Tritium Target in Hall C

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Tritium Target in Hall C

- Hall A Design/Operational Parameters
- Hall A Target Performance
  - Performance as a system
    - Containment/Confinement
    - Operations
  - Target/beam performance
- Safety Issues
  - T2 requirements…Containment/Confinement
  - Unique Hall C Safety Issues
- Summary
  - Folding the Hall A target design into Hall C

Long Long Ago…

How did the T2 Program get it's start?

- Talks began in late 1990s
  - NO WAY Tritium always makes a mess
- First formal proposal made in 2006 (MARATHON)
  - Experiment was approved with conditions on the target

"Its All About the Target"

Roy Holt -> Can we use a bit of T2 gas in a safe sealed small volume and perform the experiment?

- YES!
- Concept Review in 2010 → "This could work"
  - Grew to 5 Experiments
- Final Design Review in 2015
- First Beam: December 2017

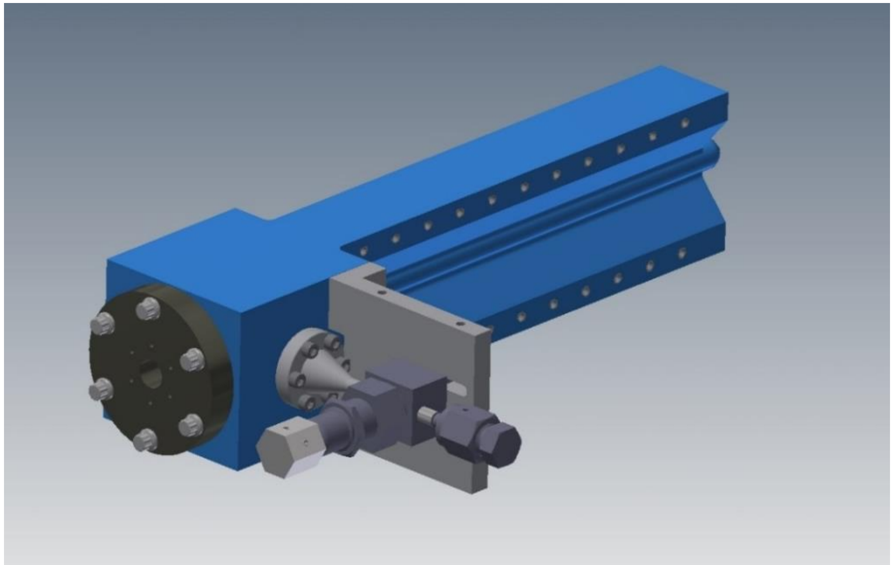
Design Philosophy

- Safety
  - Minimize impact from any release scenario
- Design is not overly complex
- Minimize amount of tritium
- Do not “handle” tritium
- Three layers of containment
  - Operations
  - Installation/removal
  - Transport
- Perform well enough to run physics

Sealed Static Gas Cell

T2 Cell

- Load ~ 1100 Ci of T_2 (0.11 g)
- Fill pressure ~ 200 psi at 295K
- Volume = 33.4 cc
- Walls ~0.5 mm thick
- Ends ~0.25 mm thick



Successful Modular Design:

-Can ship in BTSP – ovoid JLAB "handling" T2

-Store in triple containment

-Install when needed

-Stayed removable covers allowed thin walled cell to meet SRS/safety basis and experimental requirements

Limited current and raster size

$$I_{MAX} = 22.5\mu A$$

2x2 mm raster minimum

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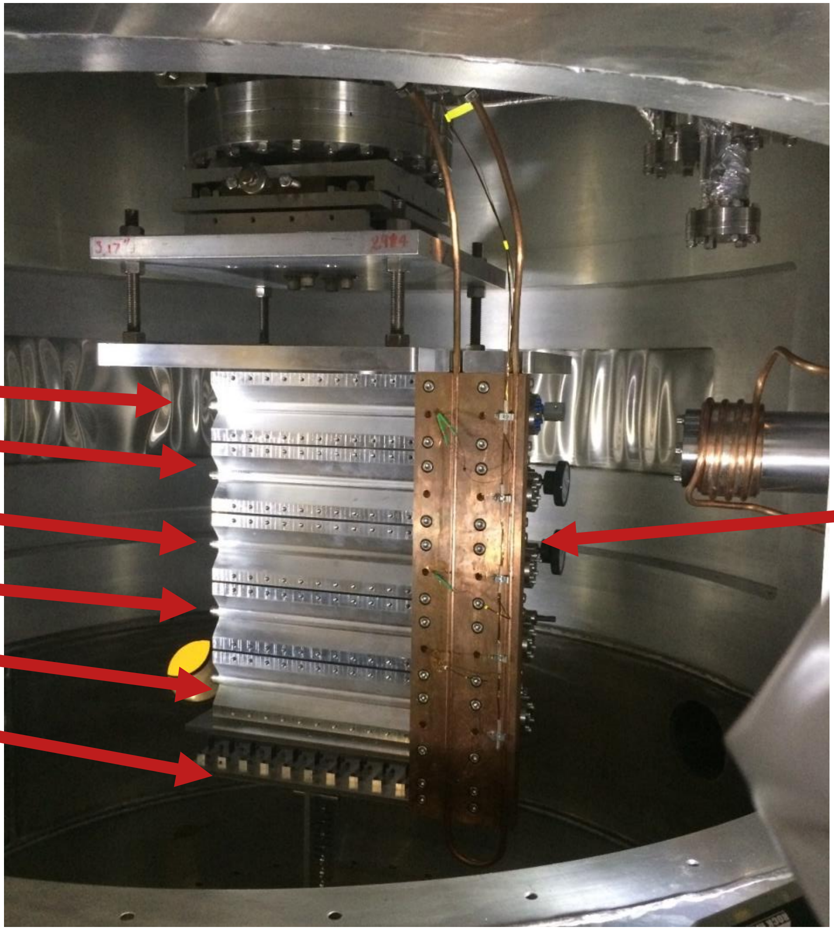
Sealed Gas Cell

Internal Target Assembly



Tritium (T2)
He-3
D2
H2
Empty
Solid Targets

Heat Exchanger

Tritium Gas Targets at Electron Accelerators

Lab	Year	Quantity (kCi)	Thickness (g/cm^2)	Current (μA)	Current x thickness (μA-g/cm^2)
Stanford	1963	25	0.8	0.5	0.4
MIT-Bates	1982	180	0.3	20	6.0
Saskatoon	1985	3	0.02	30	0.6
JLab	2017-2018	1.1	0.072	22.5	1.62

JLAB Target Stands up Well With Other Targets

Tritium Loss from Cell

Tritium(Hydrogen) Permeates Through Cell

- $T_2 \rightarrow T + T$ hops through lattice interstitial sites
- Conservative scaled estimates for unknowns based on H2 data

Gives a loss of T2 as 0.5 Ci/year

$$Q = \frac{\chi C D A}{t}$$

Molar T2 loss

$$C = \frac{C_0 \sqrt{P_{op}}}{\sqrt{P_{atm}}} e^{-\frac{\Delta H}{RT}}$$

Solubility of T2 in 7075

$\chi = molar\ density$
$C_0 = solubility\ of\ T2\ in\ 7075\ at\ STP$
$D = Diffusion\ coef\ for\ T2\ in\ 7075$
$\Delta H = heat\ of\ solution$
$A = surface\ area$
$t = thickness$

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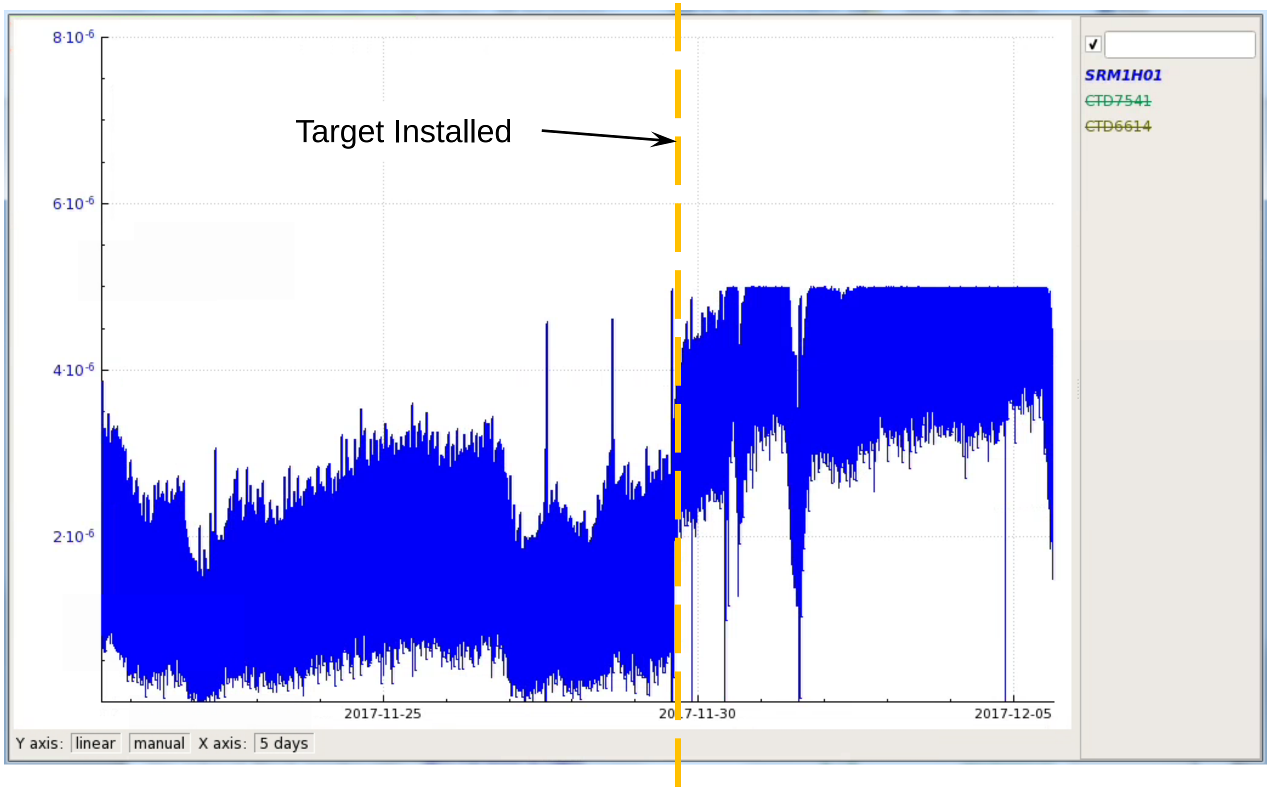
Tritium Loss From Cell

- Stack monitor measured T2 loss
  - Loss above background ~2µµCi/cc
  - ~11 mCi/month or <150 mCi/year which exceeds design estimate

Stack monitor (µµCi/cc-s)



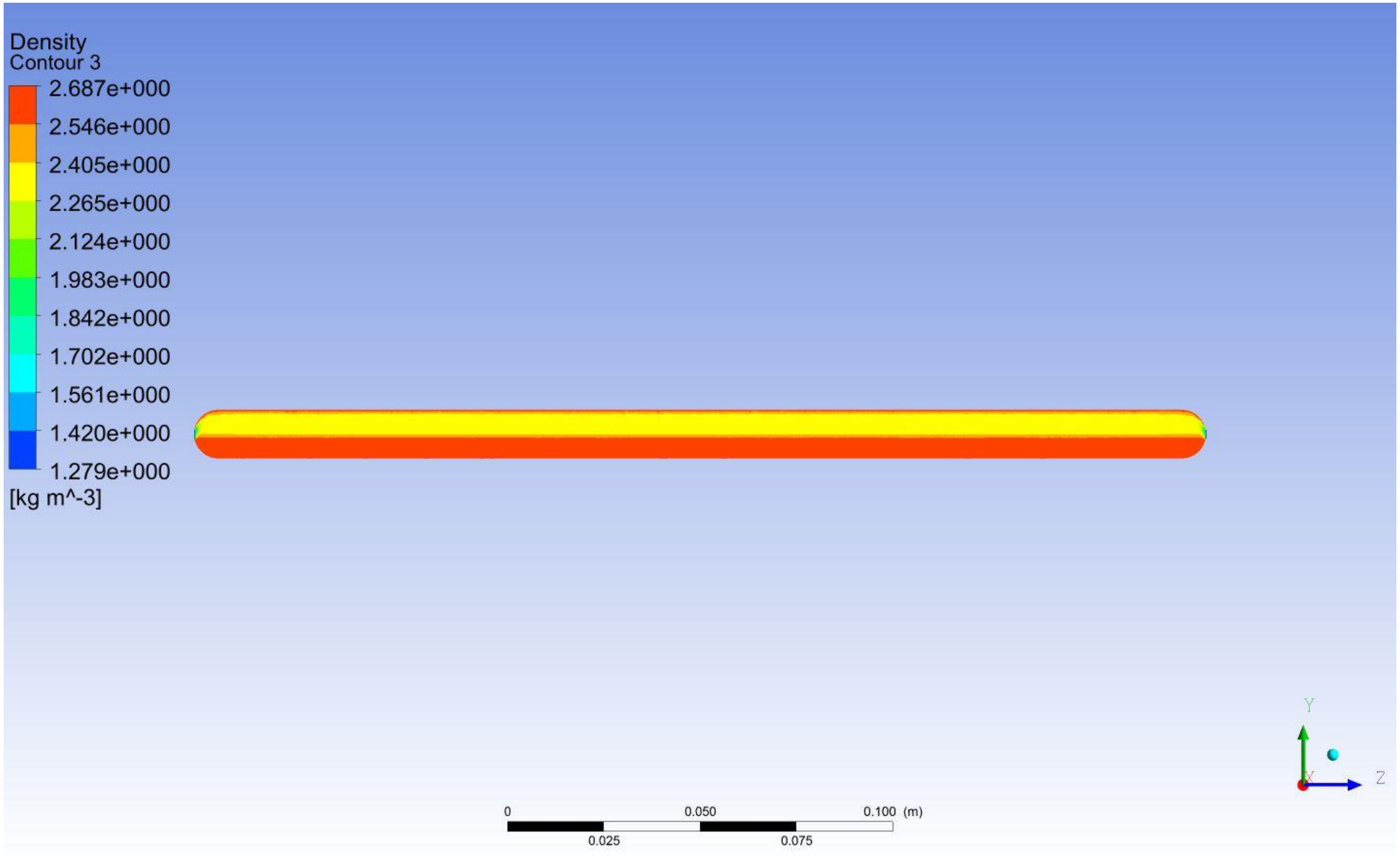
Control System

- Use EPICS (distributed I/O)
  - Temperature/motion/valve control
  - User Interface (UI) through EDM
- FSD on high temperature
  - Uses interlocks from redundant 718s
- UI has integrated alarm handler
- EPICS data logger runs continuously
- Communications failures Alarm as well
- Control system was very similar to the Standard CryoTarget

Target Performance Density Model

- T_2 properties derived from H_2
  - Viscosity, Thermal Conductivity, Heat Capacity, etc.
  - Assumed a Real Gas model
  - Buoyancy, convection on wall included
- Assumed fixed 2.8W from 20 µA and 2x2 mm raster (11 mW/mm linear power density)
  - Did not correct heat load for density
- Averaged ~11% reduction in density along beam path at 20 µA

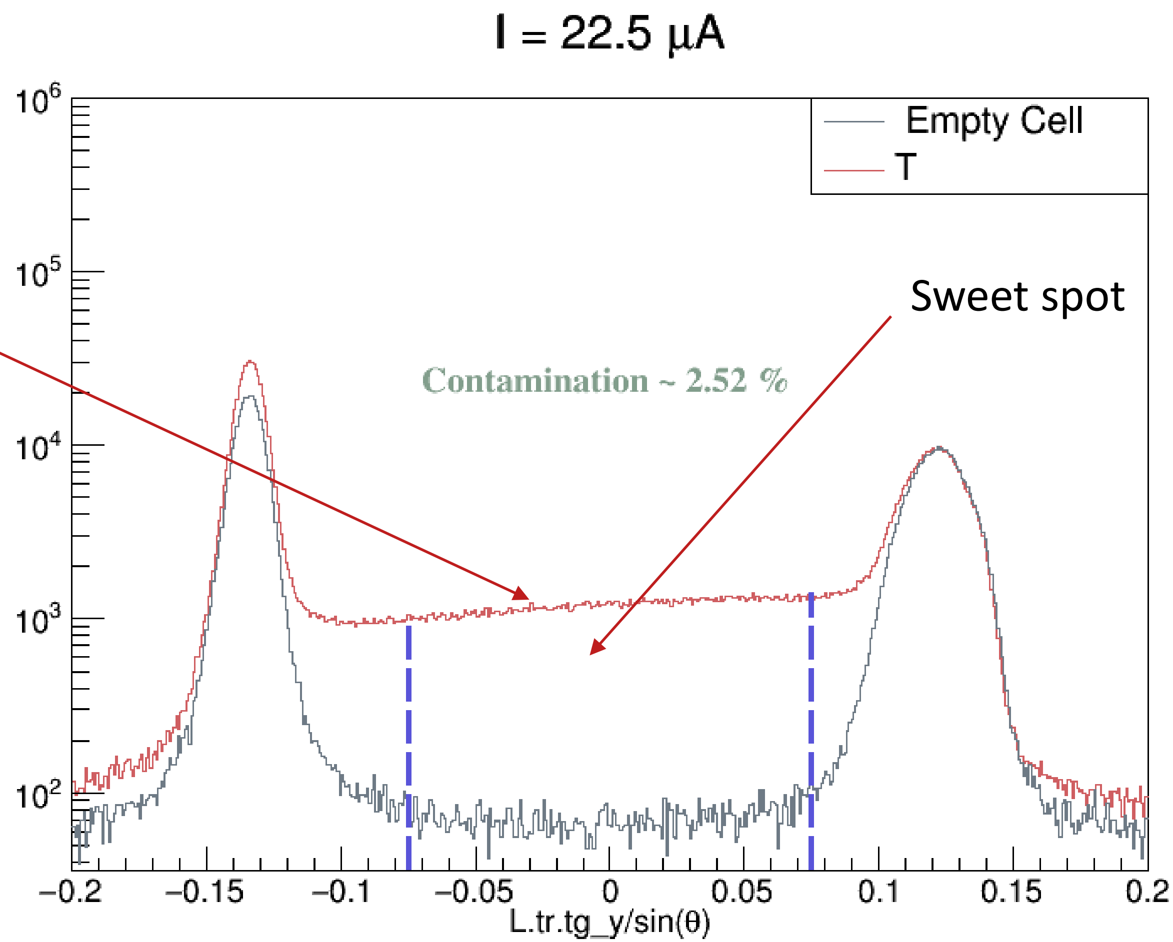
Density Change in Beam



Background from Cell Endcaps

They gave us T2

Sweet spot



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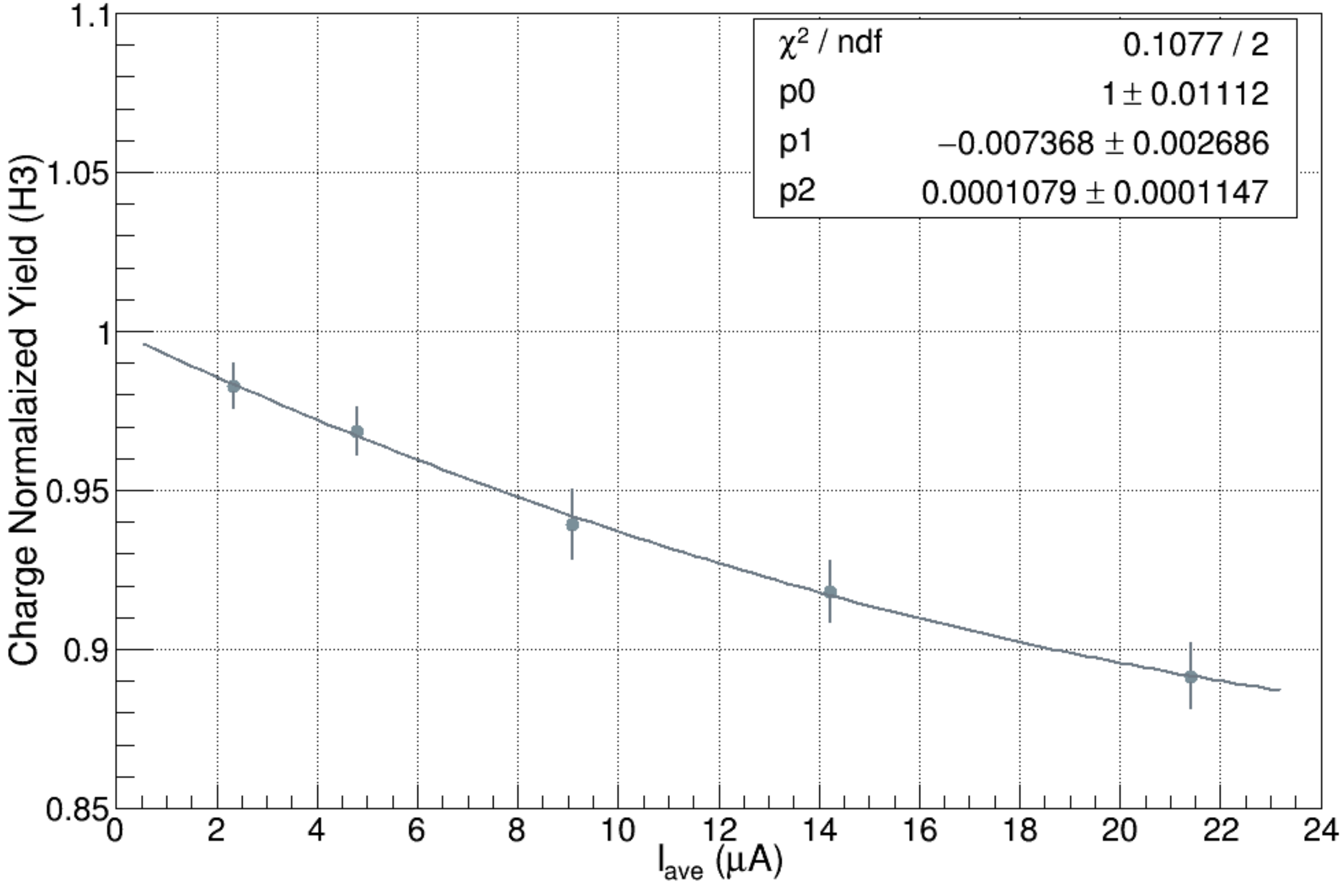
Target Performance Density Reduction



S. Alsalmi: King Saud University

Tritium Target Safety Systems

- Safety of public, personnel and environment is paramount
  - Minimize impact from any release scenario
- Responsible Engineer: Legally responsible for safe design, fabrication, inspection and testing. Ensure all applicable Codes and Standards have been met.
- Three layers of containment/confinement at all times
  - Shipping and handling
  - Loading
  - Installation/removal
  - Storage
- Controls
  - Engineering, Admin, PPE, Avoidance
- During operations the experimental Hall walls became the 3rd layer of confinement.
  - Special exhaust systems were constructed
  - Special Access Controls were implamented
- Custom Storage was developed

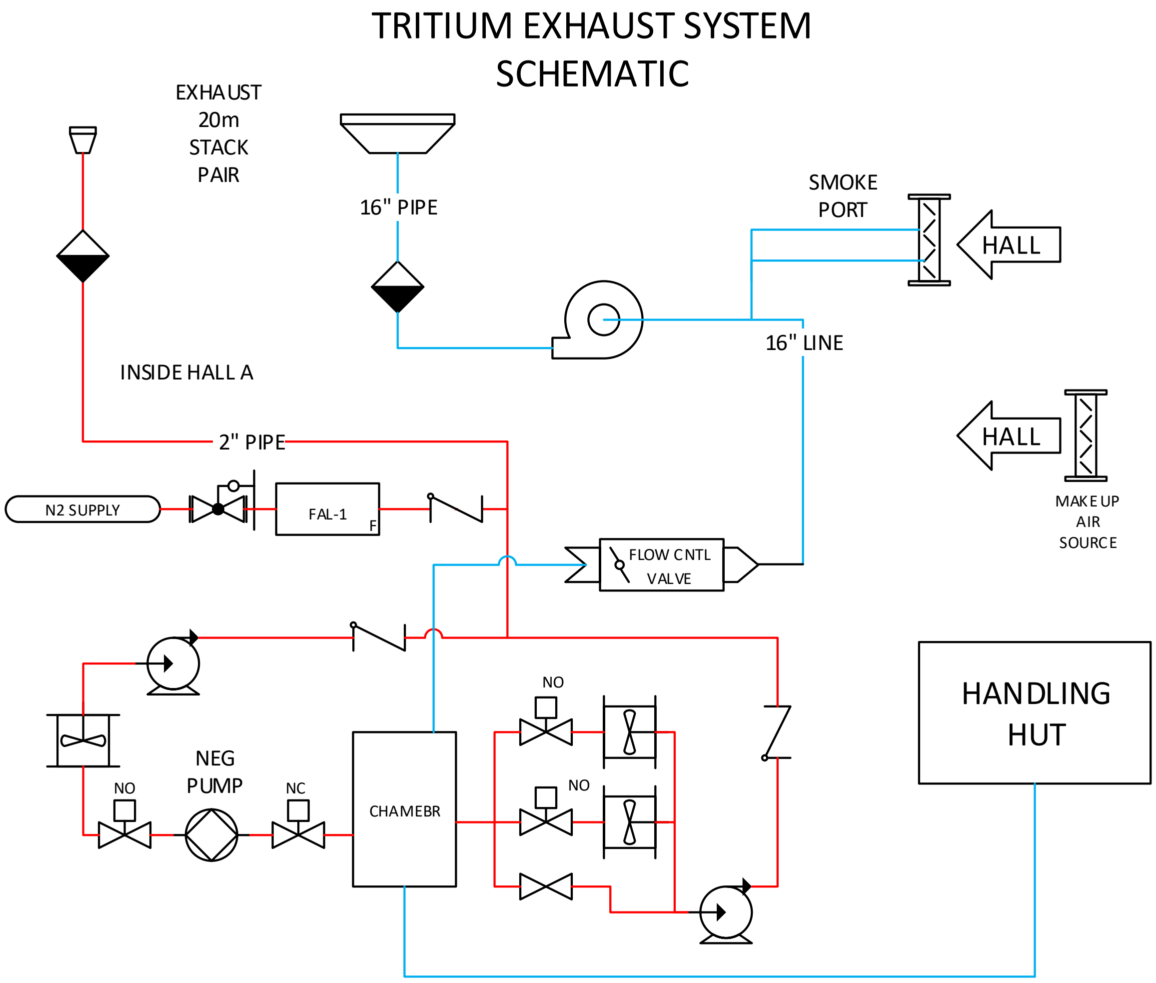
Selected Applicable Codes and Standards

10 CFR 851 (DOE worker safety and health)
10 CFR 71
10 CFR 20
49 CFR 172 and 173 (DOT HAZMAT)
NEPA National Environmental Policy Act
DOE Orders: 460.1, 441.1, 458.1
DOE Office of Science Policies
DOE NNSA Packaging, Shipping, Filling, Handling, Security
DHS/DOE NMCA
SRS safety basis
JLAB pressure safety and RadCon
JLAB ERRs
Codes:

- ASME BPVC VIII D1 and D2 and IX, B31.3, STC-1
- AWS D1.1 and 1.6

Exhaust System

- 24” OD 20m tall Stack
- 12000 cfm blower multispeed
- 2” pump exhaust
  - Run parallel to stack
- Stack must also serve as smoke removal
- Provides controlled release of secondary and tertiary confinement
- Pump exhaust is continuous
- Blower activated:
  - Manual
  - Interlocks



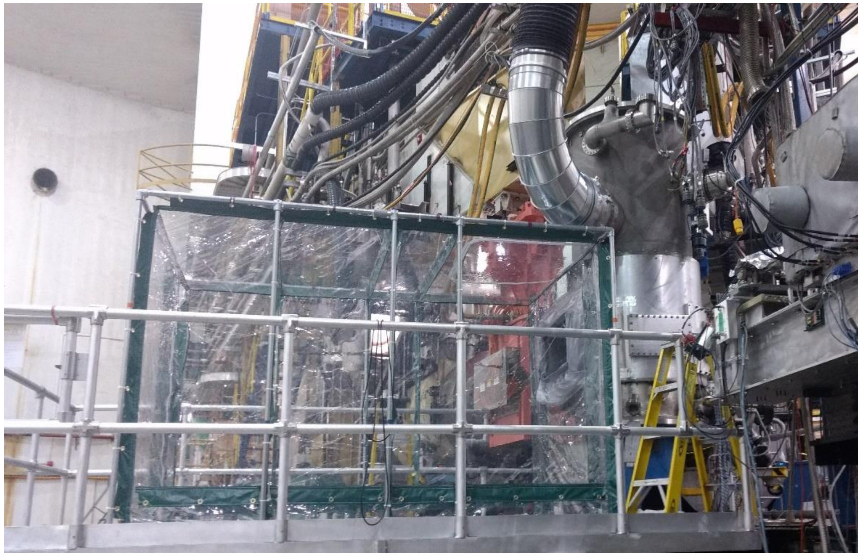
Exhaust System/Confinement

- Provided crucial 3rd layer of confinement/containment
  - Design requirements:
    - maintain slight negative pressure in Hall A (1–2 inH20) and in handling hut (2-3 inH2O)
    - 140 ft/s at chamber with hut installed ***LAMINAR***
    - Loads balanced with dampers and were concurrent
- Provide Smoke Removal
  - Required to operate in combination with other exhausts in Hall to remove smoke from fire
- System must not damage the roll up door in the Hall.
  - High suction can pull this door off tracks
- Exhaust fan speed variable
  - Pressure drops and flow rates must be balanced

Exhaust System/Confinement

Target Exhaust System and Stack

Transfer Hut



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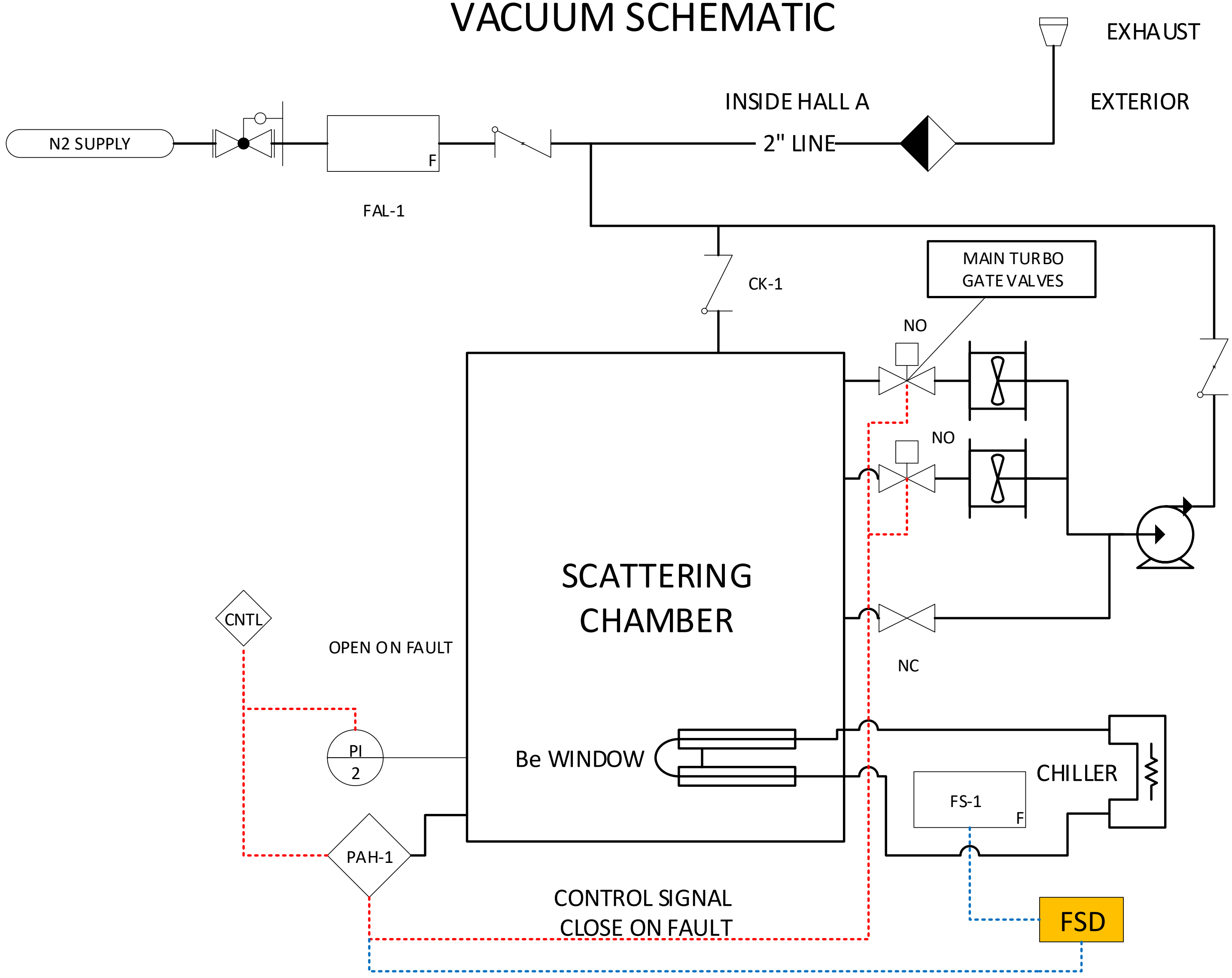
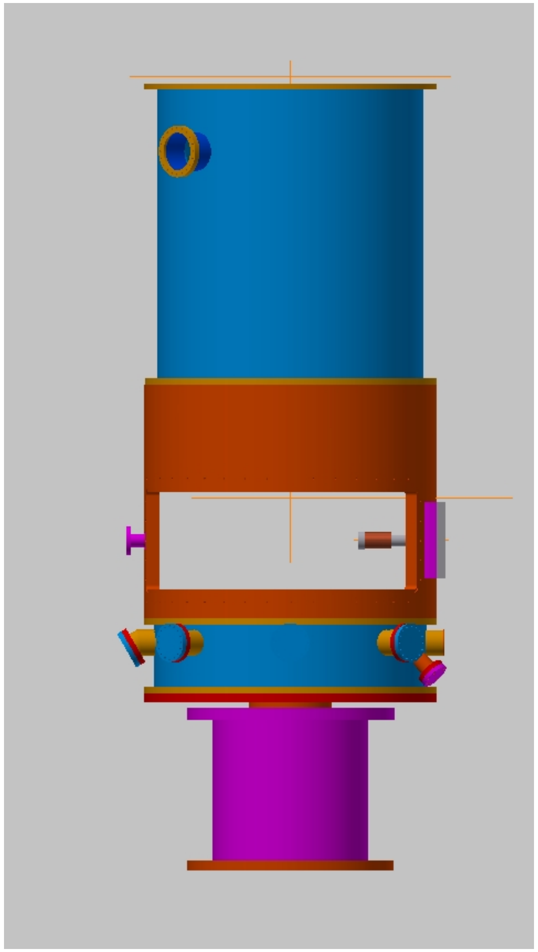
VACUUM SCHEMATIC

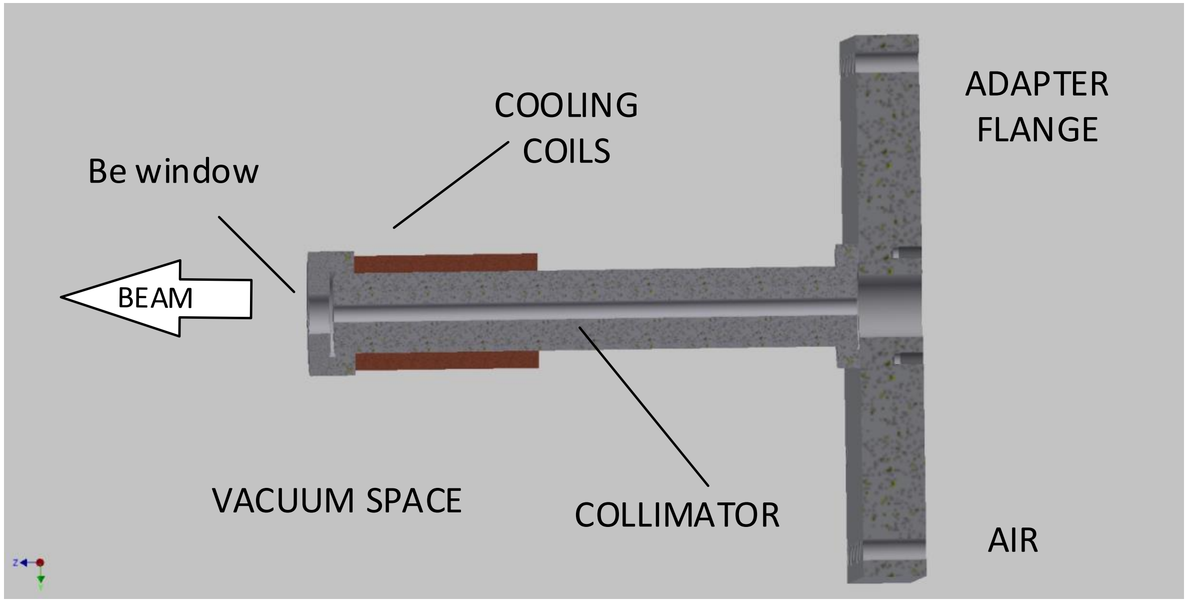


Beamline Alterations

- Beamline was not substantially altered
- Upstream beamline was isolated by a Be window
    - 0.008” thick 1” ID.
    - Water cooled (3W beam power 25 µA)
    - Reentrant (Resides in chamber)
- Window is 15 cm from entrance to cell
- Densimet collimator 10 cm long installed in tube upstream of window. (W 90% , Cu 8%, Ni 2%)
- Maintenance is possible if required.
- 12 mm thick collimator attached to cells
- Collimators should prevent steering error from affecting cell
    - Last steering element is 8 m upstream and 2” radius beam pipe.

Be Isolation Window





- 0.008” Be window
- Cooled by self contained water chiller to 10C
- Integrated collimator Densimet

Shipping Tritium To JLAB

Shipping Is not Easy

Tritium is

HAZMAT
Radio Active Material
Nuclear Material (NNSA)
Pressurized Gas

Regulators:

- USDOE OS
- USDOE NNSA
- NRC
- DOT

BTSP
Has to be packed and unpacked by NNSA approved personnel

Installation and Removal

Unique Hall C Issues

- Primary Issue: Hall C is closer to the site boundary
  - Release of tritium could have a larger potential impact at the site boundary.
  - Preliminary investigation indicates that this will not be an insurmountable hurdle.
  - This would have to be studied more carefully in order to proceed.
- New exhaust system will be required
- New access controls will need to be installed
- Does this target design meet the requirements for the physics program?
- Access to the Hall C Dome is more challenging

Summary

- Jefferson Lab has completed the Tritium Program
  - 13+ PhD Students
  - 4+ experiments completed (2 high impact)
- It seems highly likely that a tritium target similar to the Hall A target could be operated in Hall C.
  - Preliminarily no show stoppers due to a release but we need to look at this more carefully.
- Staff and T2 User Community will need to collaborate effectively to address special hazards with T2 and the needs of a comprehensive physics program.
- The budget for a Hall C target will likely be similar to that of the Hall A target.