# LBNF MI Extraction Area Bus & LCW Relocation Preliminary Design Review

Karlton E. Williams, II

13 December 2022

v3 – posted 12 December 2022

## Who am I, a few highlights

- Working in shops as machinist, mechanic, draftsman, since 1973
- USN, 1975-1980, E-5 / Machinery Repairman 2nd Class Petty Officer
- Northampton Community College, 1988, AS Engineering, AAS Design Technology
- Hired in 1990 for the LINAC Upgrade, became the TM/CC for all of the piping for that project, as well as the initial start-up of the LCW systems
- AD/MS Fluids Technician, 1993 - 1998
- Northern Illinois University, 1996, BS Physics, Energy Emphasis
- Lead or sole TM/CC for all of the Main Injector LCW and gas lines, 1993 – 1997
- Project manager for the NuMI Upgrades, 2008 – 2013
- Machine Engineer for Fluid Systems, 1998 – about 2016
- Part of original crew for LBNE project, 2007 on, for all of LBNF LCW and RAW system development thru Preliminary Design Reviews

# My Team

I'd like to thank my team, especially:

- Scott Oplt
- Dave Holeman
- Dave Hixson
- Dez Deshpande

- Please note: This review package also serves as a turnover package, as Dave Hixson inherits the design after this review

# Outline

- Overview
  - Purpose
  - Scope
- LCW
  - 6” MI Global Headers
  - Quad Location Manifolds
  - MI-14 LCW and Fluorinert lines
  - LBNF PB Fill Line
- Bus
  - 1” x 4”, 2-5/8” Dipole bus
  - 2-1/8” Quadrupole Bus
- Fluorinert Systems
- Enclosure Utilities
- Cost & Schedule Estimates
- Risks & Issues
- Summary

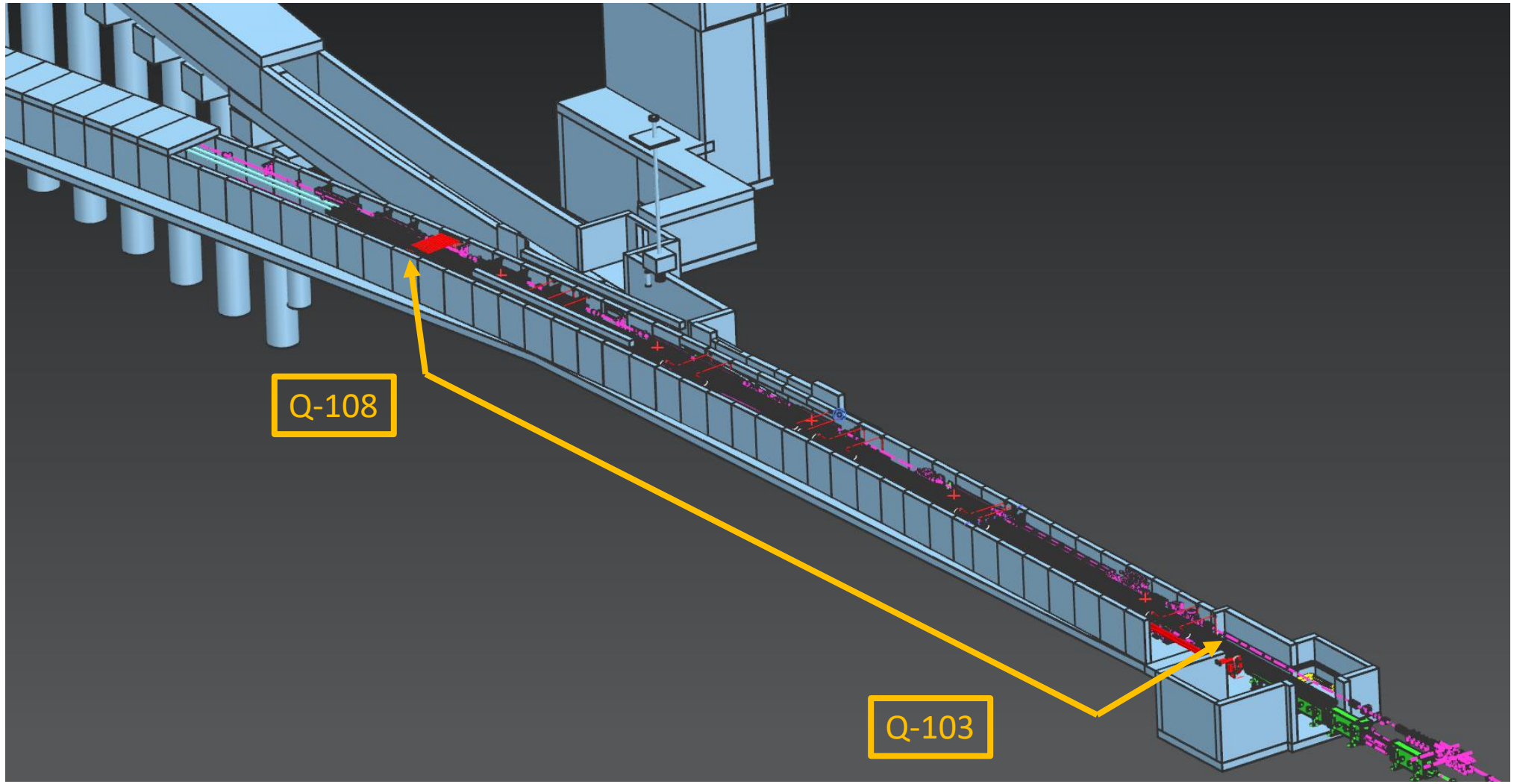
# Overview - Purpose

- LBNF Extraction Beamline installation in the MI-10 Main Injector region requires rerouting of LCW main headers, manifolds, and bus runs, as well as kicker Fluorinert systems
- This review presents the modifications and pathways considered as the best fit choice, and offers an opportunity for others to see and comment on the proposed modifications
- This Preliminary Design Review focuses on the LCW and Bus modifications required
  - This represents the majority of the fluids relocation work required
  - The decision to change the WBS to include Fluorinert systems was made too late to cover fully in this review, rests currently with Power Supply Systems in those WBS's

# Overview - Scope

- Modifications begin at the DS wall of the MI10 enclosure alcove
- Extend from Q-103 thru Q-107 / Q-108 region
  - Major relocation of LCW headers
  - Extensions to LCW manifolds and MI-14 lines
  - Removal and reinstallation of LCW and Fluorinert from enclosure thru Gerardi boxes
    - Fluorinert systems are not included in this WBS, referenced only as needed
  - Addition of LBNF PBE fill line
  - Temporary removal & replacement of dipole bus
  - Major relocation of quadrupole bus
  - Requires relocation of some utilities
  - Fluorinert systems are referenced where necessary for the work involved, and in the References page, but are not included in this review

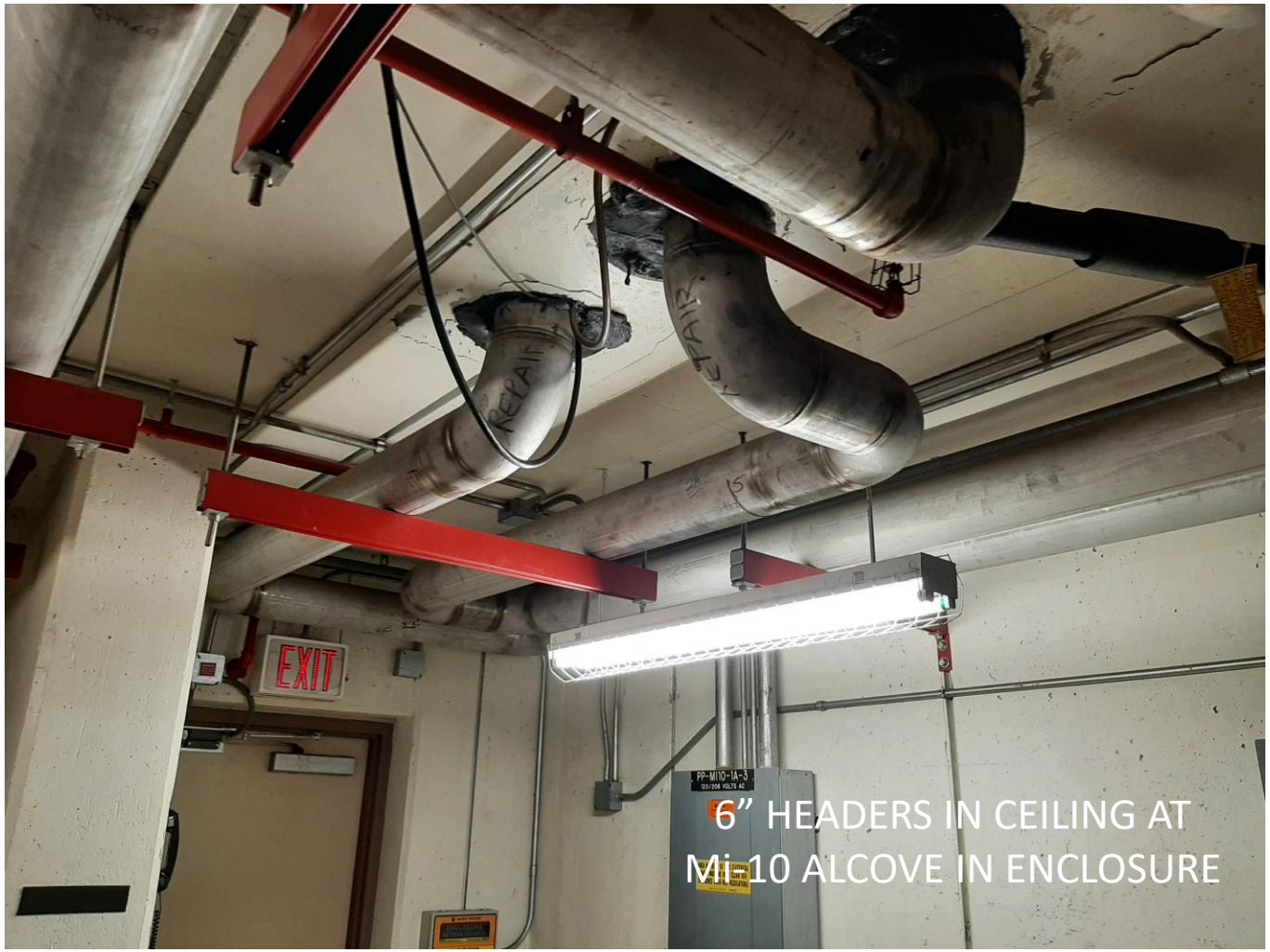
# Affected Area
# Q-103 trhu Q-108



# LCW – Global 6” Headers
# General Layout, Enclosure Run, Q-103 thru Q-108

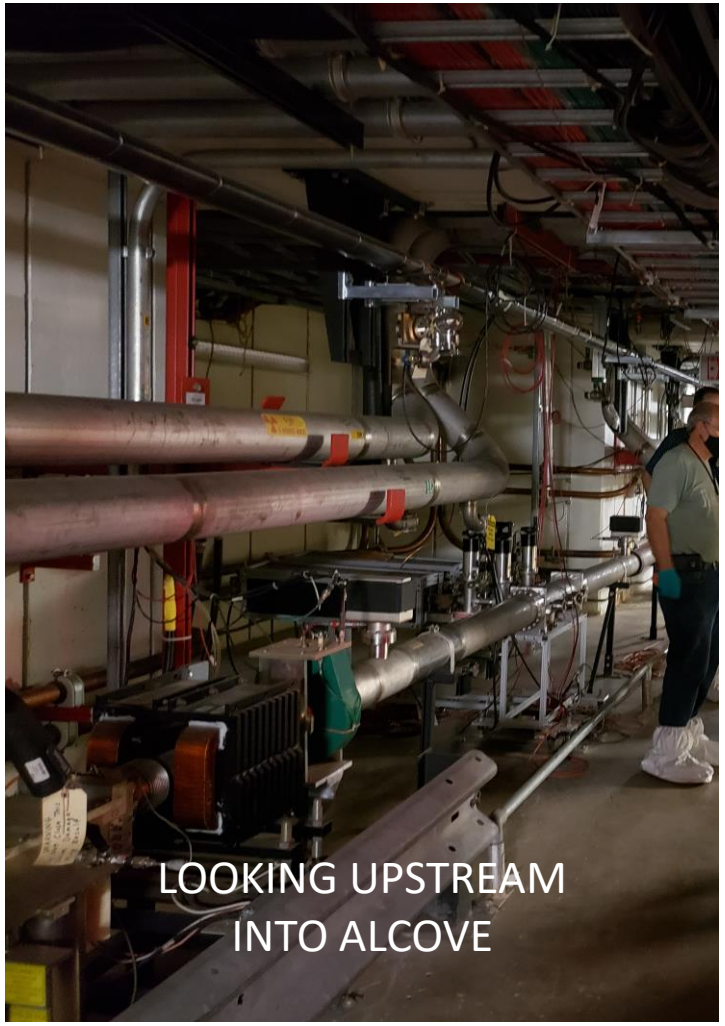
- Between Q-103 thru Q-108, the LCW headers are to be relocated from above magnets at chest height, to high up on aisle side, above current lighting fixtures
- New location must avoid magnet mover and other equipment
- Requires relocation of some utilities and lighting along upper aisle wall
- Cell taps for manifolds can remain in the general Z axis location for each cell manifold connection
- Isolation valves remain connected to header, move with it to the new path, and are located above aisle side for easy access
- Same or similar hoses connect to the manifolds
- Strategic cutting of pipe should result in all of it being reusable
  - If not reusable, add up to $25k and 80 hours labor

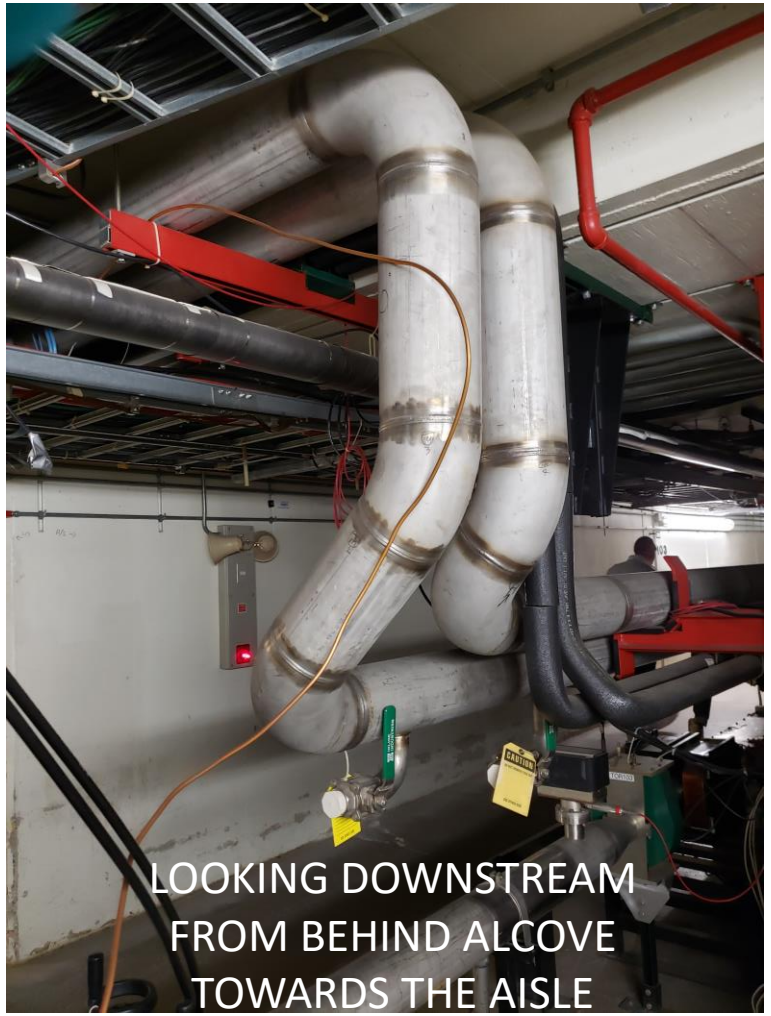
# Affected Area
# MI-10 Alcove



6” HEADERSS FROM SURFACE, THRU OVERHEAD

# Affected Area
# MI-10 Alcove



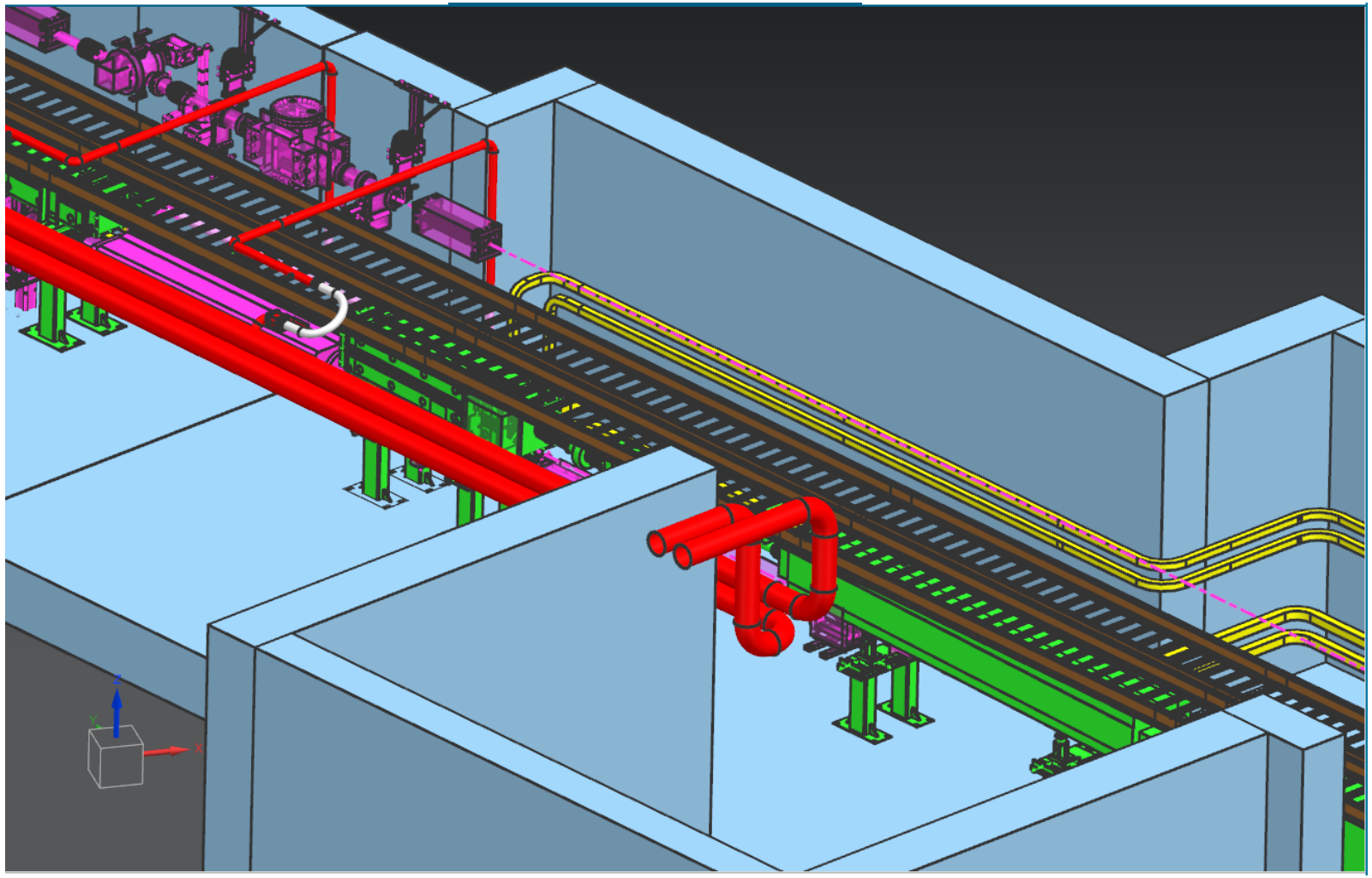



# Affected Area
# Q-103 trhu Q-108

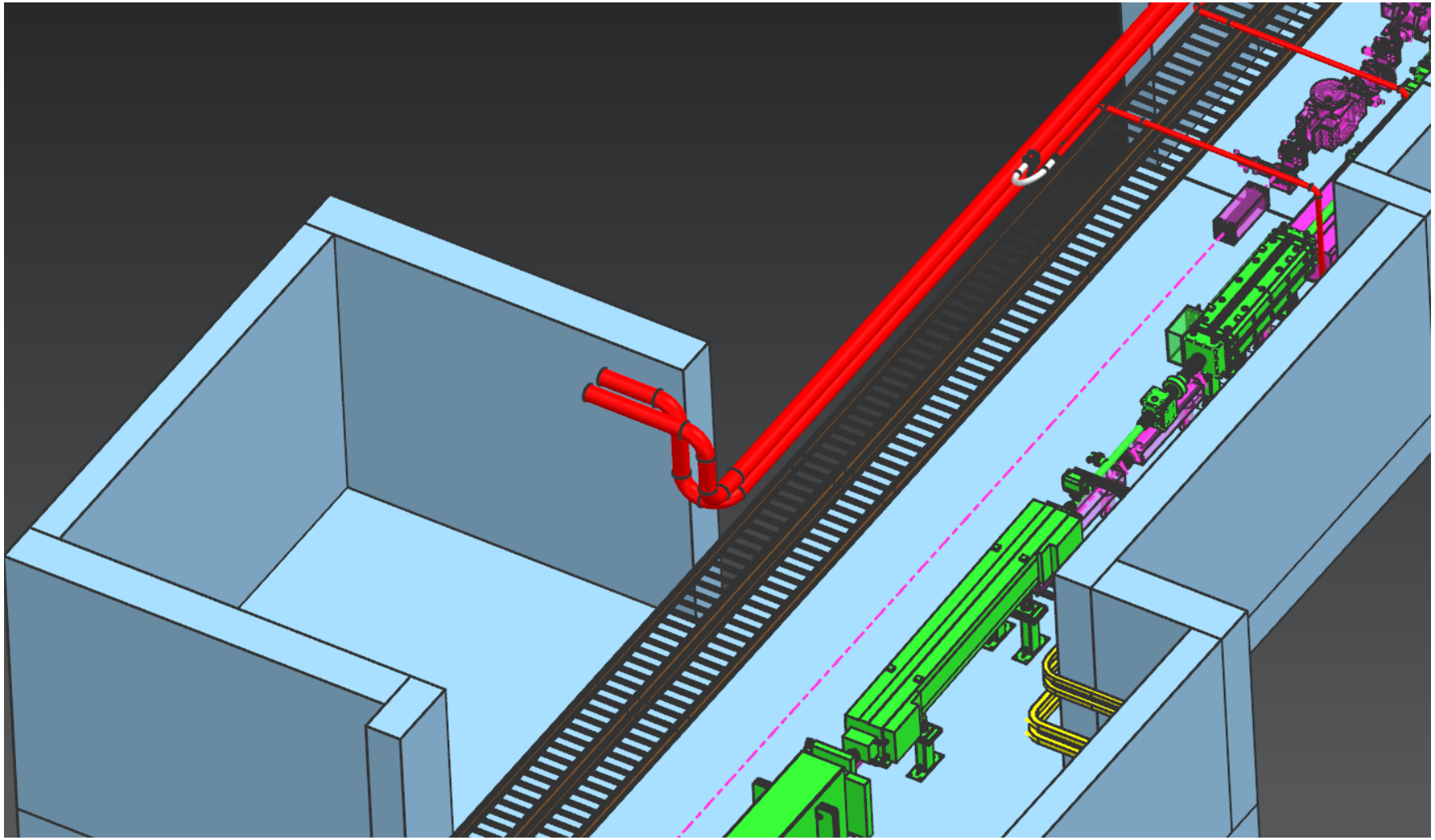

# LCW – Global 6” Headers
# Upstream End at MI-10 Alcove

- Path of current LCW headers come from overhead near stairwell in alcove, crosses overhead to the beamline, and to their current placement at chest-high over the magnet line
- Modification will truncate that path to make a 90 degree bend downstream along inner aisle wall, near the top, just below utilities conduits
- Little modification is required at this end

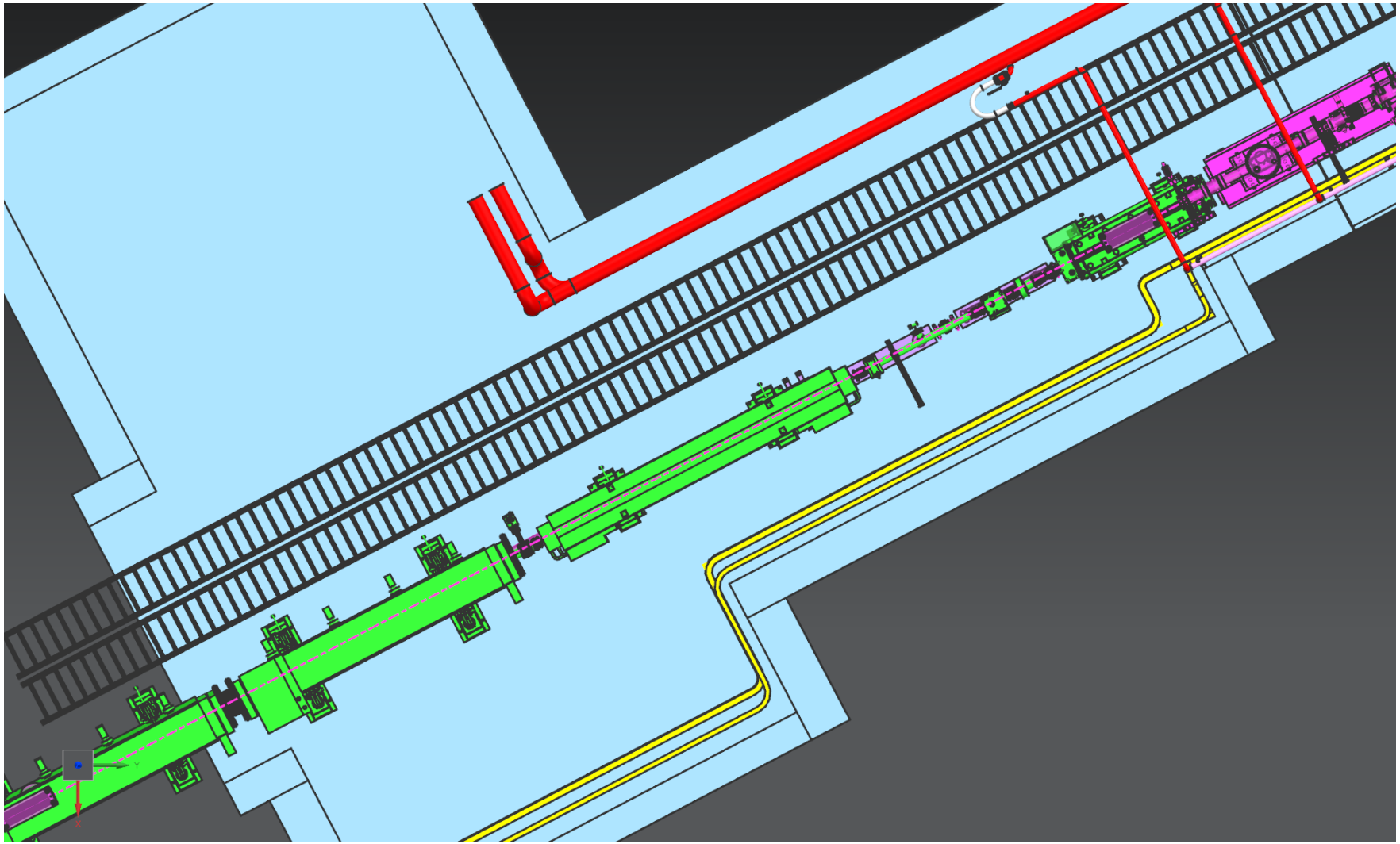
# LCW – Global 6” Headers
# Upstream End at MI-10 Alcove



# LCW – Global 6” Headers
# Upstream End at MI-10 Alcove



# LCW – Global 6” Headers
# Upstream End at MI-10 Alcove

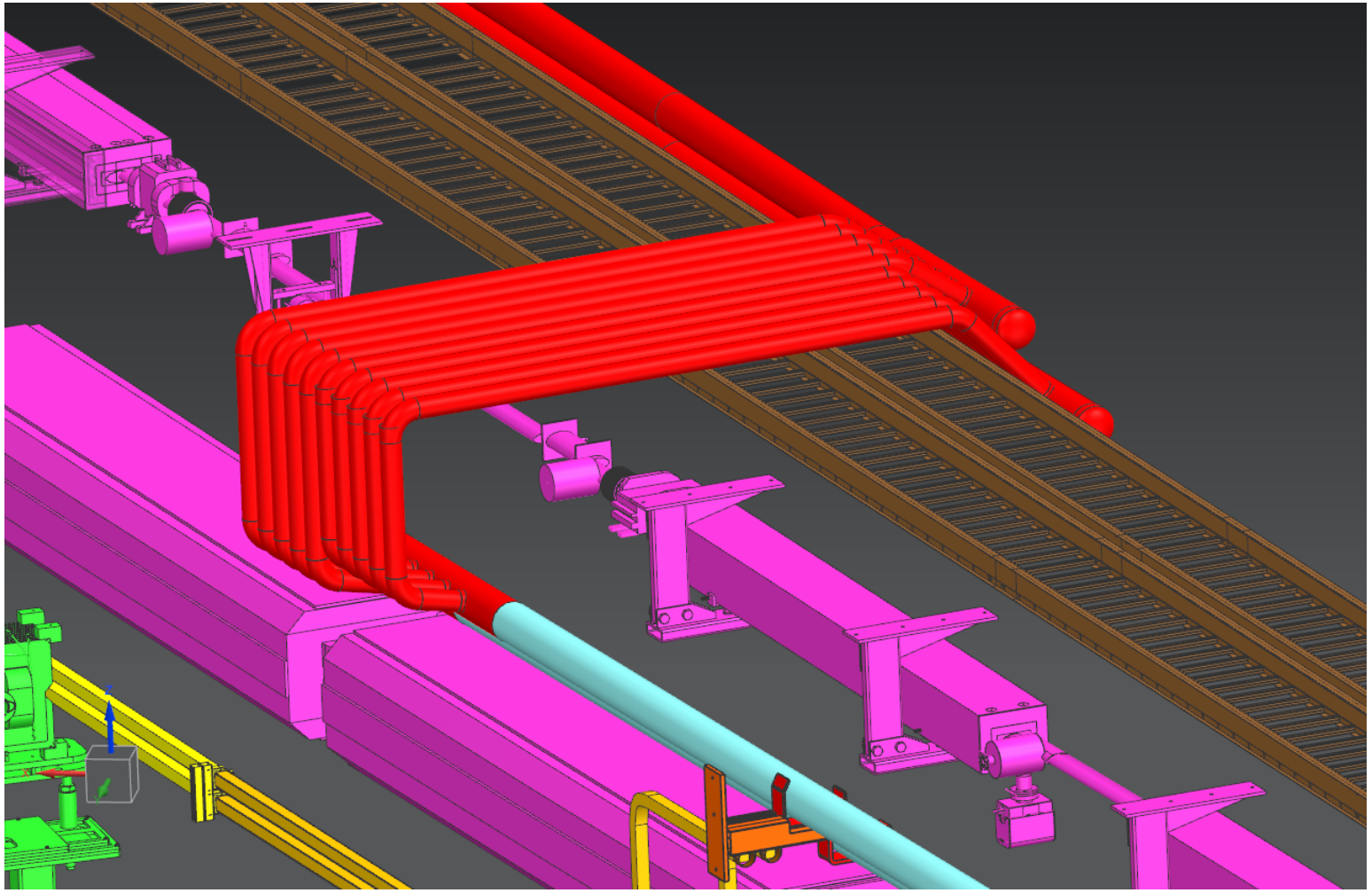


# LCW – Global 6” Headers
# Downstream End at Q-107 / Q-108

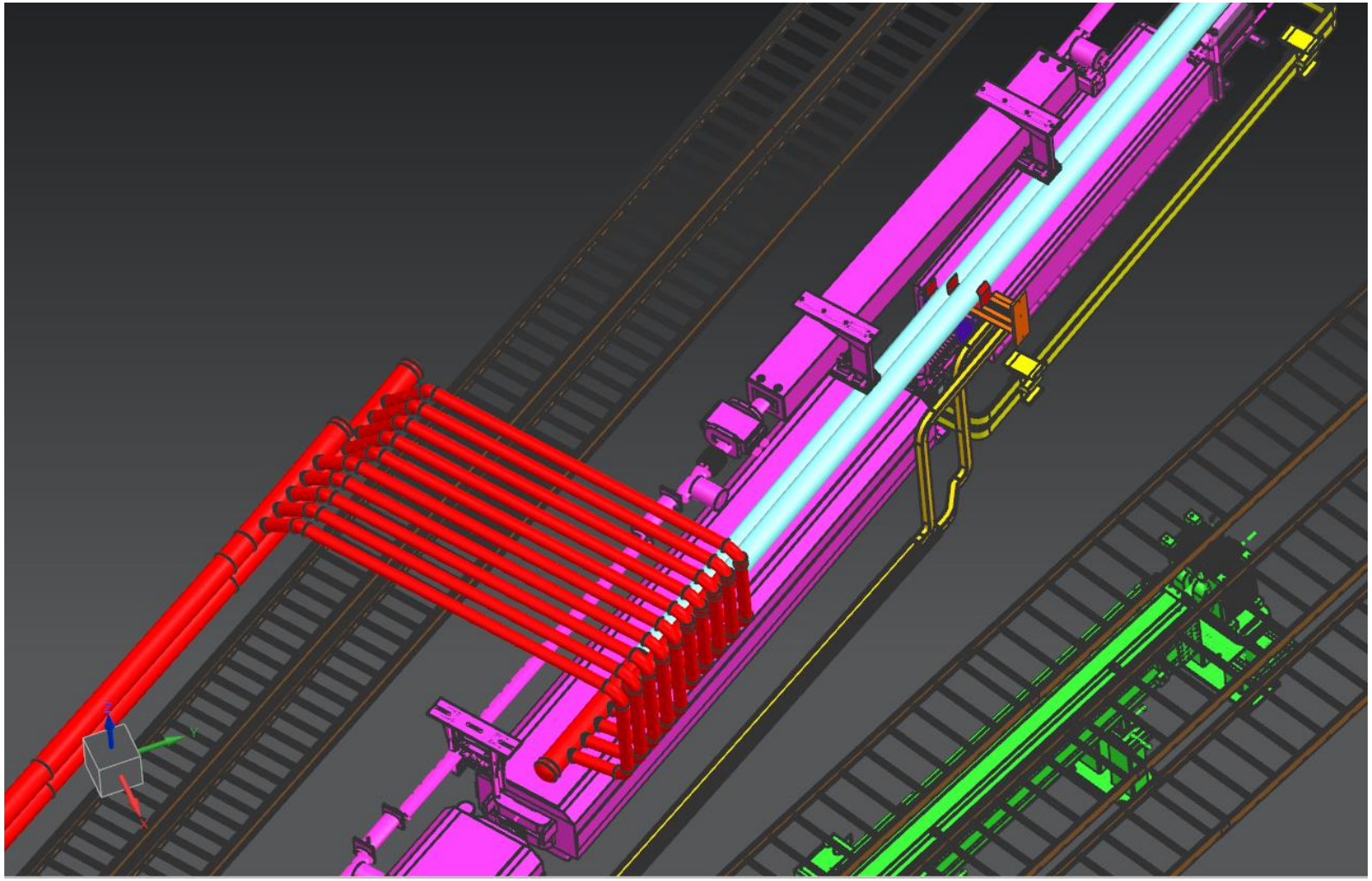
- At the downstream end, at D-107-2, the 6” LCW headers need to return from the aisle side, back to the magnet run and the original configuration
- There is no room above the aisle cable trays for 6” IPS headers to fit without pushing the cable tray downward into harm’s way
- 2 choices for optional piping runs:
  - 5 each of 3”IPS pipe runs per header, utilizing standard piping components
    - This “pipe organ” approach is only one presented herein
    - Complex, and requires more installation room & labor, but uses off-the-shelf components
  - 1 each per header of a custom 3” x 25” rectangular pipe, custom fabricated
    - Simpler, requires less room, but would require engineering development
- Both designs increase cross-sectional area by about 20% to allow for additional losses

# LCW – Global 6” Headers
# Downstream End at Q-107 / Q-108

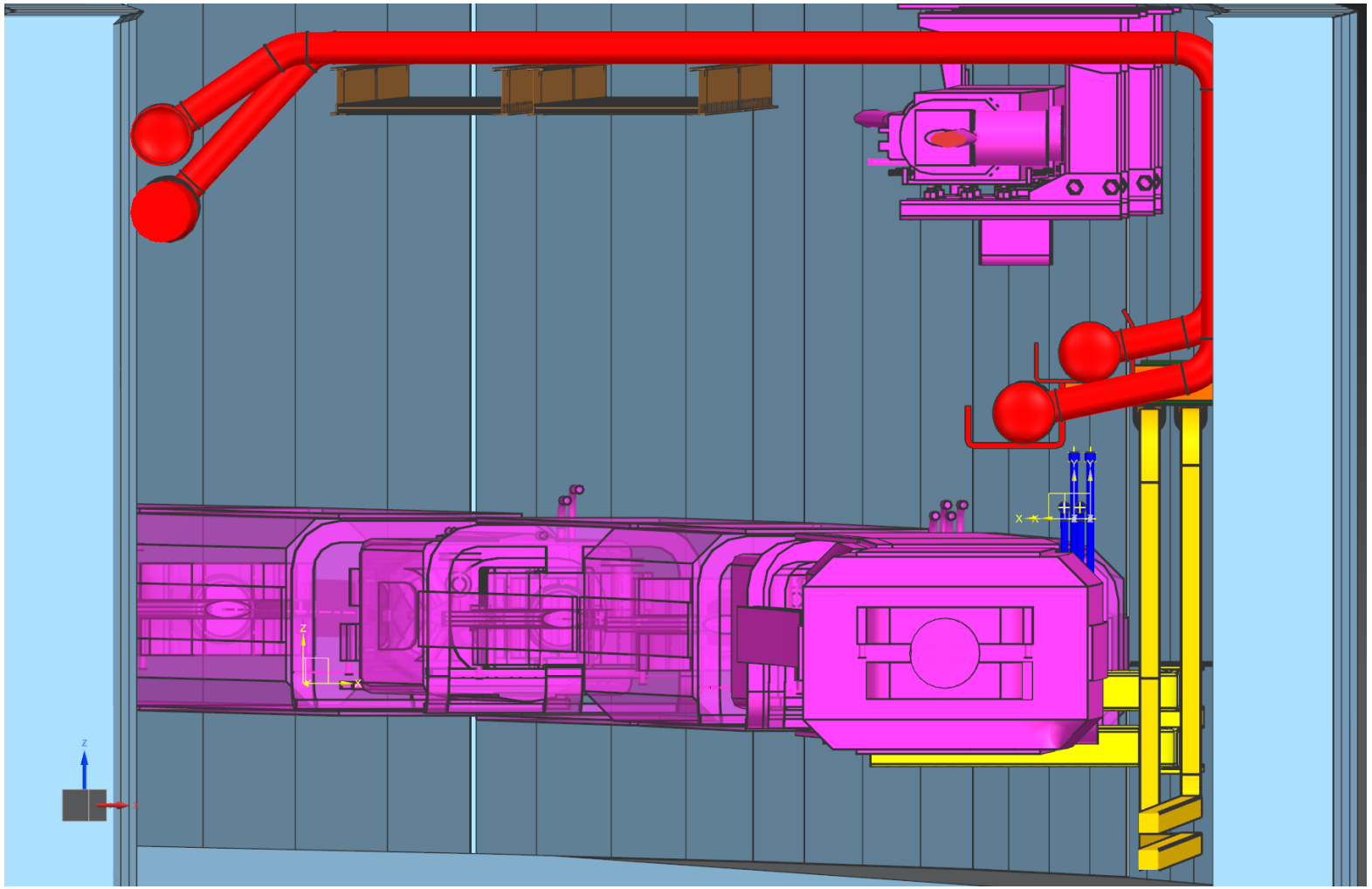
3” IPS “PIPE ORGAN” APPROACH



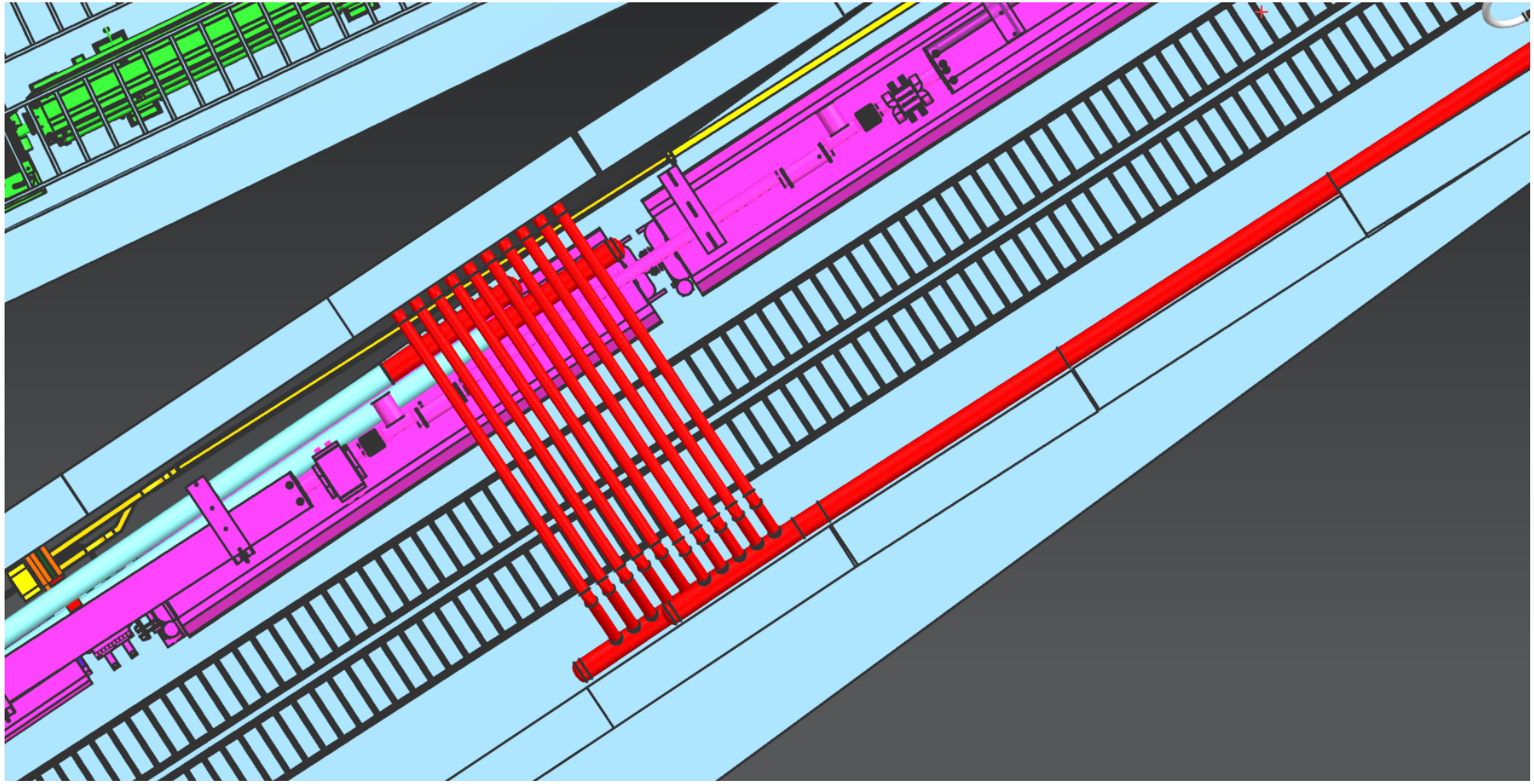
# LCW – Global 6” Headers
# Downstream End at Q-107 / Q-108



# LCW – Global 6” Headers
# Downstream End at Q-107 / Q-108

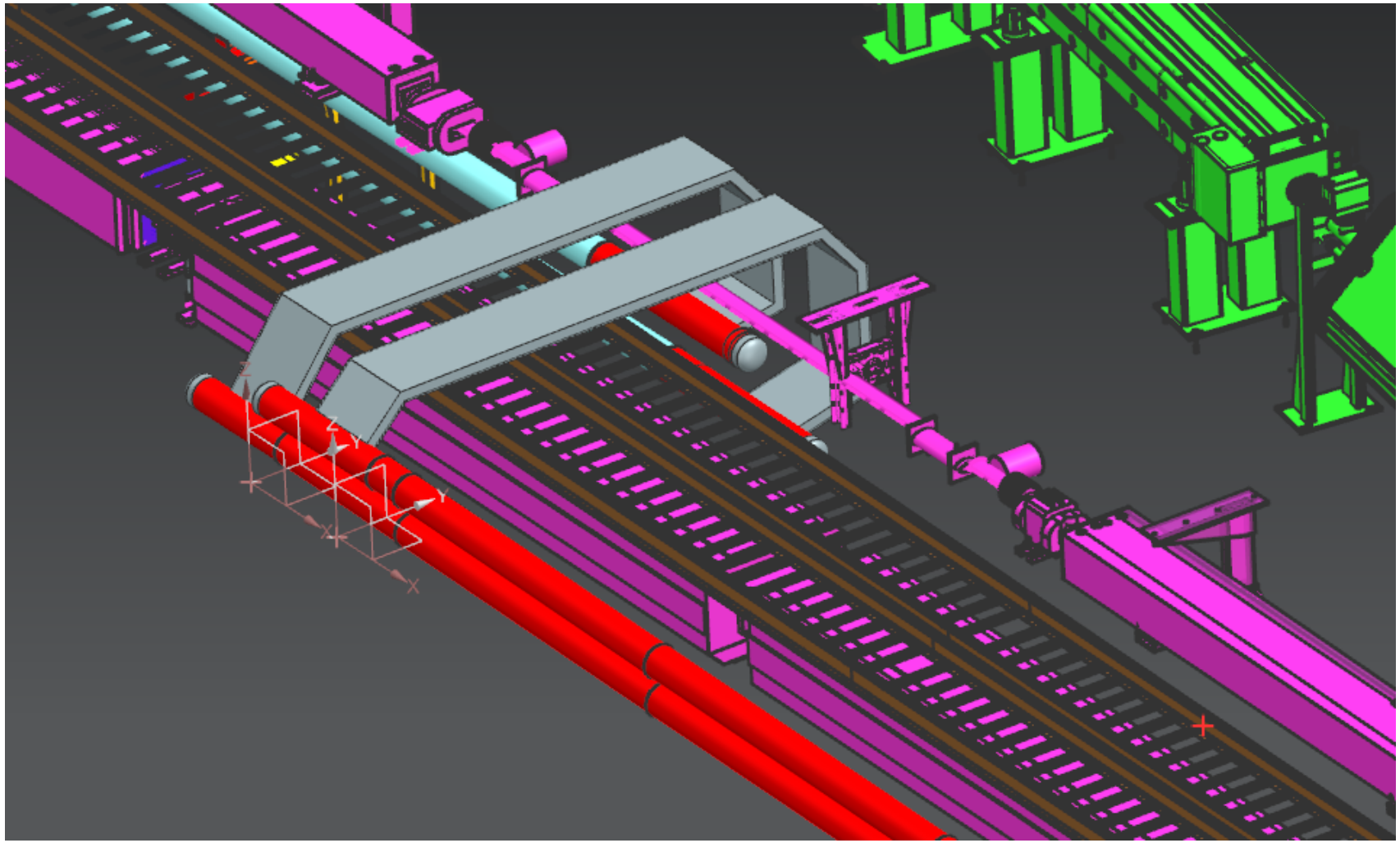


# LCW – Global 6” Headers
# Downstream End at Q-107 / Q-108

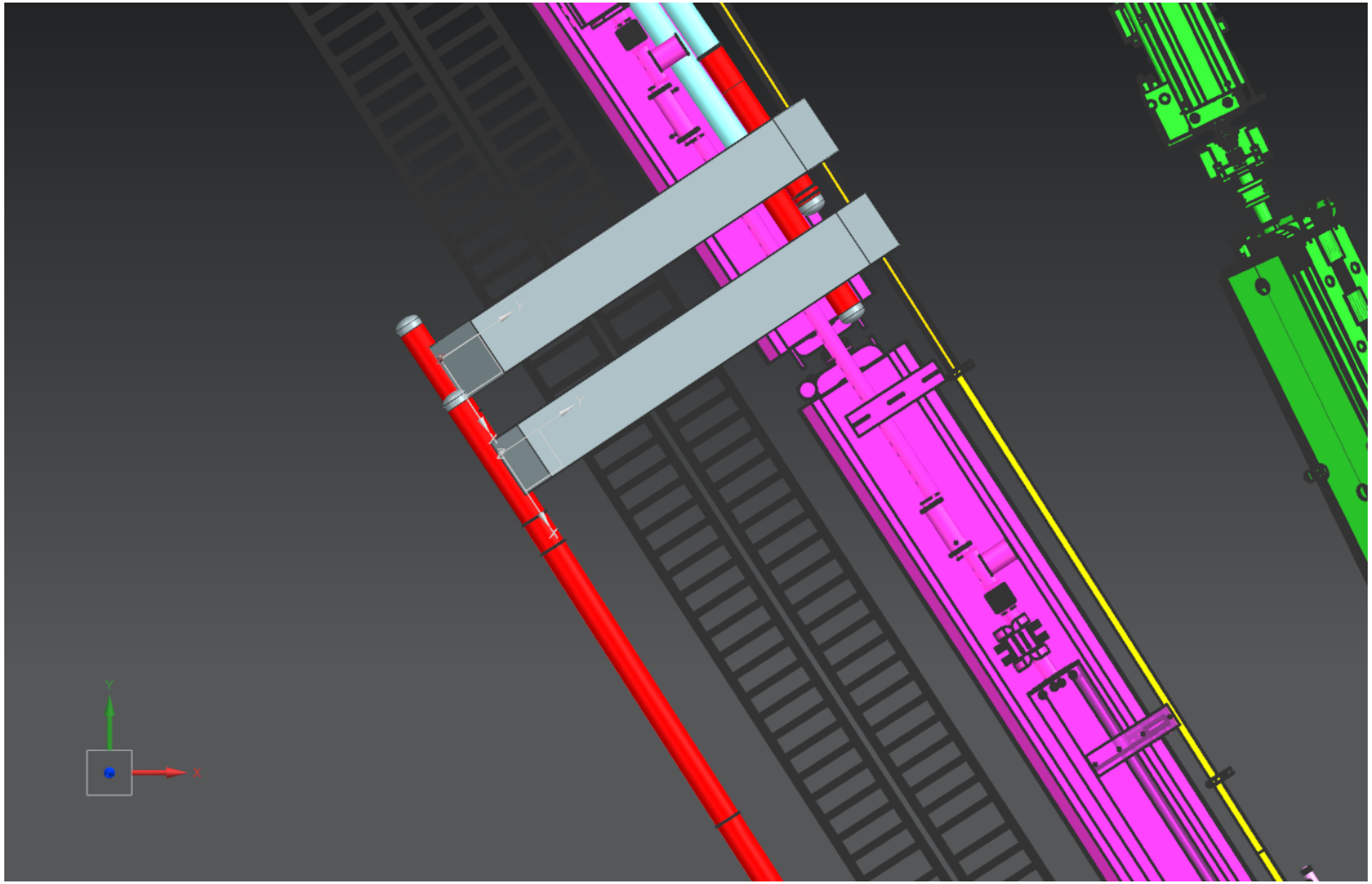


# LCW – Global 6” Headers
# Downstream End at Q-107 / Q-108

3” X 25” RECTANGULAR
PIPE APPROACH



# LCW – Global 6” Headers
# Downstream End at Q-107 / Q-108



# LCW – Quad Cell Manifolds

- 8 components get removed from the current MI Q-641 to Q-106 area:

| |
|---|
| SQA-851 |
| SQA-852 |
| LAMB AZERO |
| STOICH |
| Kicker 1 |
| Kicker 2 |
| STOICH |
| STOICH |

- 9 components get added into the PB Extraction beamline, Q-102 to Q-104:

| |
|---|
| LAM-10 |
| LAM-11A |
| LAM-11B |
| V-100 |
| Q-201A |
| Q-201B |
| HV-201 |
| Q-202 |
| Q-203 |

# LCW – Quad Cell Manifolds

- 3 ways to add the taps for the 9 new magnets:
  - adding their own specific 2" manifold lines
  - adding taps from the existing manifolds
  - directly adding taps to the 6" headers
- New components to be added are shown in P&ID # F10127805, LBNF Primary Beam Line LCW and Bus Flow Schematics, as fed from the addition of separate 2” MI manifolds, feeding just that string of LBNF components
- Proposed here, due to space restrictions new components are shown in P&ID # F00305689-G as being fed from existing manifolds at Q-102, -103, &-104
- Addition of individual taps directly to the 6” headers may be preferable upon study
- All solutions are suitable from an LCW system standpoint, and components will receive the required cooling water flow
- TBD during Final Design

# LCW – Quad Cell Manifolds
# Modifying Existing Manifolds

- All manifolds may stay where they are, minor adjustments may be required
- Extensions added to follow up back wall, across overhead
- Connection hoses to headers kept in similar arrangement, but relocated to aisle overhead space
- Connections to current magnets may remain
- Connections for new beamline elements added to existing manifolds
- Some manifolds may require minor modifications due to new beamline components. The full extent of this is unknown at this time
- The following chart summarizes the flow changes at each cell

# LCW – Quad Cell Manifolds
## Change in quad cell LCW loads

| | COMPONENTS TO REMOVE | | | | COMPONENTS TO ADD IN | | | |
|---|---|---|---|---|---|---|---|---|
| # | Location | Component | Flow, gpm | @ Quad Cell | Location* | Component | Flow, gpm | @ Quad cell |
| 1 | Q-641 | SQA-851 | 10 | -10 | Q-102 | LAM-10 | 16 | |
| 2 | Q-100 | SQA-852 | 10 | -10 | Q-102 | LAM-11A | 16 | |
| 3 | Q-101 | LAMB AZERO | 10 | -10 | Q-102 | LAM-11B | 16 | +48 |
| 4 | HDR-102 | STOICH* | 5 | -5 | Q-103 | V-100 | 9 | |
| 5 | Q-103 | Kicker 1 | 2 | | Q-103 | Q-201A | 8 | |
| 6 | | Kicker 2 | 2 | -4 | Q-103 | Q-201B | 8 | |
| 7 | HDR-103 | STOICH* | 5 | -5 | Q-103 | HV-201 | 9 | +34 |
| 8 | HDR-106 | STOICH* | 5 | -5 | Q-104 | Q-202 | 8 | |
| 9 | | | | | Q-104 | Q-203 | 6 | +14 |
| | Reduced Flow, ttl, gpm | | 49 | | Increased Flow, ttl, gpm | | | 96 |
| | **NET TOTAL LCW LOAD CHANGE, gpm** | | | | | | | **+47** |

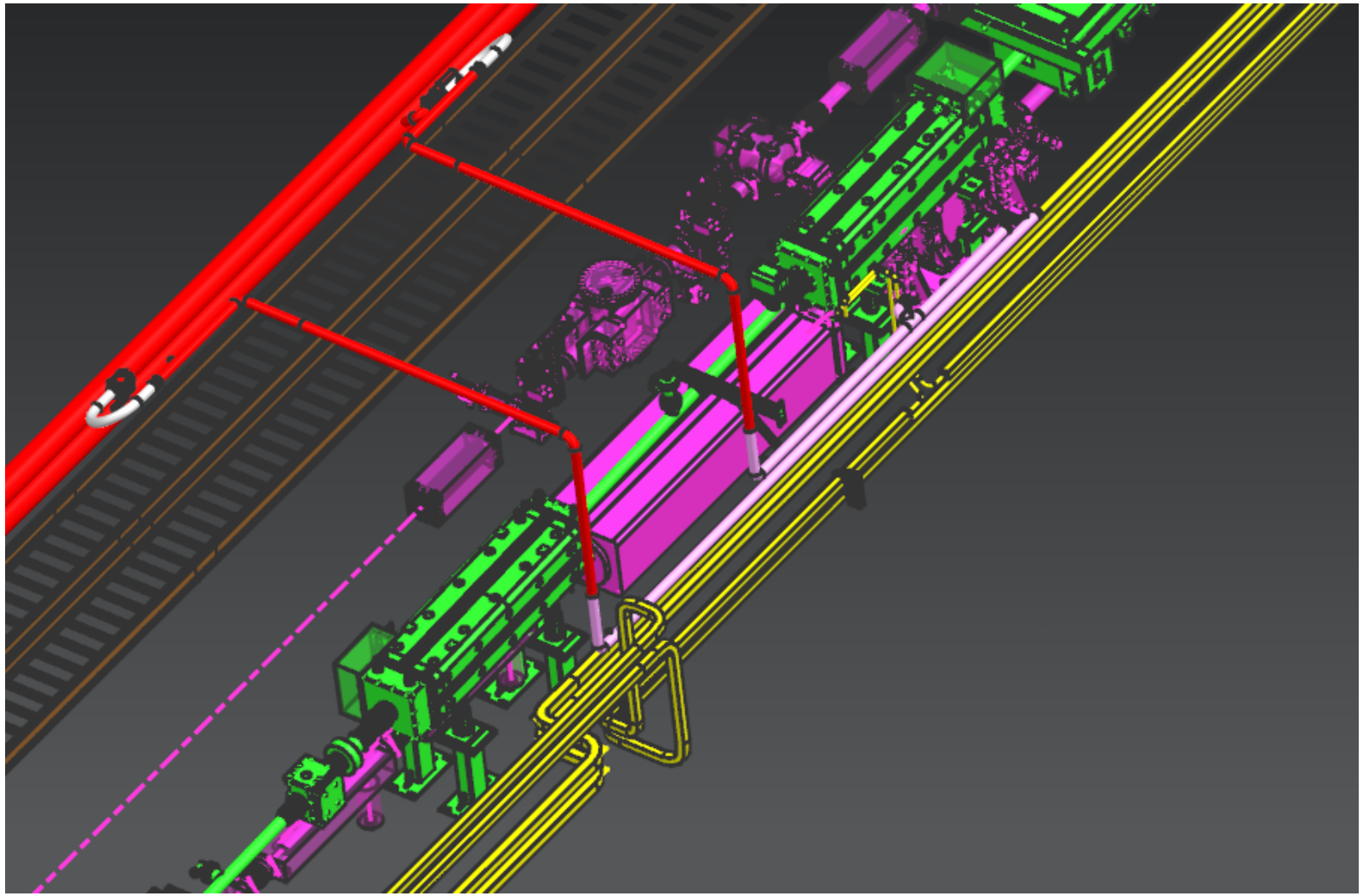
* denotes stoichastic cooling tanks which are fed directly from the header

# LCW – Quad Cell Manifolds

EXISTING MANIFOLD TAPS

EXISTING MANIFOLDS

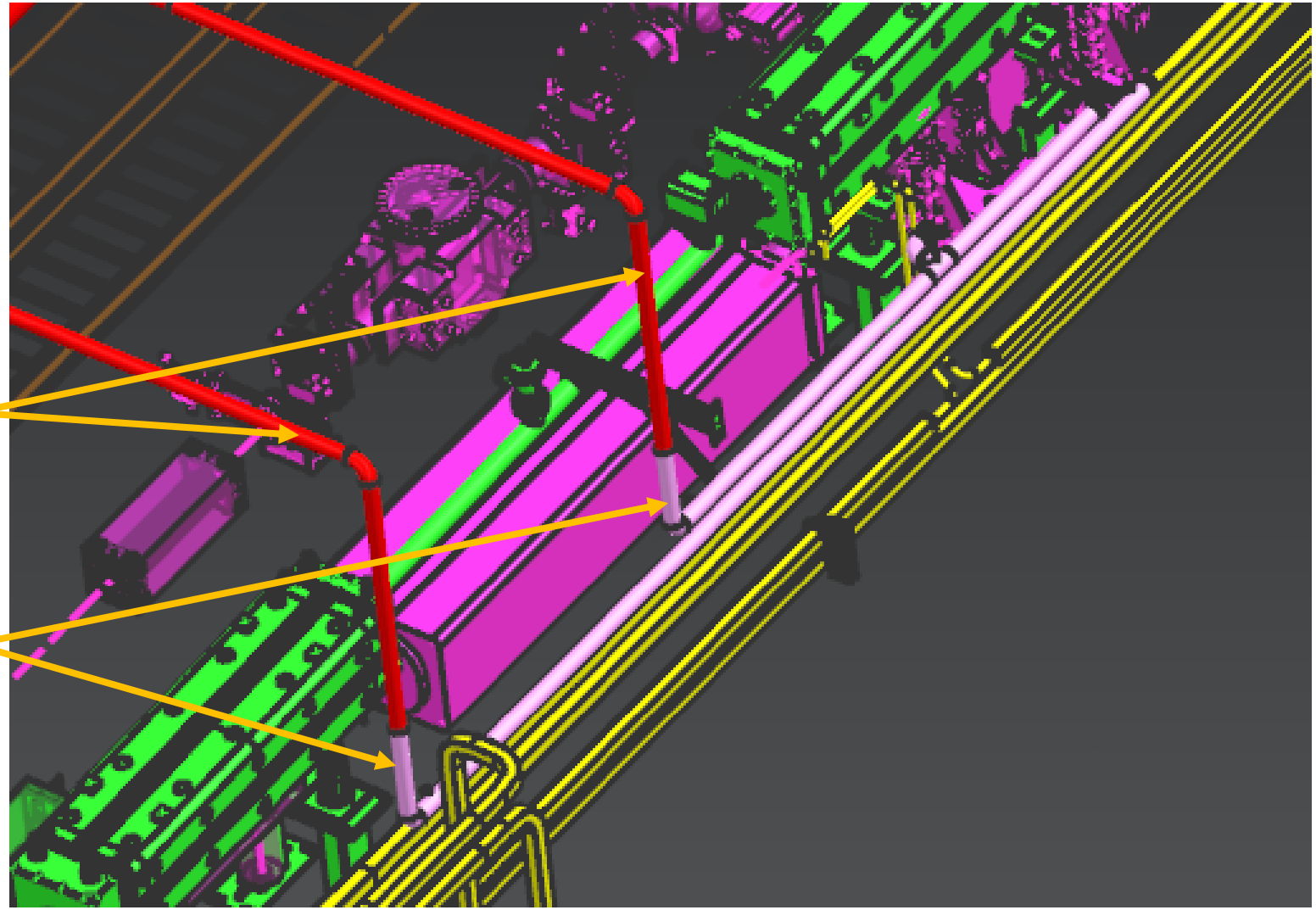
# LCW – Quad Cell Manifolds



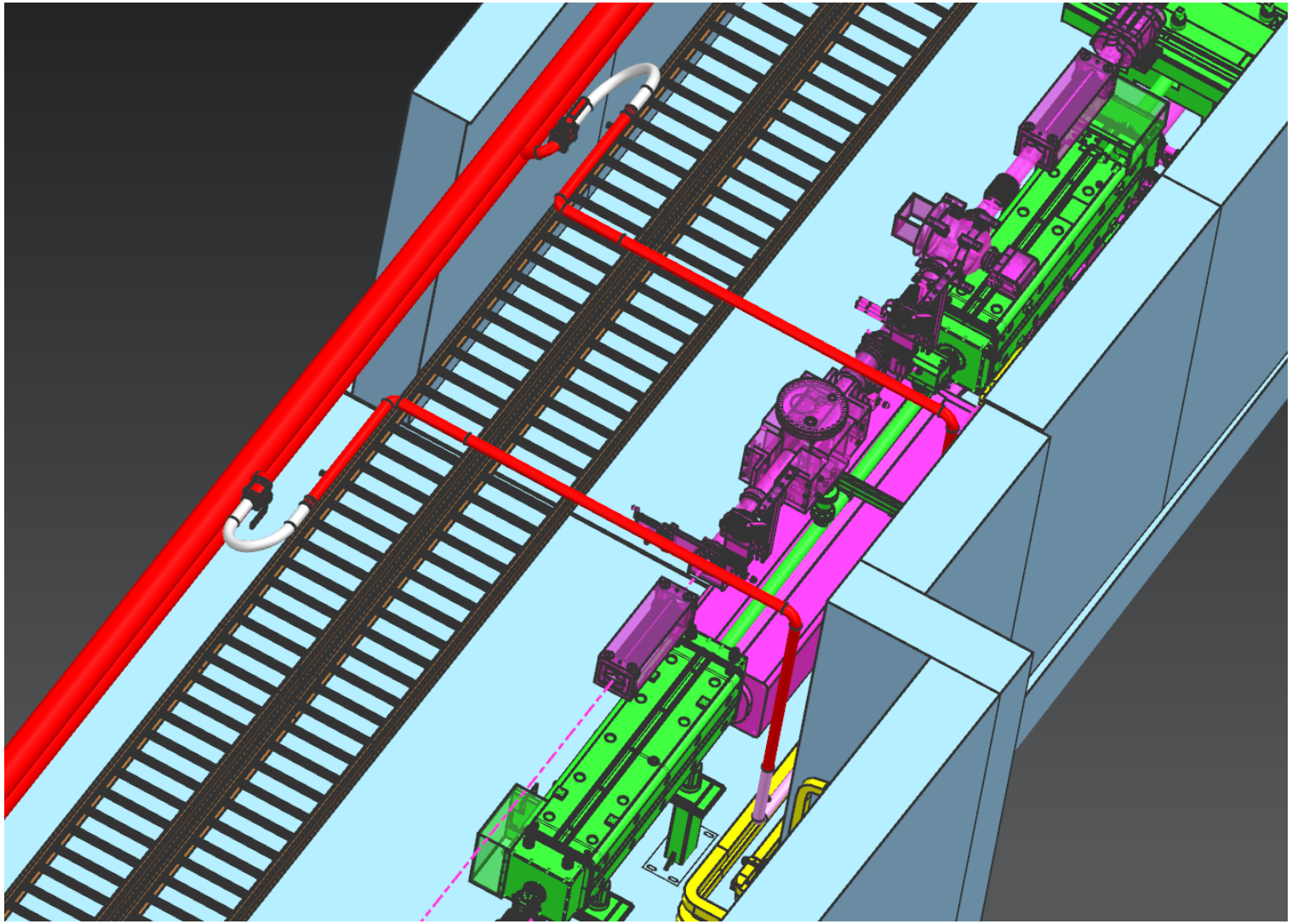
# LCW – Quad Cell Manifolds

MANIFOLDS EXTENSIONS TO AISLE SIDE

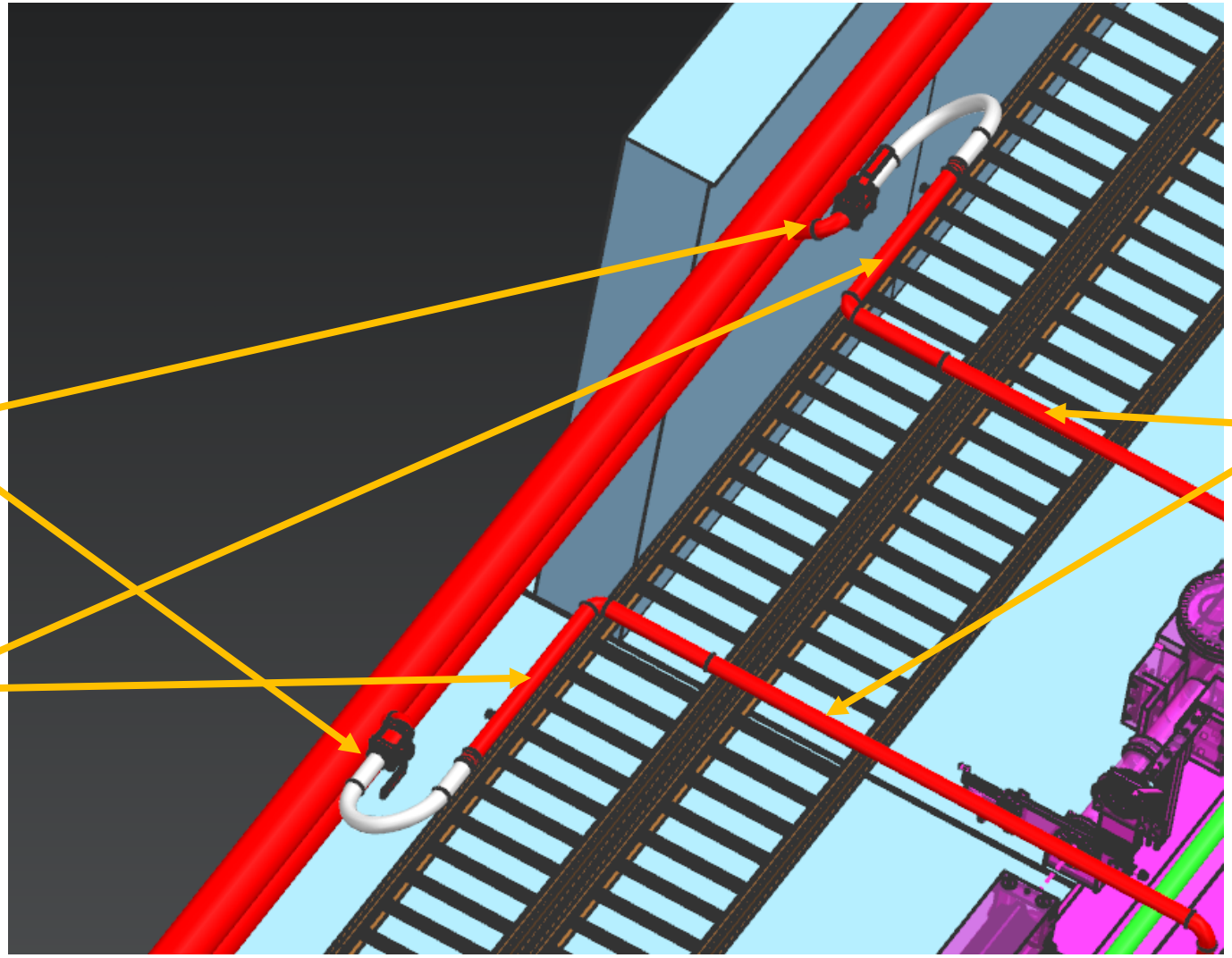
CURRENT MANIFOLDS



# LCW – Quad Cell Manifolds



# LCW – Quad Cell Manifolds



REUSE TAPS & HOSES FROM CURRENT MI

MANIFOLDS EXTENSIONS TO AISLE SIDE

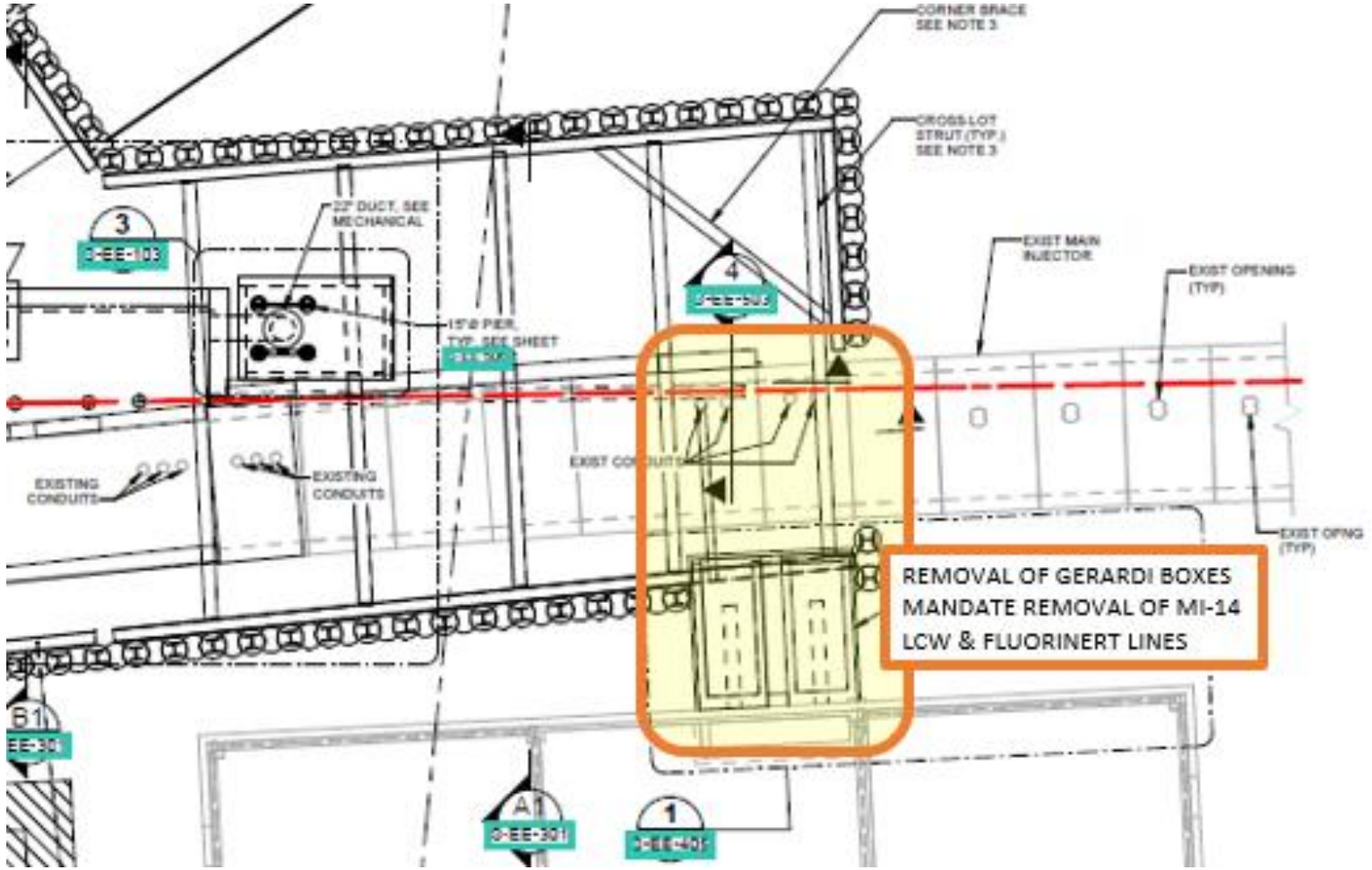
MANIFOLD EXTENSIONS PASS OVER CABLE TRAYS

# LCW - MI-14 LCW and Fluorinert lines

- Civil construction requires removal of the Gerardi Boxes behind MI-14 at grade, with penetrations to the enclosure overhead at about Q-105
  - Both boxes and penetrations packed with poly beads
- Both LCW and Fluorinert lines in the Q-105 region require full removal from enclosure and penetrations to skid inside MI-14
- Once Gerardi box replacements with penetrations are installed, LCW & Fluorinert lines may be reinstalled and reconnected as original
- LCW lines require cross-over extensions similar to manifolds
- Fluorinert lines appear not to need modification, only reinstallation
- Fluorinert work for MI-14 needs to be combined into this WBS
- Both require extra work if penetration arrangement is changed

# LCW - MI-14 LCW and Fluorinert lines

Extraction Stub Construction, Drawing Reference: AECOM S-EE-102

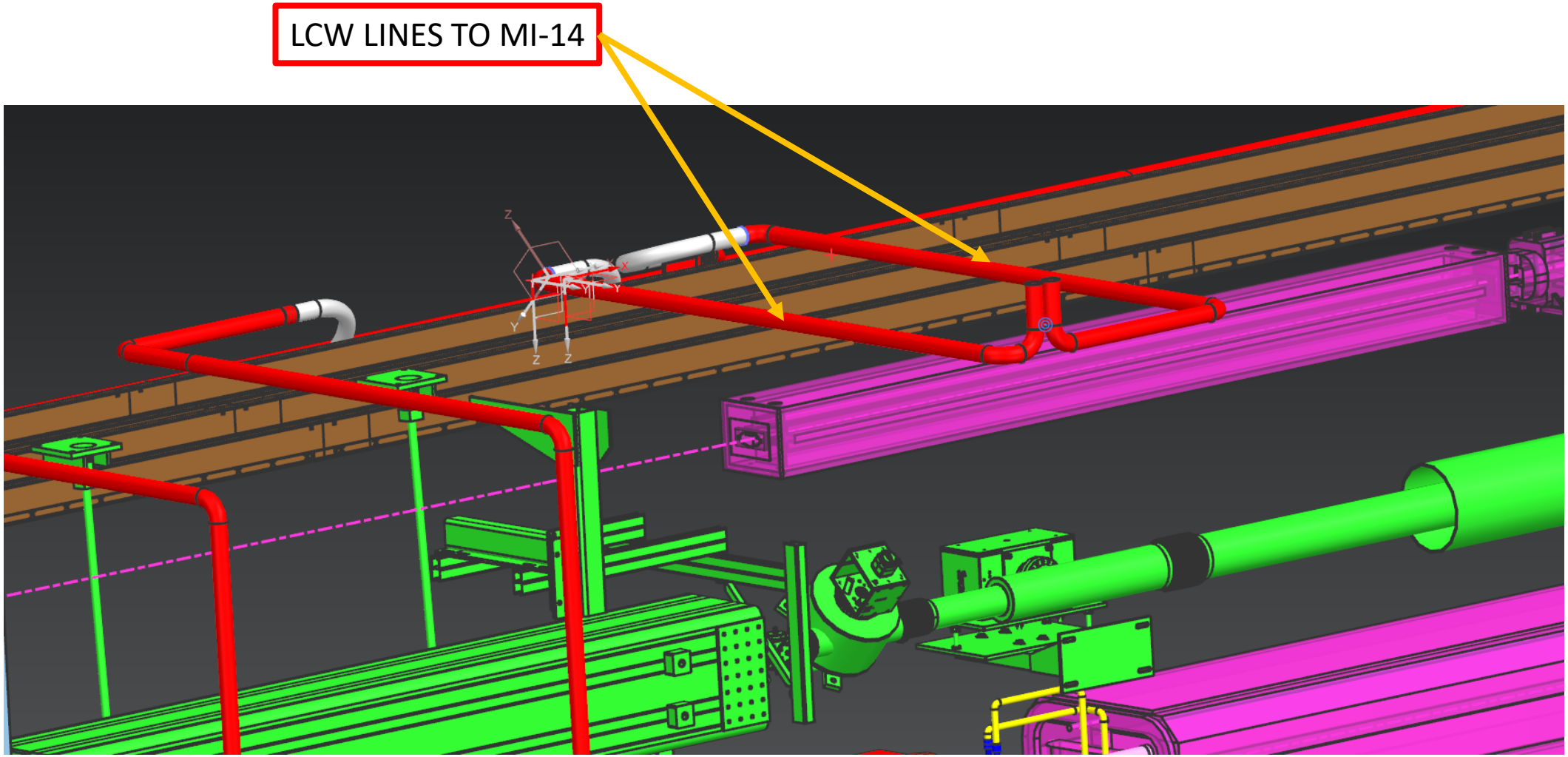


# LCW - MI-14 LCW and Fluorinert lines
# Gerardi Boxes Outside of MI-14

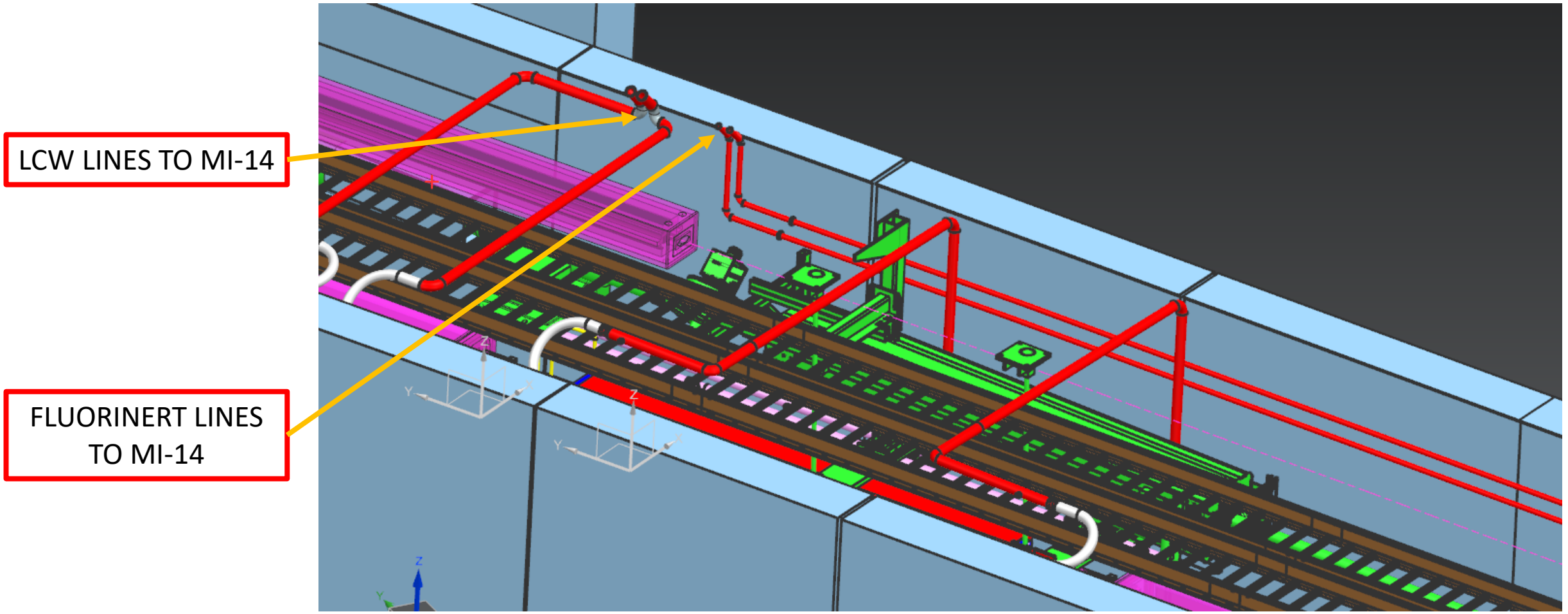
# LCW - MI-14 LCW and Fluorinert lines
# Current Lines at Penetrations in Overhead at DS End of Q-105

# LCW - MI-14 LCW and Fluorinert lines
# Current Lines at Penetrations in Overhead at DS End of Q-105

# LCW - MI-14 LCW and Fluorinert lines
# Added Extensions to Aisle Side



# LCW - MI-14 LCW and Fluorinert lines
# Added Extensions to Aisle Side

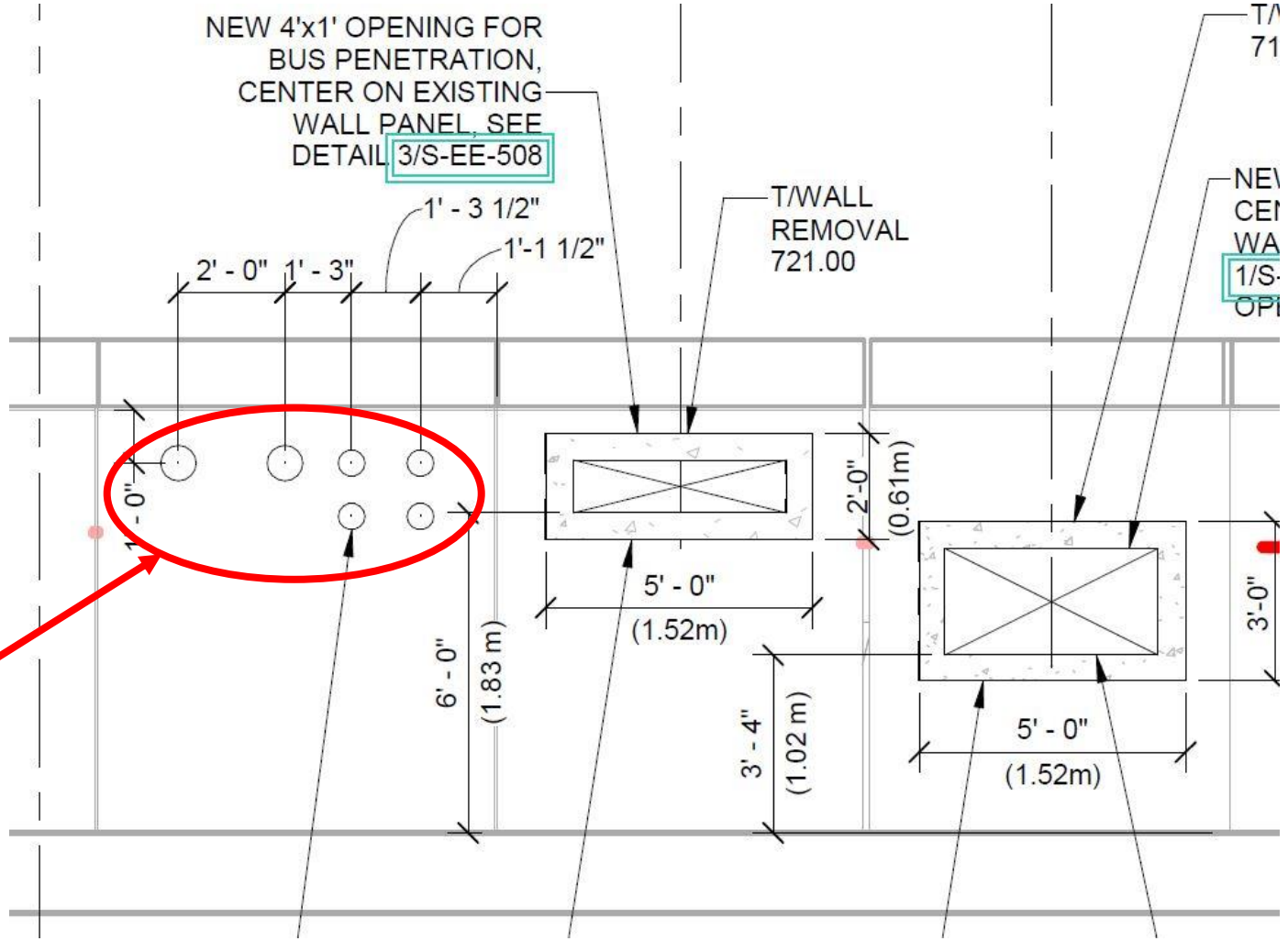


# LCW - LBNF PB Fill Line

- Primary Beamline LCW requires a fill source line from global MI LCW
- Located downstream of D-106-2
- Penetration area is loosely defined in AECOM drawings S-EE-102 and S-EE-104
- Fill line to be 2” Sch 10 SS, allows approx. 80 gpm max fill rate
- Fill line flow is intermittent use, during system fill / make-up only
- LCW line will require aisle cross-over path similar to manifolds
- Line is to have isolation valves at each end, w/ remote actuator on one side TBD

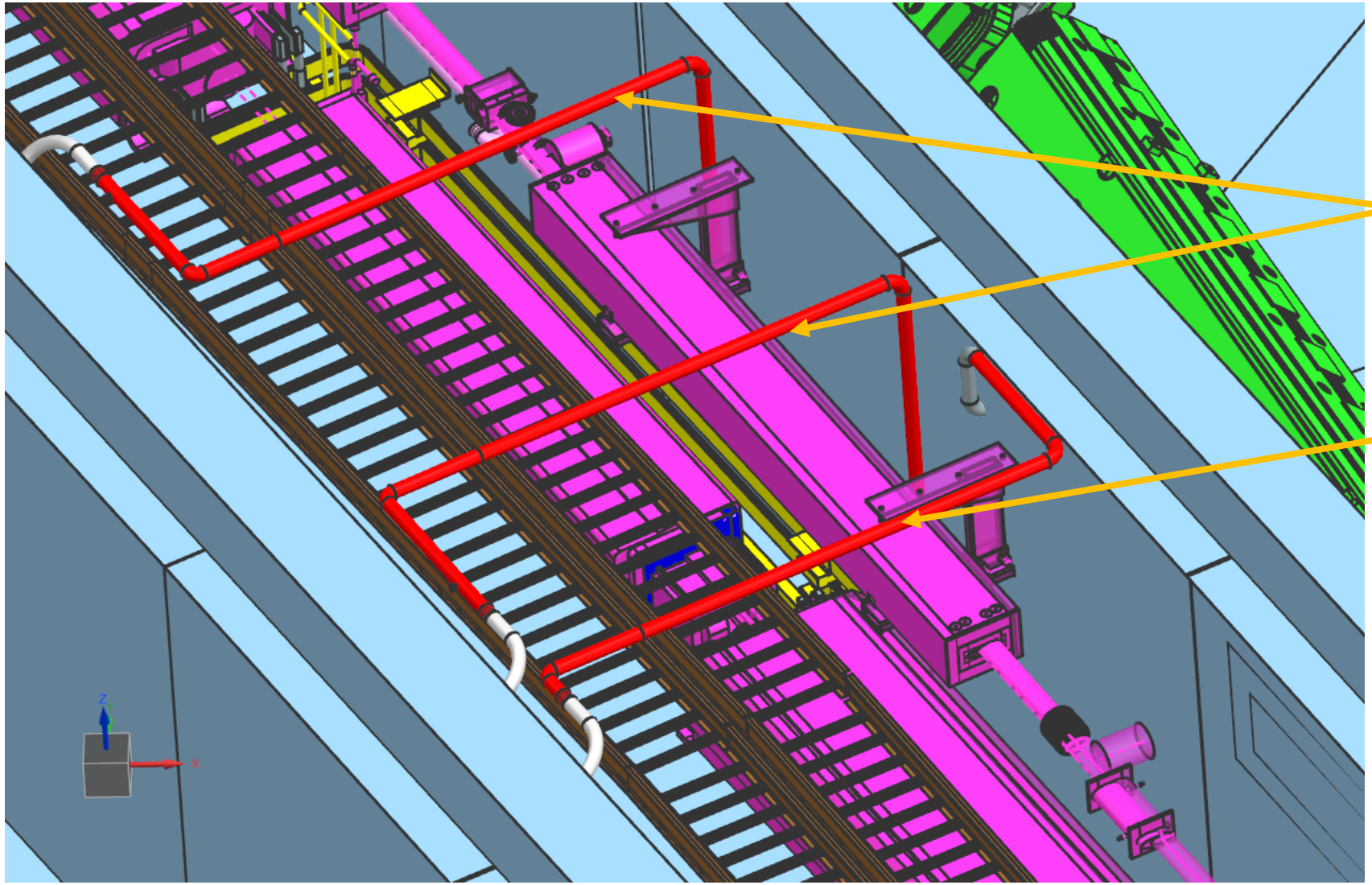
# LCW - LBNF PB Fill Line

Drawing Reference:
AECOM S-EE-104




Which penetration to use is undeclared at this time

# LCW - LBNF PB Fill Line



# Fluorinert Piping - MI-10 to Q100
# Adapt existing piping

- 131133.0202.A6400 Design/Adapt Fluorinert Piping, MI-10 to Q100
- The LBNF kicker needs reconfigured lines in the tunnel, coming from MI-10, in place of the MI injection kicker
- Fluorinert work for MI-10 needs to be combined into this WBS
- This has not been investigated sufficiently, and not included in the work presented here
- Needs further design work

# Bus - General

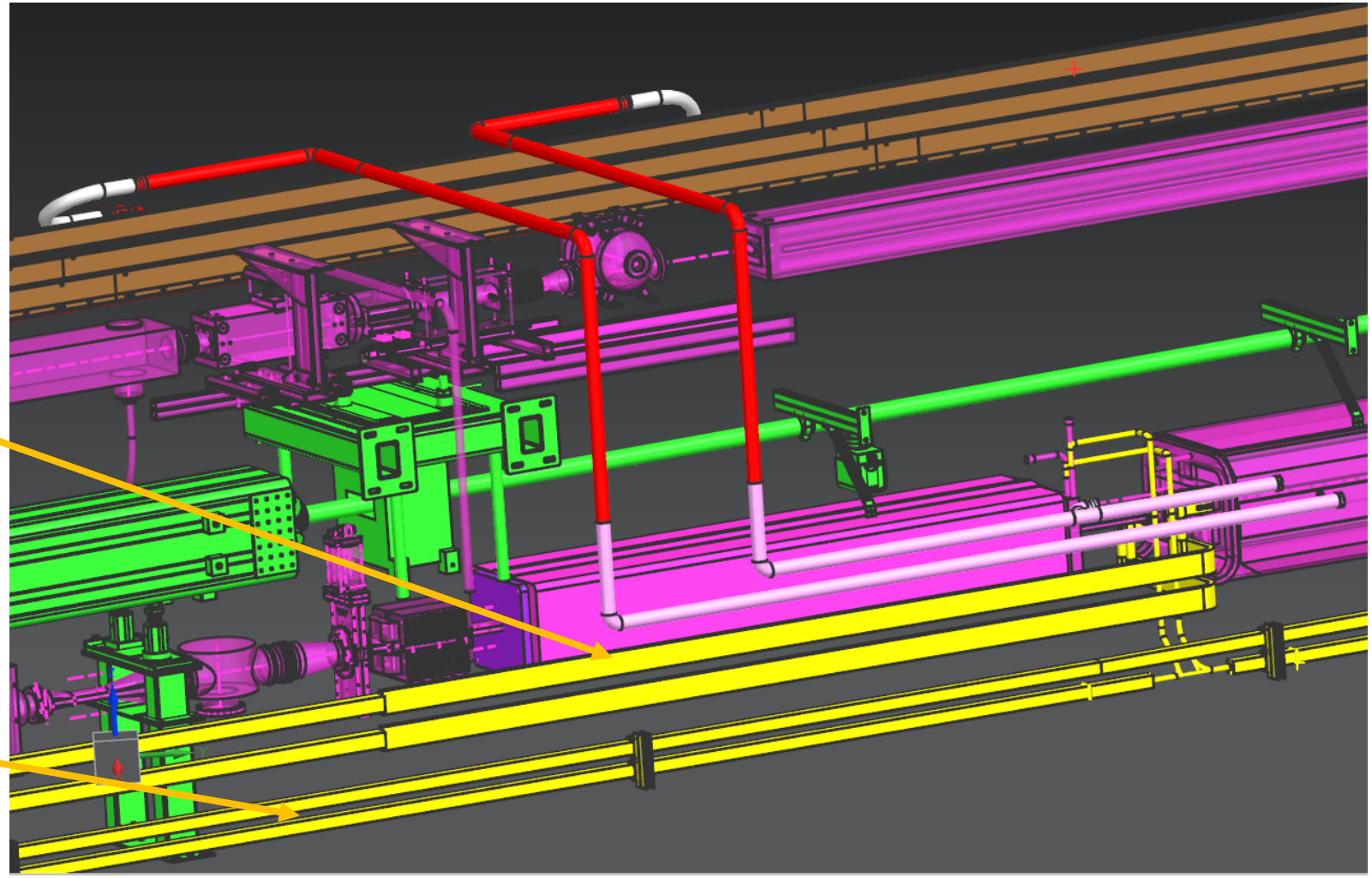
- Includes both Dipole and Quad Bus
- Dipole Bus looks to require simple removal and reinstallation
- Quad bus will require significant effort, and relocation

# Bus - General
# Current Arrangement Upstream at Q-103 Alcove

# Bus - General

DIPOLE BUS RETURNS
TO CURRENT POSITIONS

QUADRUPOLE BUS
MOVED TO LOWER
ON OUTSIDE WALL

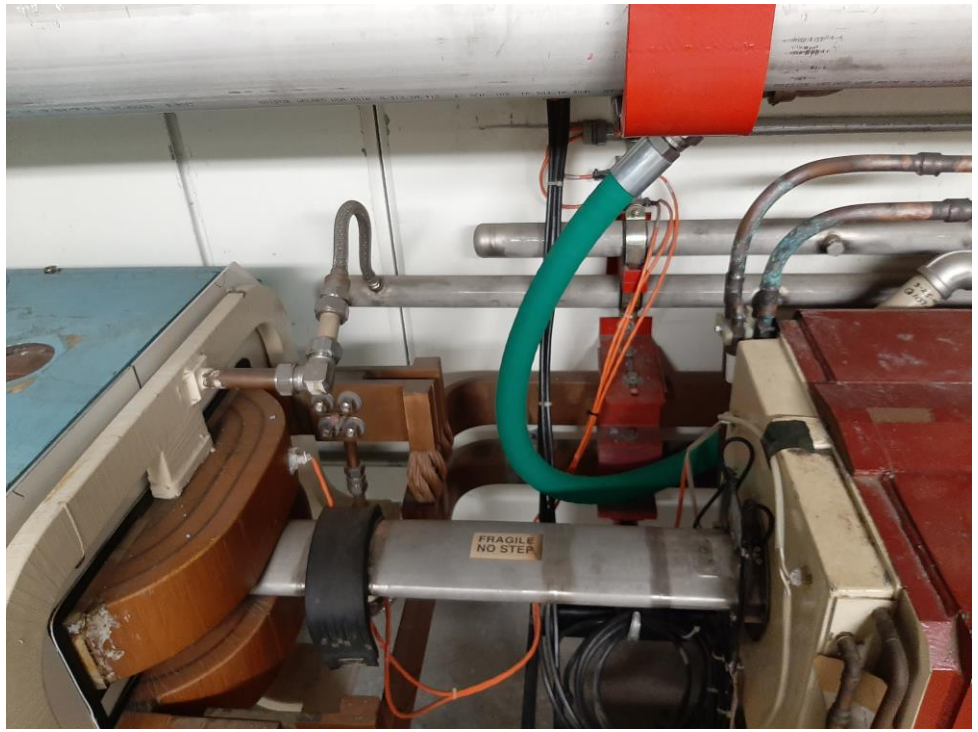


# Dipole Bus

- At each quad magnet, 1” x 4” bus pair behind quads
- Each has bus flags and SS flex hoses to each dipole
- Require temporary removal and storage
- To be reinstalled in same configuration
- Minor alterations may be necessary, unknown at this time
- Upstream 2-5/8” bus run from MI-10 does not require modification

# Dipole Bus

CURRENT CONFIGURATION: Dipole Bus as 1” x 4” behind Quadrupoles, gets removed for construction and replaced into same positions

# Quadrupole Bus

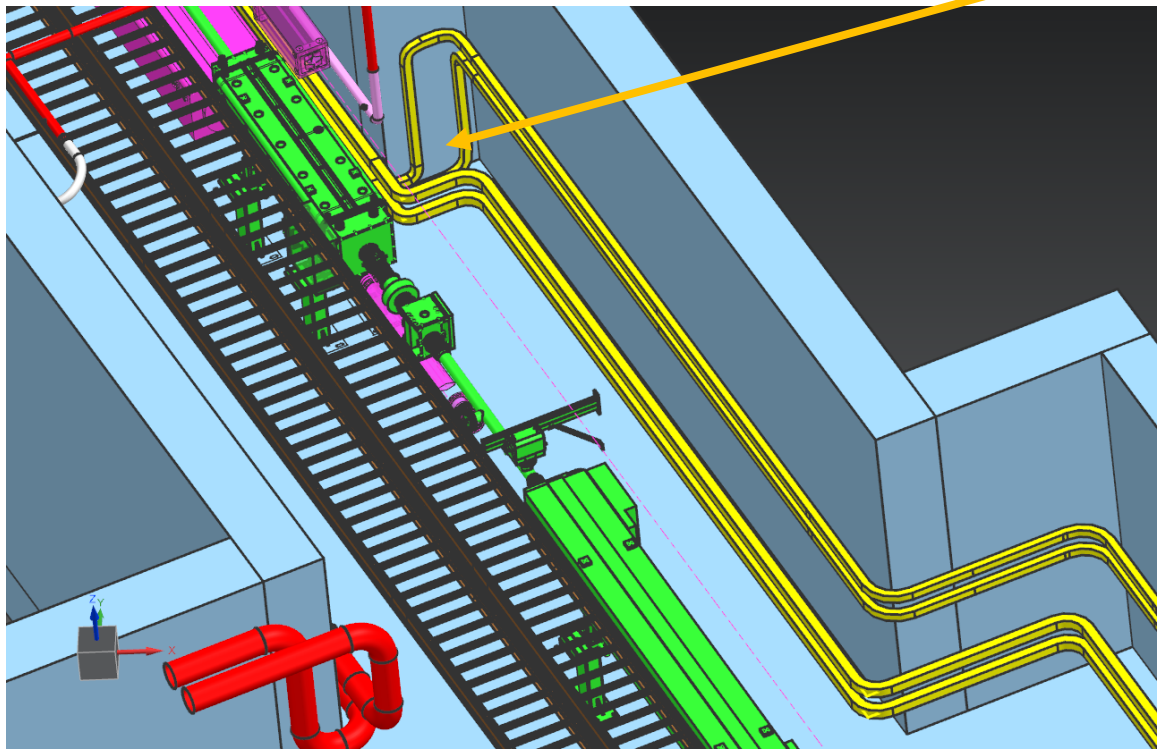
- Mainly 2-1/8” diam bus currently mounted under LCW headers
- Require temporary removal and storage
- To be replaced in modified configuration
- Remains on magnet side wall
- Lowered on wall to just above enclosure floor and ground cable
- New 7/8” bus runs from 2-1/8” quad bus to quadrupole connections
- Any need for replacement bus stock material can use TeV 2” square bus
  - Mainly at Q-103 and Q-108 transitions
- Quad bus expansion joints need studied for best placement

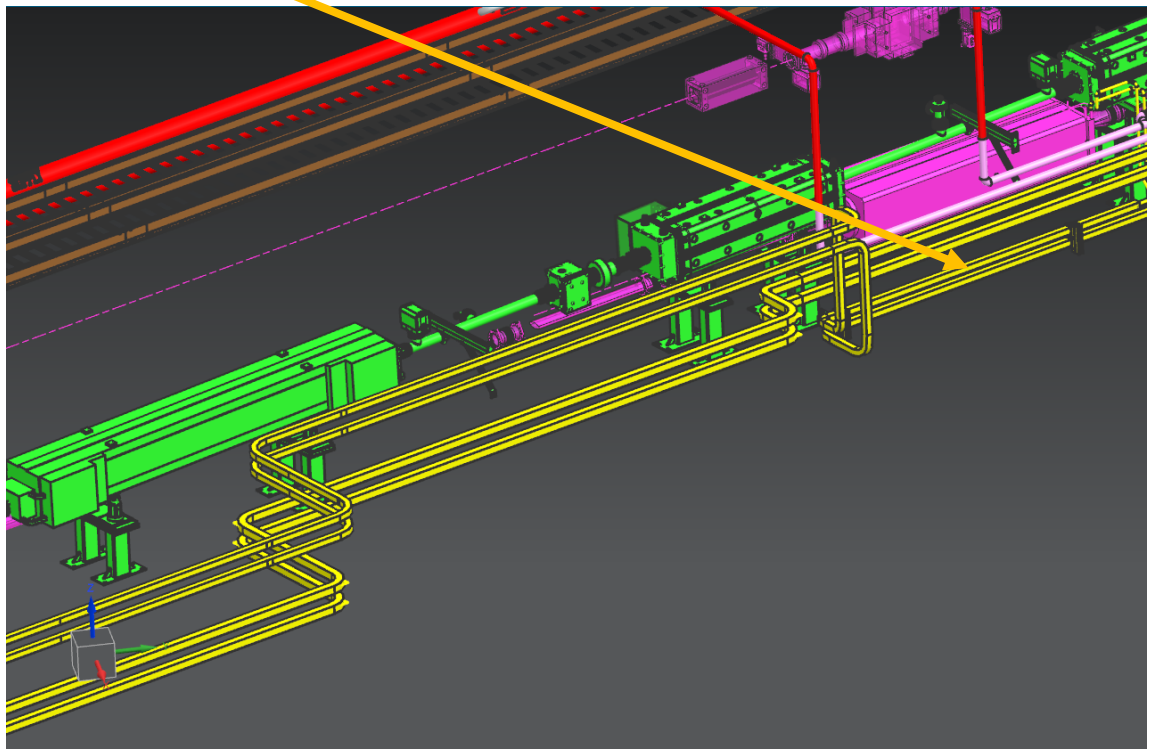
# Quadrupole Bus

CURRENT CONFIGURATION: 2-1/8” Bus located behind LCW headers, 7/8” Bus connects to quads

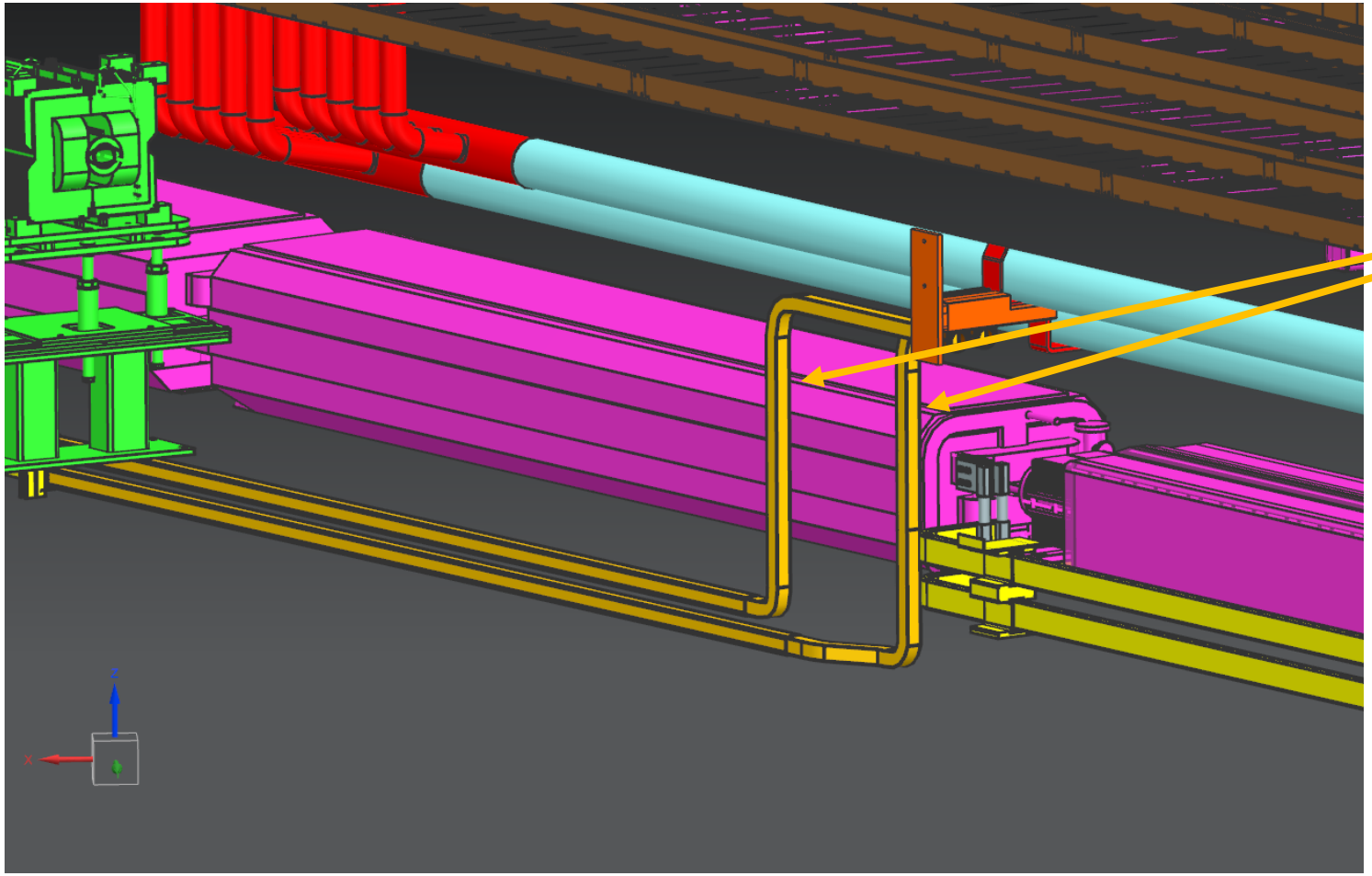
# Quadrupole Bus
# 2-1/8” Bus Runs - Downstream

QUAD BUS MOVES TO LOW ON THE OUTER WALL,
JUST ABOVE GROUNDING CABLE
SHOWN AT Q-103





# Quadrupole Bus
# 2-1/8” Bus Runs - Upstream



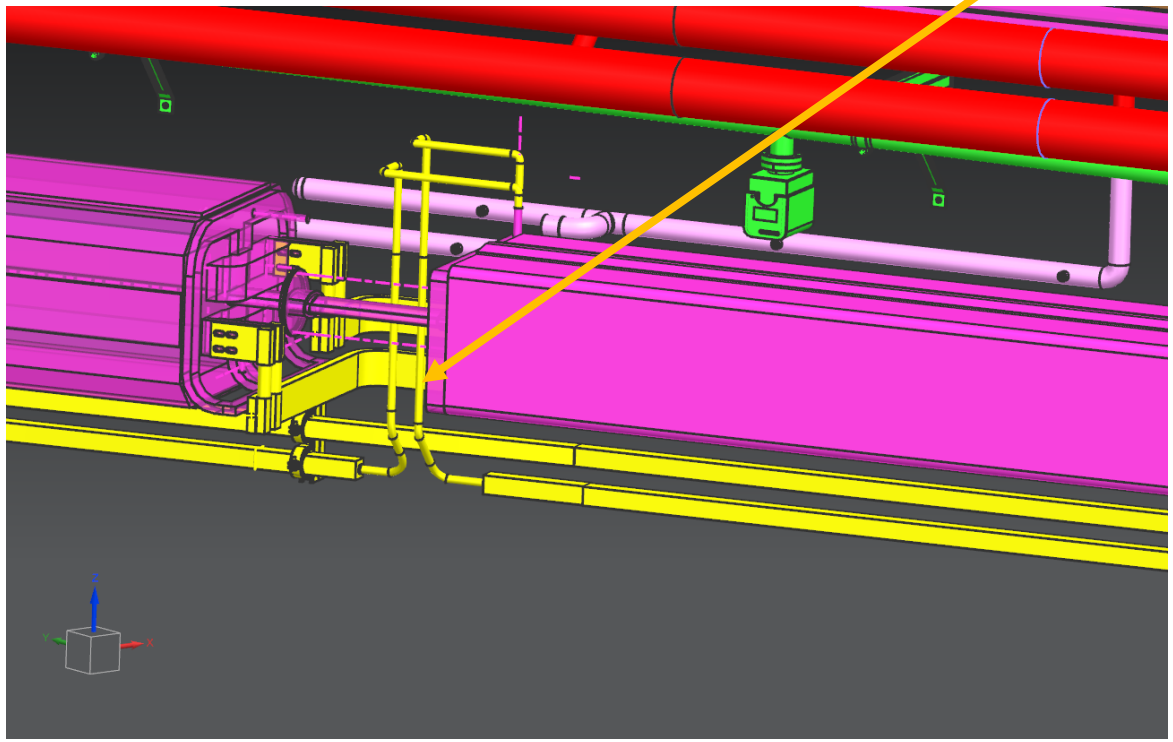
QUAD BUS RETURNS TO ORIGINAL POSITION BEHIND LCW HEADERS, SHOWN AT Q-107

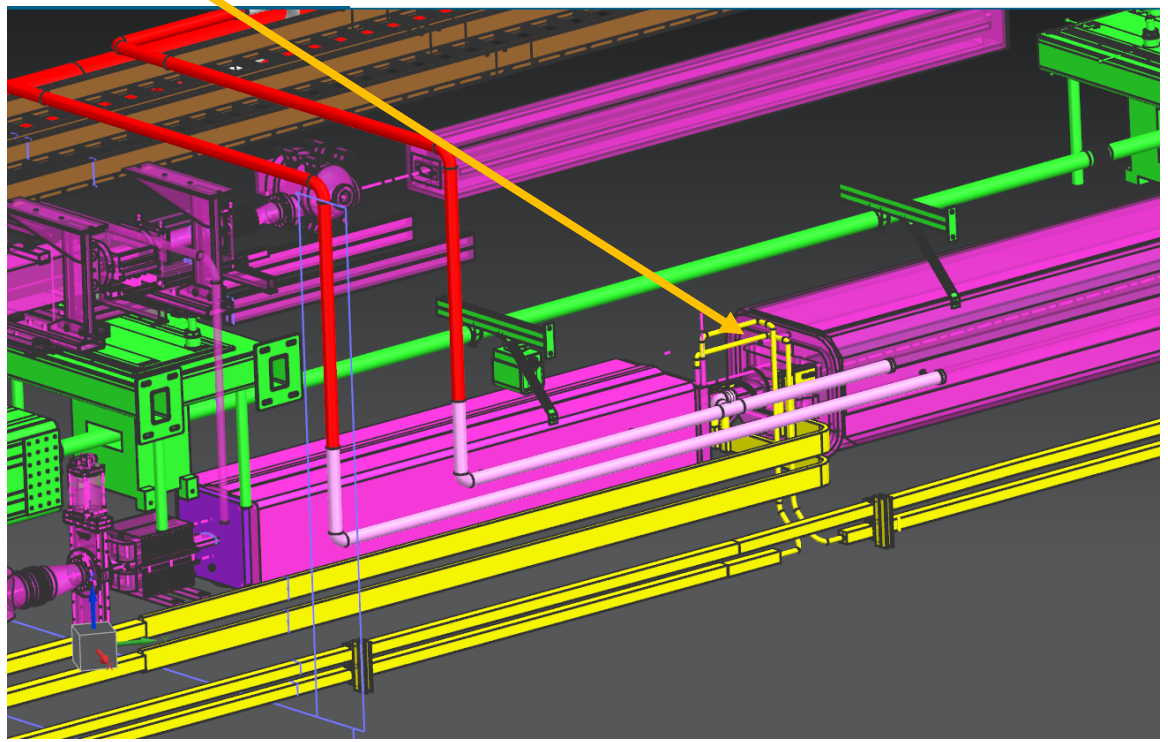
# Quadrupole Bus
# 7/8” Quad Connections


CONNECTIONS FROM QUAD BUS TO MANIFOLDS AND MAGNETS WILL MOVE WITH RELOCATED BUS DOWN TO NEW LOCATIONS

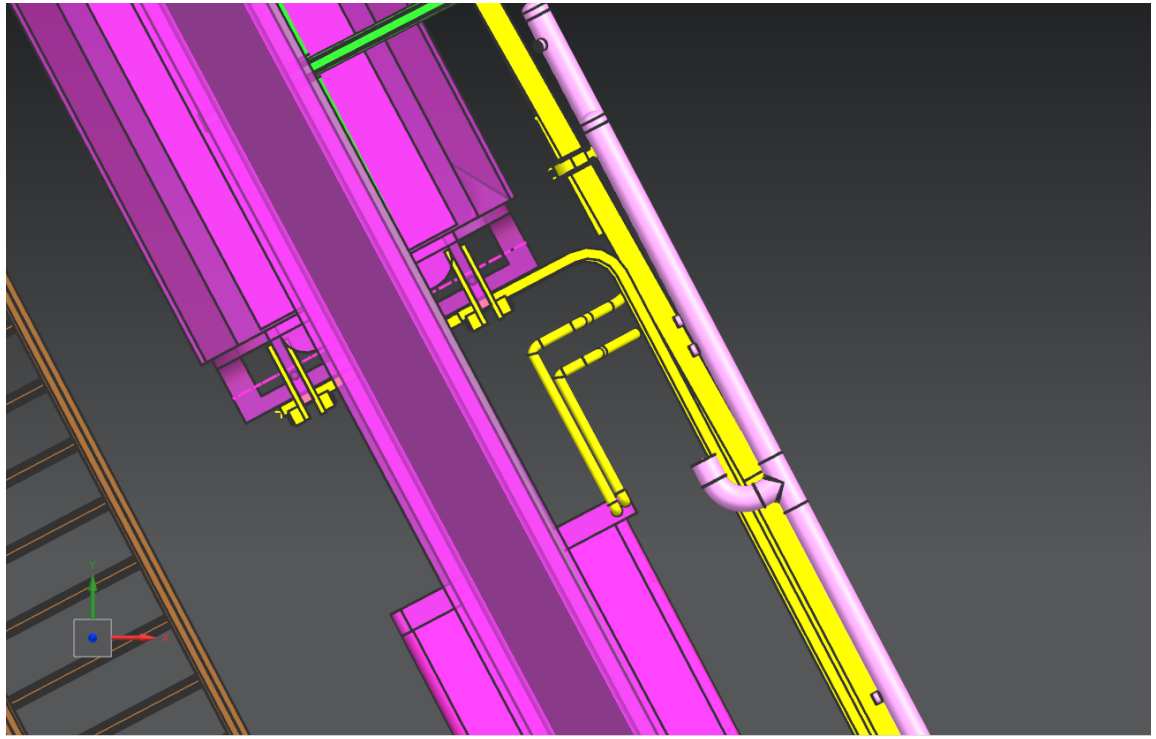
# Quadrupole Bus
# 7/8” Quad Connections

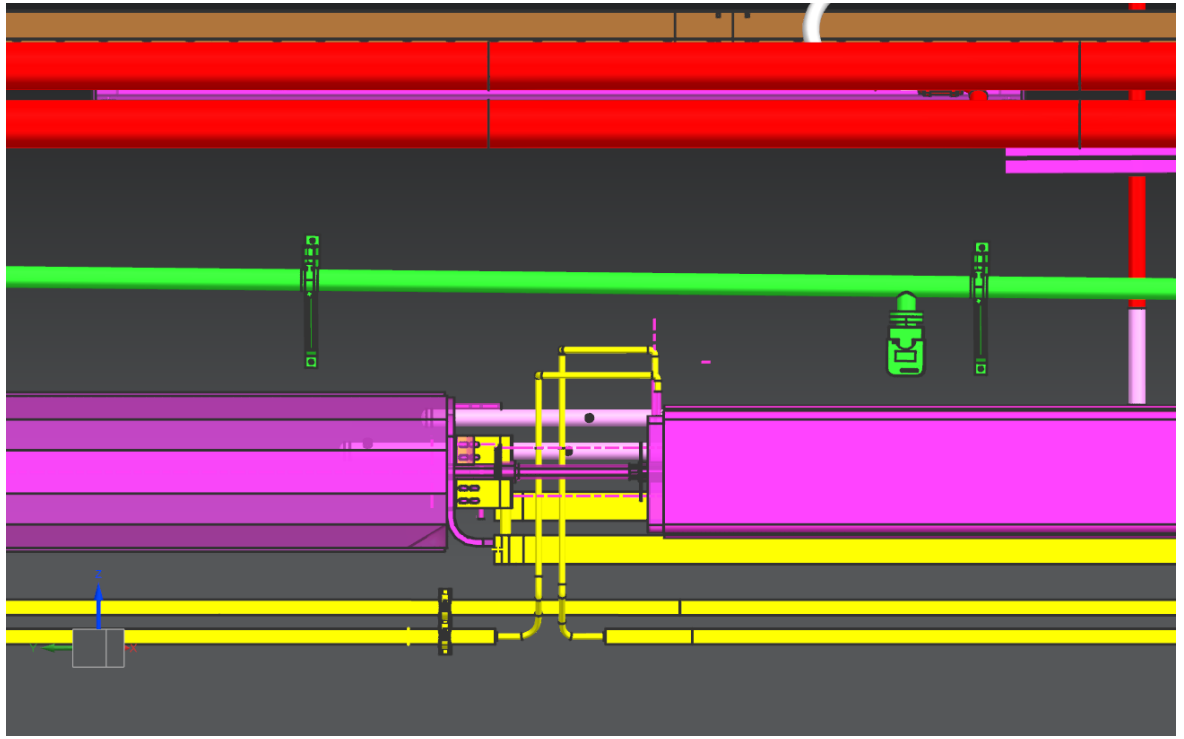
7/8” QUAD BUS CONNECTIONS IN NEW LOCATION,
“CANDY CANE” CONNECTIONS BEHIND QUAD GIRDERS





# Quadrupole Bus
# 7/8” Quad Connections





# Quadrupole Bus Expansion Joints

Expansion joint arrangement and locations need studied

# Enclosure Utilities

- Outer “Magnet” wall will require relocation of grounding cable as low as possible to allow for quad bus to be installed below other wall-mounted features
- Inner “Aisle” wall will require relocation of some lighting and conduits to allow for relocation of the LCW headers
- May also require some relocation of loudspeakers etc.
- Overhead cable trays will require temporary lowering for the installation of crossover piping
- Transition range for lowering, up to 2 quad cells both US and DS of affected area

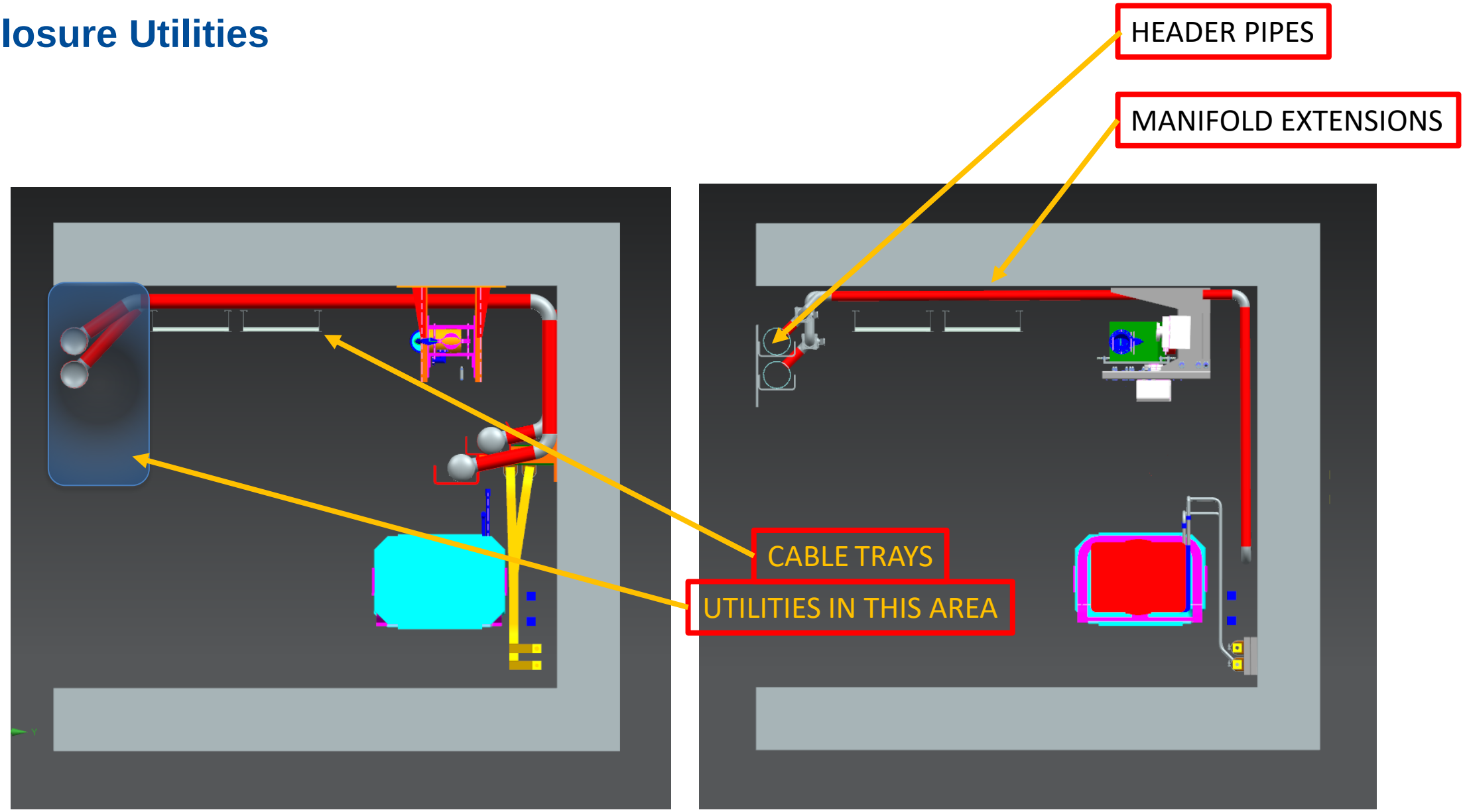
# Enclosure Utilities

CABLE TRAYS OVERHEAD

ELECTRICAL CONDUIT

ENCLOSURE LIGHTING

# Enclosure Utilities



CHARGE QUESTION X

# Cost & Schedule

- Both Labor and Cost estimates are entirely new
  - From the ground-up
  - Independent of former estimates
  - As such, they do not meet the current documentation requirements, and will need to be reformatted to agree with current protocol and formatting

# Cost
# Materials

| ACTIVITY | COST |
|---|---|
| Aisle cross-over extensions | 2885.94 |
| Component taps, to mfld's or header | 2933.64 |
| Pipe organ Crossover at Q-107 | 7758.40 |
| 6" Header, US End Mods | 1039.34 |
| Hardware | 17245.00 |
| Buswork | 8675.00 |
| | **40537.32** |
| | |
| 6" Header, full replacement, risk | 25076.94 |

# Schedule
## Labor Hours - Fermilab

| LABOR TYPE | HOURS |
|---|---|
| Bead Crew | 56 |
| Drafter/Designer | 608 |
| Elec. Eng'r | 64 |
| Elec. Tech | 32 |
| Fluids Eng'r | 428 |
| Fluids Tech | 856 |
| Machine Eng/Phys | 60 |
| Magnet Eng'r | 64 |
| Rad Tech | 24 |
| **FTE, ttl** | **2192** |

# Schedule
# Labor Hours - Trades

| TRADE | SOLO CREW | COMBINED CREW - 3 | TOTAL HOURS |
|---|---|---|---|
| Pipfitter | 232 - 1 | 240 | 472 |
| Electrician | 240 - 2 | 440 | 680 |

NOTES ON TRADES:

1 – PIPEFITTER SOLO CREW is primarily pipe work

2 – ELECTRICIAN SOLO CREW is estimate for Utilities work, refer to C. Gatusso work for more accurate values

3 – COMBINED CREW is for the mixed crew for Buswork

4 – 3/5 of labor is for the bus work alone

# Schedule
# Labor Hours – Task Duration

Duration Time expressed as FTE days

| | |
|---|---|
| **FINAL DESIGN** | **129** |
| Final Design Engineering | 75 |
| Final Design Review | 21 |
| Installation | 20 |
| Installation Document Review & As-Builts | 13 |
| **PIPE & BUS REMOVAL** | **36** |
| Global LCW Pipe | 10 |
| Quadrupole Bus | 7 |
| Dipole Bus | 5 |
| MI-14 LCW & Fluorinert Pipe | 14 |
| **ENCLOSURE UTILITIES PREP FOR TO REINSTALL** | **11** |
| **PIPE & BUS INSTALLATION** | **79** |
| Global LCW Pipe | 38 |
| MI-14 Fluorinert & LCW Pipe | 20 |
| Primary Beamline LCW Fill Line Pipe | 3 |
| Quadrupole Bus | 12 |
| Dipole Bus | 6 |
| **TOTAL DURATION, Days** | **255** |

CHARGE QUESTION X

# Risks and Issues

- First risk is that of every retrofit: when we get to performing the tasks, there may be unforeseen issues with what is planned vs. what can be done
- Labor force handling the bus may need to be mixed trades composite crew, requiring local union buy-in
- 6” headers may require all new pipe, rather than rework of current pipe, est. up to $25k additional materials, 80 Pipefitter hours
- Needing additional bus not on hand, est. $7 - $10 per pound, 7 to 15 pound/foot
- MI-14 penetration piping may require extensive rework, depending on planning and design ahead of time
- Refilling the LCW into headers and components before the system is ready to come back on line would encourage a repeat of the Microbe Influence Corrosion (MIC) issues of the MI LCW start-up
- Preliminary Design contingency of 40% is appropriate

## Risks and Issues

# WARNING

ABSOLUTELY NO REFILL OF **ANY** LCW UNTIL SYSTEM IS READY TO BE FILLED, TESTED, AND OPERATIONAL WITH FILTRATION LOOP ON LINE 24-7 !!!

This is non-negotiable.

CHARGE QUESTION X

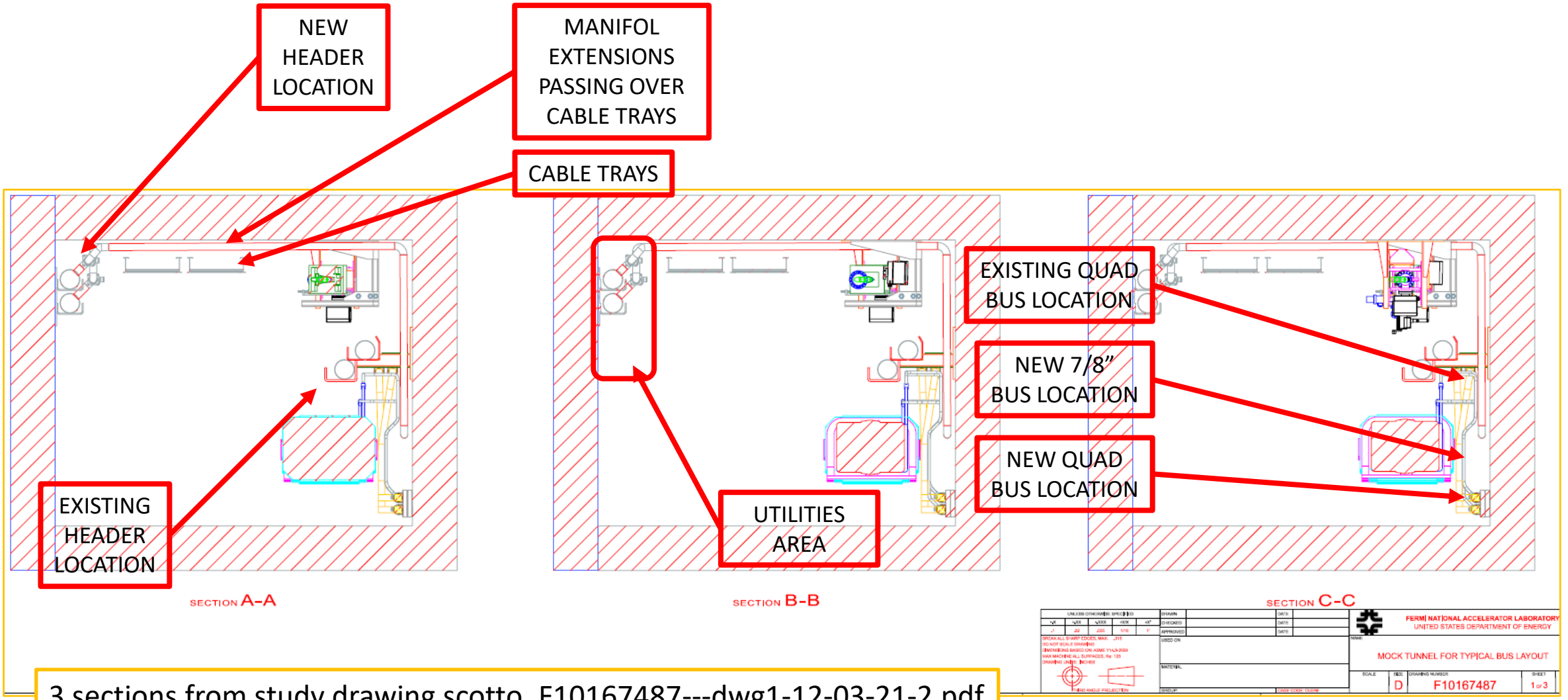
# Further Work To be Done

- Format and upload documentation into proper LBNF project protocol
- Combine Fluorinert work for MI-10 and MI-14 into this WBS
- Receive buy-in approval from other vested parties
- Initiate Final Design process
- The following Standards and Codes shall be followed:
  - Fermilab Engineering Manual
  - ASME B31.3 - Process Piping
  - ASME BPVC.VIII.1 - Rules for Construction of Pressure Vessels
  - FESHM 5031.1 - Piping Systems
  - FESHM 5100 - Structural Safety
  - FRCM Chapter 4 - Radioactive Materials
  - FRCM Chapter 11 - Environmental Radiation Monitoring and Control

# Summary

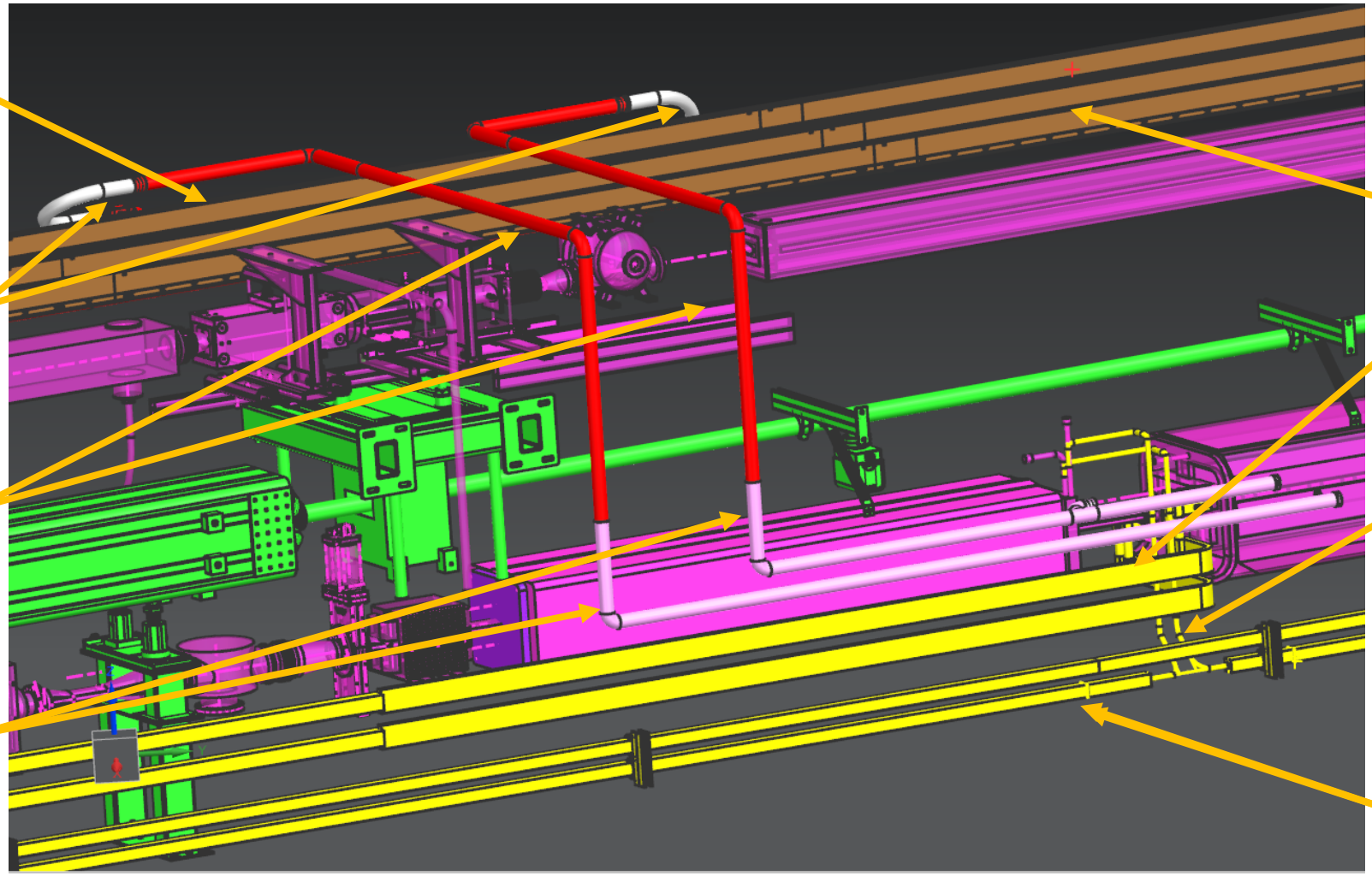
- The installation of the LBNF Extraction Line in the Q-100 region requires relocation of main LCW headers and quadrupole bus, as well as numerous small modifications
- Possible solutions have been discussed with many concerned parties over the last number of years
- The paths for relocation of the piping and buswork have been well studied in the current enclosure, as well as with a CAD model
- A reasonable plan for the retrofit work is presented herein
- Cost and schedule have been re-evaluated from the ground up

# Summary




3 sections from study drawing scotto_F10167487---dwg1-12-03-21-2.pdf

# Summary
## Typical Quad Cell Layout, Viewed From Behind Magnet Towards Aisle



# References

- Review Charge and Agenda: LBNF DocDB  as DUNE-doc-27115-v1
  https://docs.dunescience.org/cgi-bin/sso/ShowDocument?docid=27115
- F10178761, LBNF FULL MODEL FOR LCW AND BUS REWORK
- scotto_F10167487---dwg1-12-03-21-2.pdf
- F00305689-G, Main Injector Hydraulic LCW and Bus Flow Schematic MI-10 Ser Bldg – Q108 to Q639 (Originally 9512.000-MF-305689) (updated to reflect current status with LBNF upgrades) (P&ID)
- F10127805 thru 810, LBNF Primary Beam Line LCW and Bus Flow Schematic (proposed plan at this time) (P&ID)
- ME-463356, MAIN INJECTOR/RECYCLER Q105 PENETRATION FLUORINERT LAYOUT
- ME-463455, MAIN INJECTOR/RECYCLER MI-14 SERVICE BUILDING LCW AND FLUORINERT INSTALLATION
- ME-463464, MAIN INJECTOR/RECYCLER Q104 KICKE`R COOLING MANIFOLD INSTALLATION
- PBE Extraction LCW & Bus - Materials Estimate - PDR.xlsx
- PBE Extraction LCW & Bus - Labor Estimate - PDR.xlsx

Return to title slide