-design and re-installation may require more effort than estimated due to the physical constraints in the area of bay L	Start design work immediately so potential schedule impact can be accomodated if necessary.
2490c			MPTS Beam Dump Window re-design and re-installation may require more effort than estimated due to the physical constraints in the area of bay L	Start design work immediately so potential schedule impact can be accomodated if necessary.
7400a	7400	Health Physics Support	Unplanned overtime	

- *Risks mitigated or work included in base estimate*

