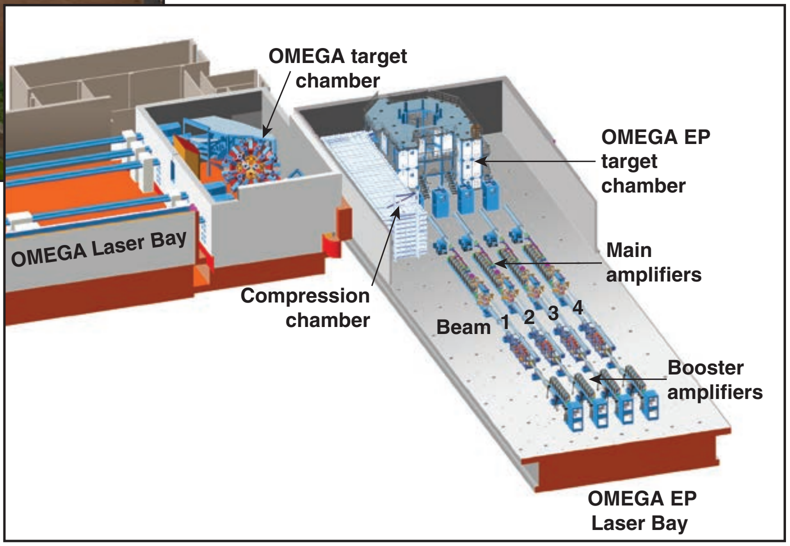
Radiological Challenges at the Laboratory for Laser Energetics



- Faculty equivalent staff: 110
- Professional staff: 162
- Associated faculty: 24
- Contract professionals: 5
- Graduate and undergraduate students: 124

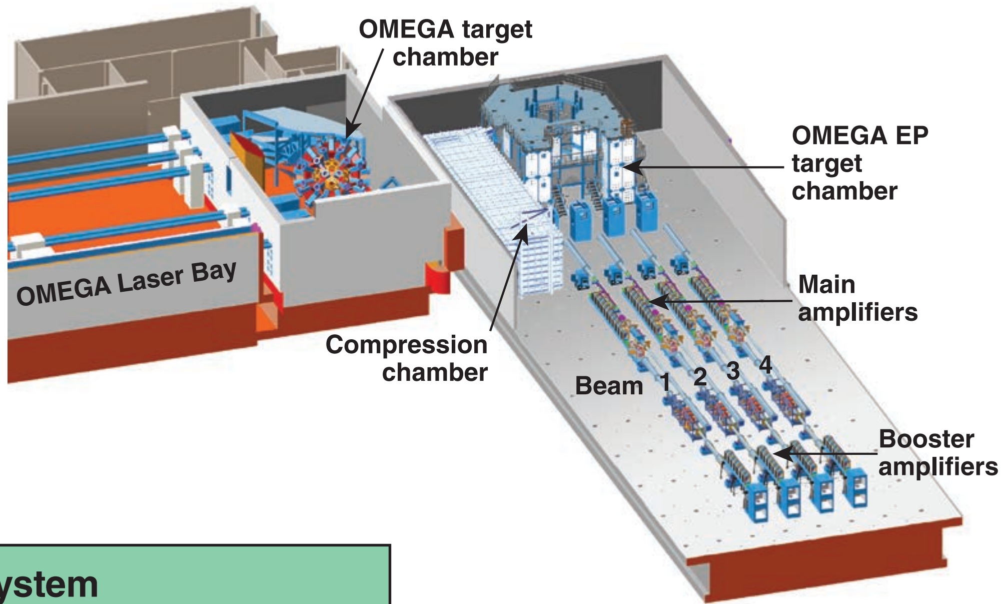
W. T. Shmayda
University of Rochester
Laboratory for Laser Energetics

Tritium Focus Group Meeting
Los Alamos, New Mexico
3–5 November 2015

Successful radioactivity management requires a blend of training, situational awareness, and engineered systems

- **Introduce the Laboratory for Laser Energetics (LLE)**
- **Describe Radiation Safety initiatives to address LLE needs**
- **Discuss engineered systems used at LLE**
- **Closing remarks**

The Laboratory for Laser Energetics (LLE) operates two of the world's largest lasers for high-energy-density-physics research



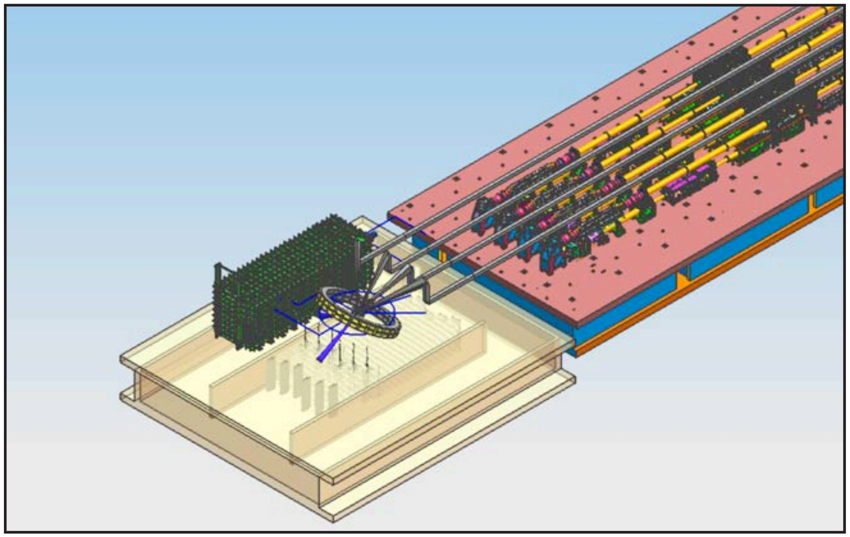
OMEGA Laser System
- Operating at LLE since 1995
- Up to 1500 shots/year
- 60 beams
- >30-kJ UV on target
- Flexible pulse shaping
- Short shot cycle (1 h)

More than half of OMEGA's shots are for external users.

OMEGA EP Laser System
- Operating since mid-2008
- Adds four National Ignition Facility (NIF)-like beamlines; 6.5-kJ UV (10 ns)
- Two beams can be high-energy petawatt
  - 2.6-kJ IR in 10 ps
  - can propagate to the OMEGA or OMEGA EP target chamber

G10425e

LLE is exploring the possibility of installing a multi-MA pulsed-power machine coupled to OMEGA EP



Source terms:

- **Neutrons**
- **Tritium**
- **X-ray**

- **This machine would fill the gap between the 1-MA university machines and the 25-MA Z machine**
- **The coupling of OMEGA EP will allow new physics platforms to be developed**
  - **magnetized liner inertial fusion (MagLIF)**
  - **Thomson scattering in warm dense matter**
  - **novel bright x-ray sources**

I2186b

LLE has an infrastructure designed to fill and handle DT targets and contaminated equipment safely

- **Site inventory limit: 15,000 Ci**
- **Hold gaseous emissions below NYS-DEC environmental limits (0.1 μCi/m^3)**

Tritium Facility:	4.0 Ci
OMEGA:	2.2 Ci
Tritium Laboratory:	3.2 Ci

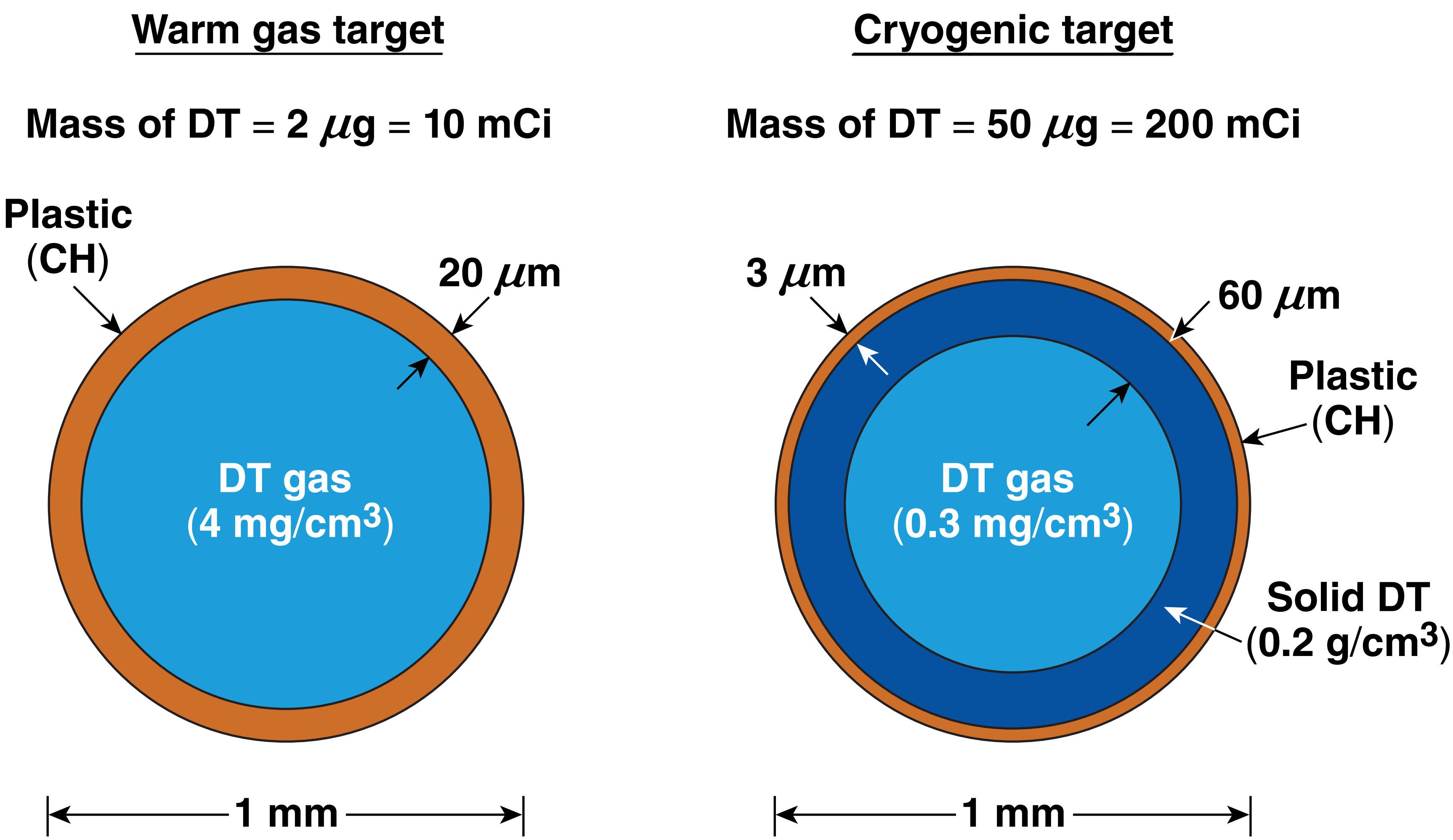
- **Maintain airborne tritium concentrations:**

Radiological work areas:	$<$20 μCi/m^3
Uncontrolled areas:	$<$0.1 μCi/m^3

- **Maintain exposed-surface contamination**
  - levels below 1000 dpm/100 cm^2 in radiological work areas

E24654

Cryogenic targets enable a greater mass of DT to be imploded



TC5701b

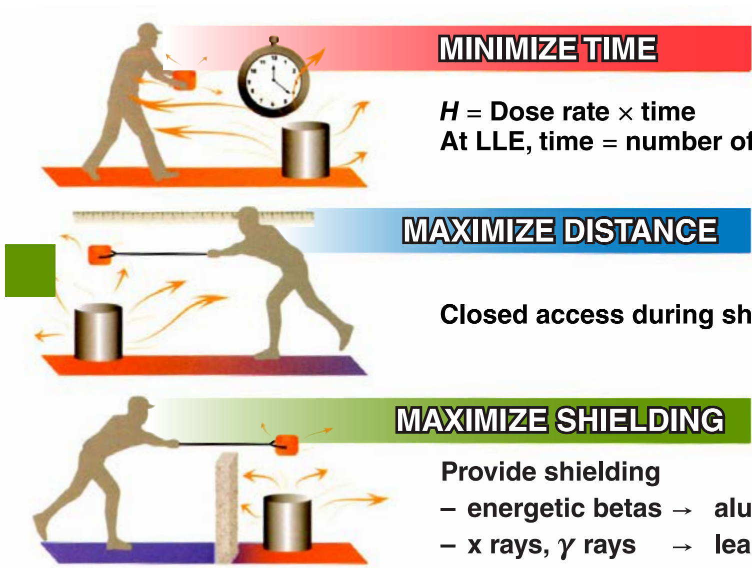
Principal radiation sources at LLE

- DT fusion—prompt neutron radiation
  - maximum credible yield shot of 3×10^{15} neutrons yield 516 rem at the surface of the OMEGA target chamber (radius = 1.6 m)
  - maximum neutron yield on OMEGA EP is $\sim 10^{12}$ neutrons
- Activated structures—short-term gamma radiation
  - neutrons interact with OMEGA
  - protons interact with film pack on OMEGA EP
- Tritium—contaminate equipment
  - surface contamination } long-term diffuse radiation
  - airborne releases }
- Fast-electron deceleration in high-Z materials in OMEGA EP—prompt, high-energy x rays

E17573d

The aim of radiation protection is to reduce exposure to As Low As Reasonably Achievable: the ALARA principle

Fixed/Activated Sources



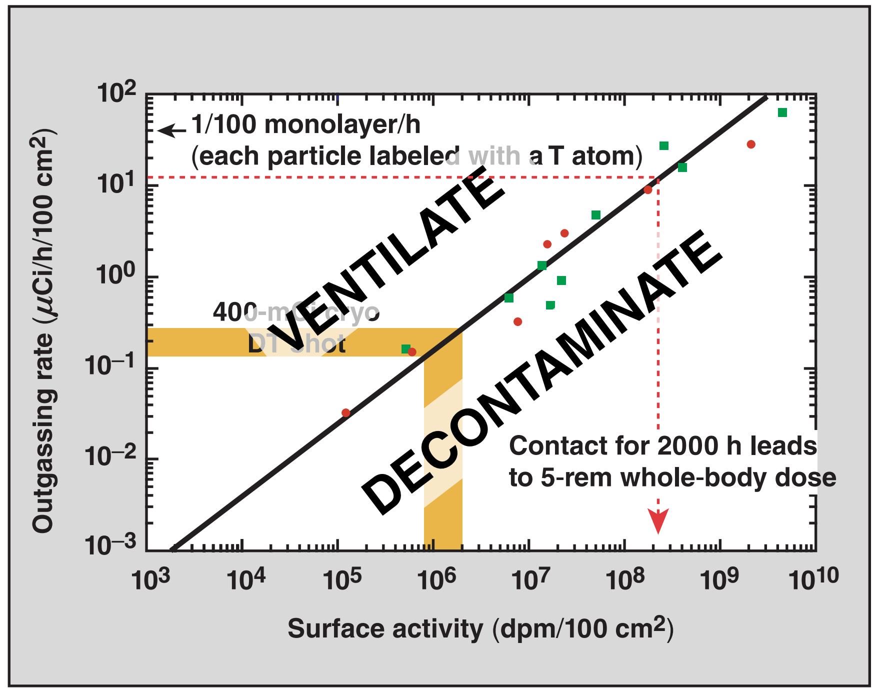
H = Dose rate × time
At LLE, time = number of target shots

Closed access during shots

Provide shielding

– energetic betas → aluminum, plastic
– x rays, γ rays → lead, concrete
– neutrons → concrete, paraffin

Diffuse Sources



The application of ALARA differs for activated and diffuse sources.

E17006e

Implementing radiation safety effectively at LLE requires several approaches

UR LLE

- Training
  - annual recertification
  - proficiency evaluation
- Procedures
  - living documents
  - referenced during the evolution
  - no changes on the fly
- Monitoring
  - thermoluminescent devices
  - bioassays
  - airborne activity/radiation fields
- Engineered safety systems

E24655a

After radiation safety, the overarching goal is to minimize the impact of tritium on nonradiological facilities

UR LLE

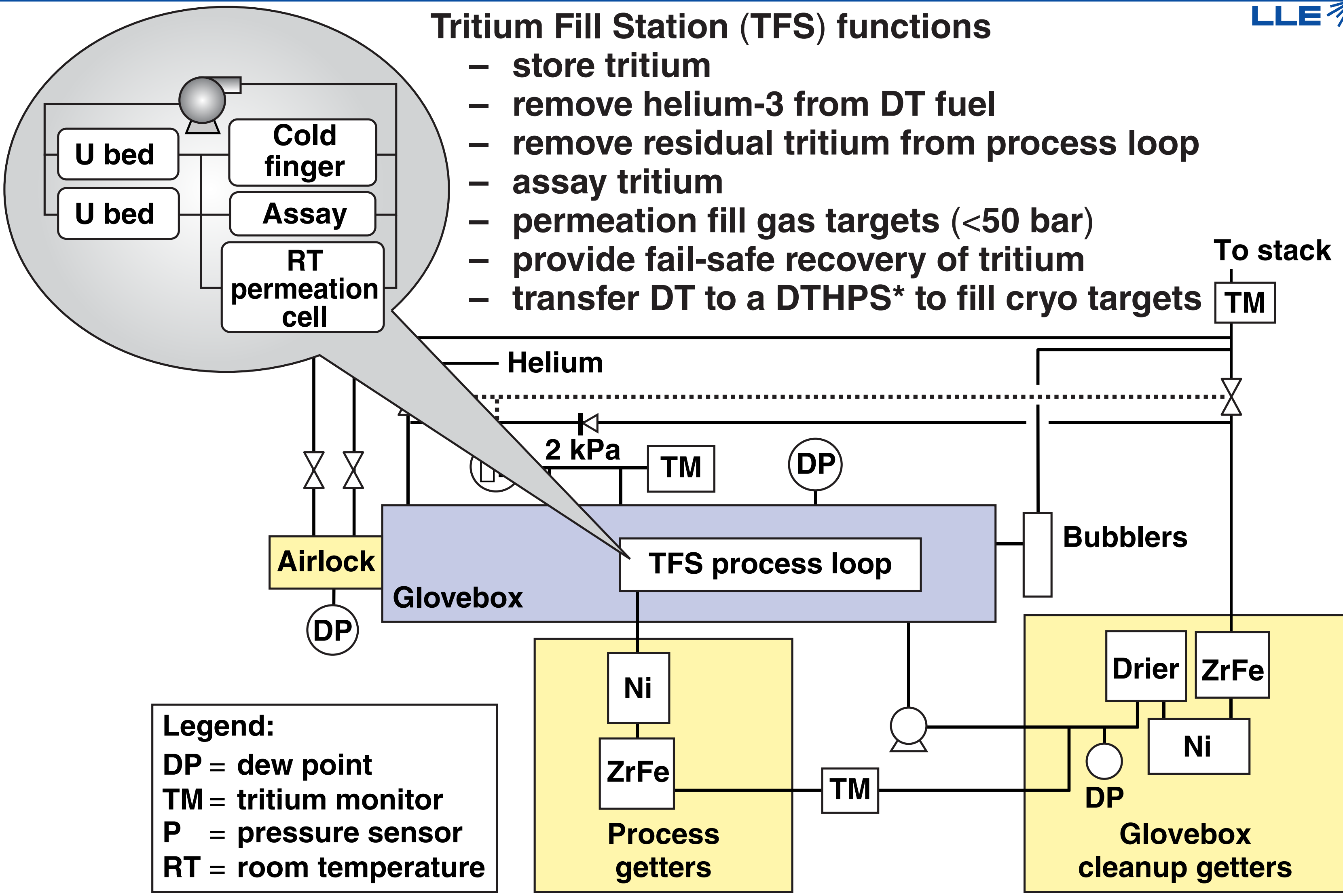
- Compartmentalization
  - isolate processes
  - tailor gloveboxes to suit the application
  - secondary containment
- Staged commissioning
  - $D_2 \rightarrow$ trace DT $\rightarrow$ high-activity DT
- Minimize the chronic release of tritium
- Monitor all effluent streams and work spaces to get a better handle on tritium operations
  - permits fine-tuning of the procedures
  - reduces the number of surprises

E24656

Tritium is captured from each process and inert containment stream with getters

Tritium Fill Station (TFS) functions

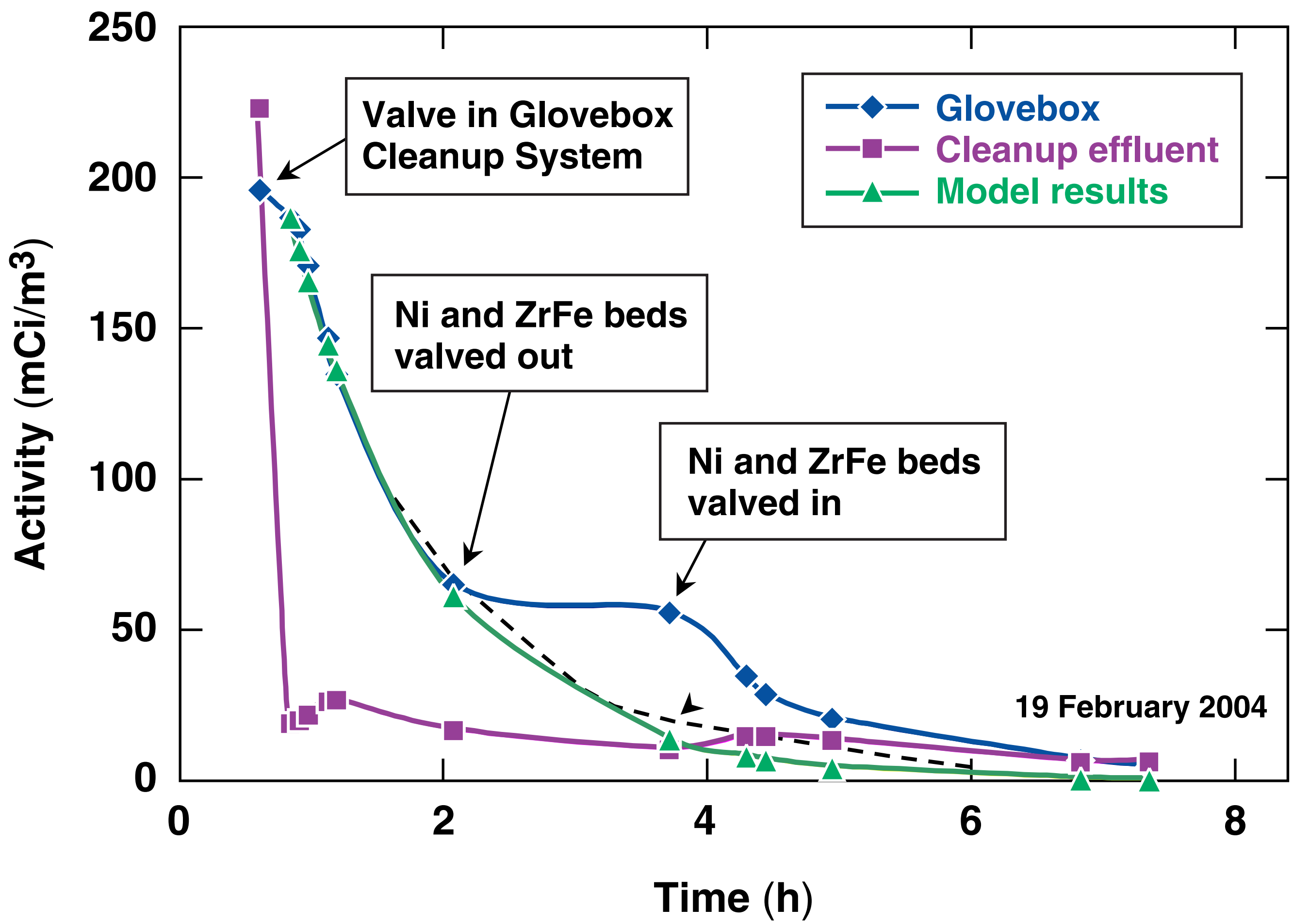
- store tritium
- remove helium-3 from DT fuel
- remove residual tritium from process loop
- assay tritium
- permeation fill gas targets (<50 bar)
- provide fail-safe recovery of tritium
- transfer DT to a DTHPS* to fill cryo targets



E13735e

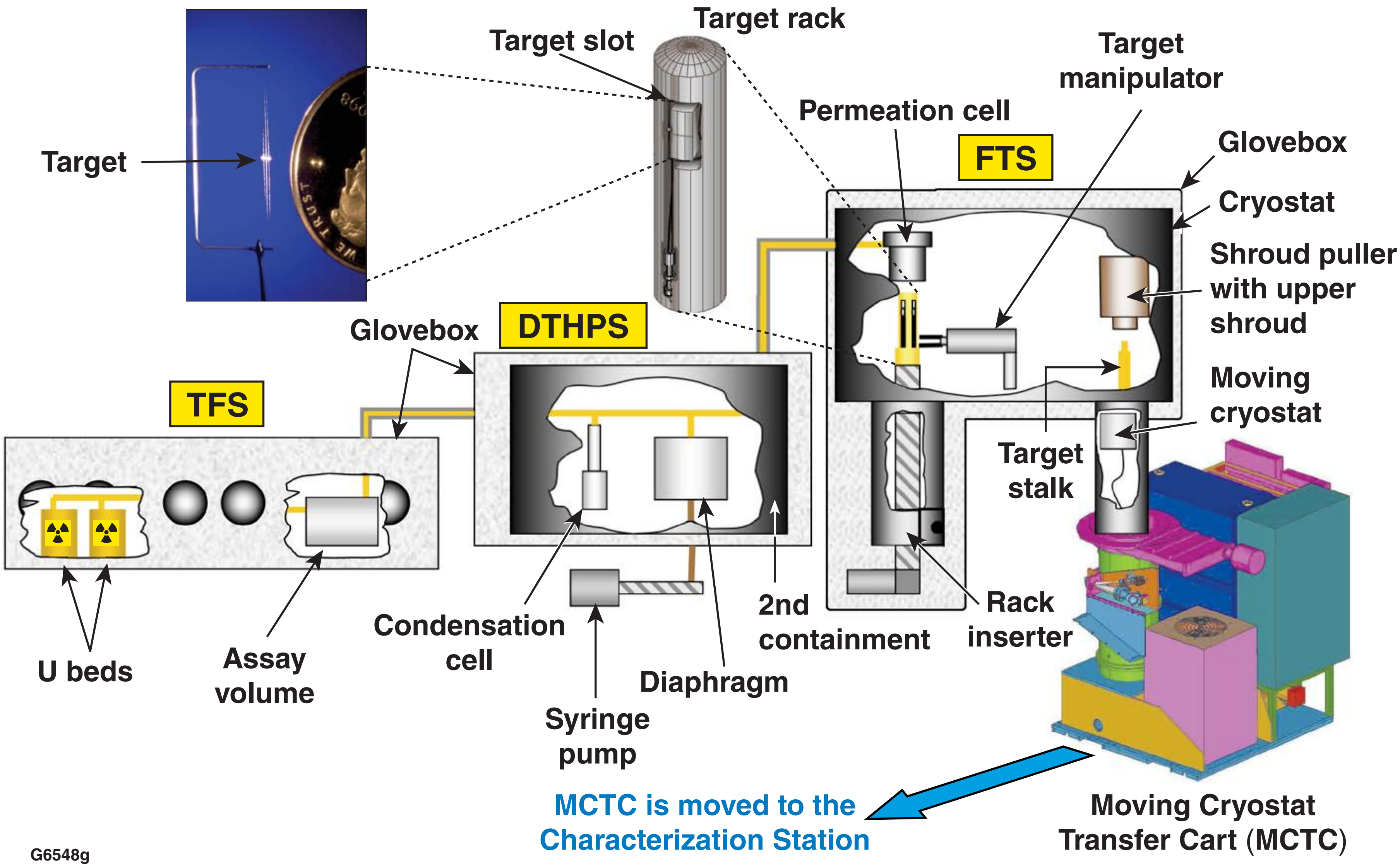
*DTHPS = DT high-pressure system

The getter-based Glovebox Cleanup System provides a robust platform against accidental releases

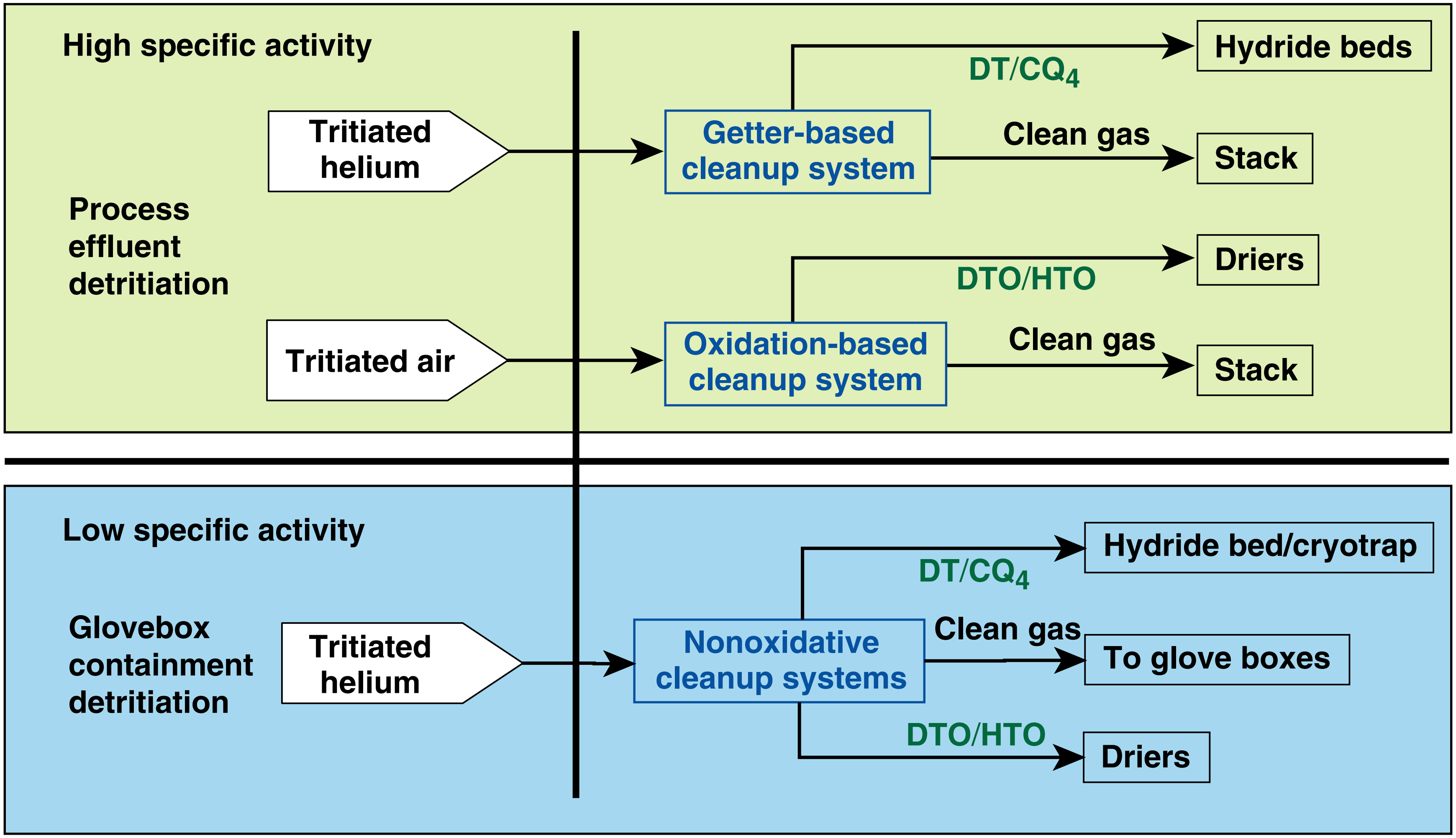


E13094b

Cryogenic targets are formed by cooling DT gas at 1000 bar to 17 K in the Fill Transfer System (FTS)

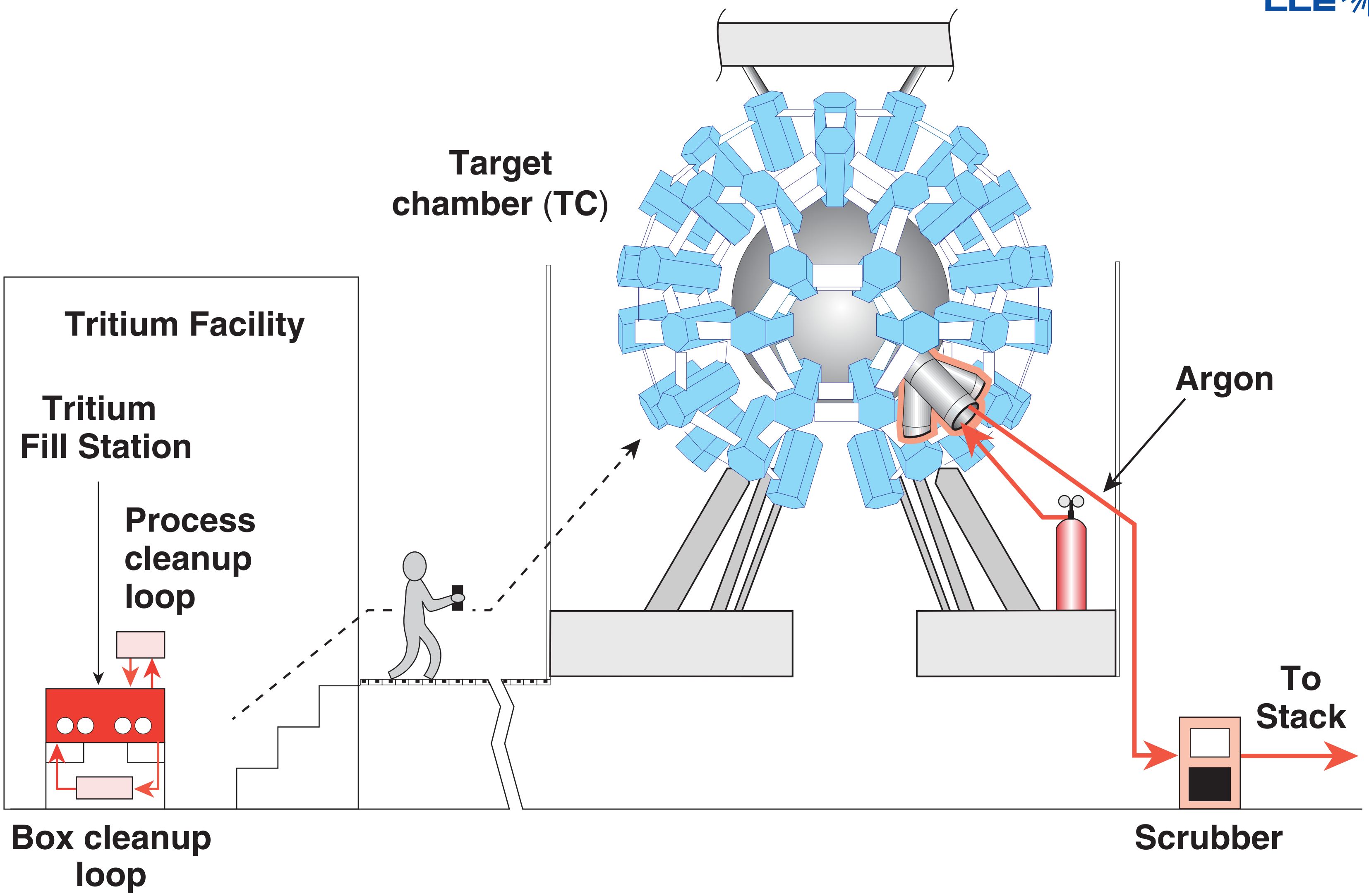


High- and low-activity streams of air and inert gas are treated separately



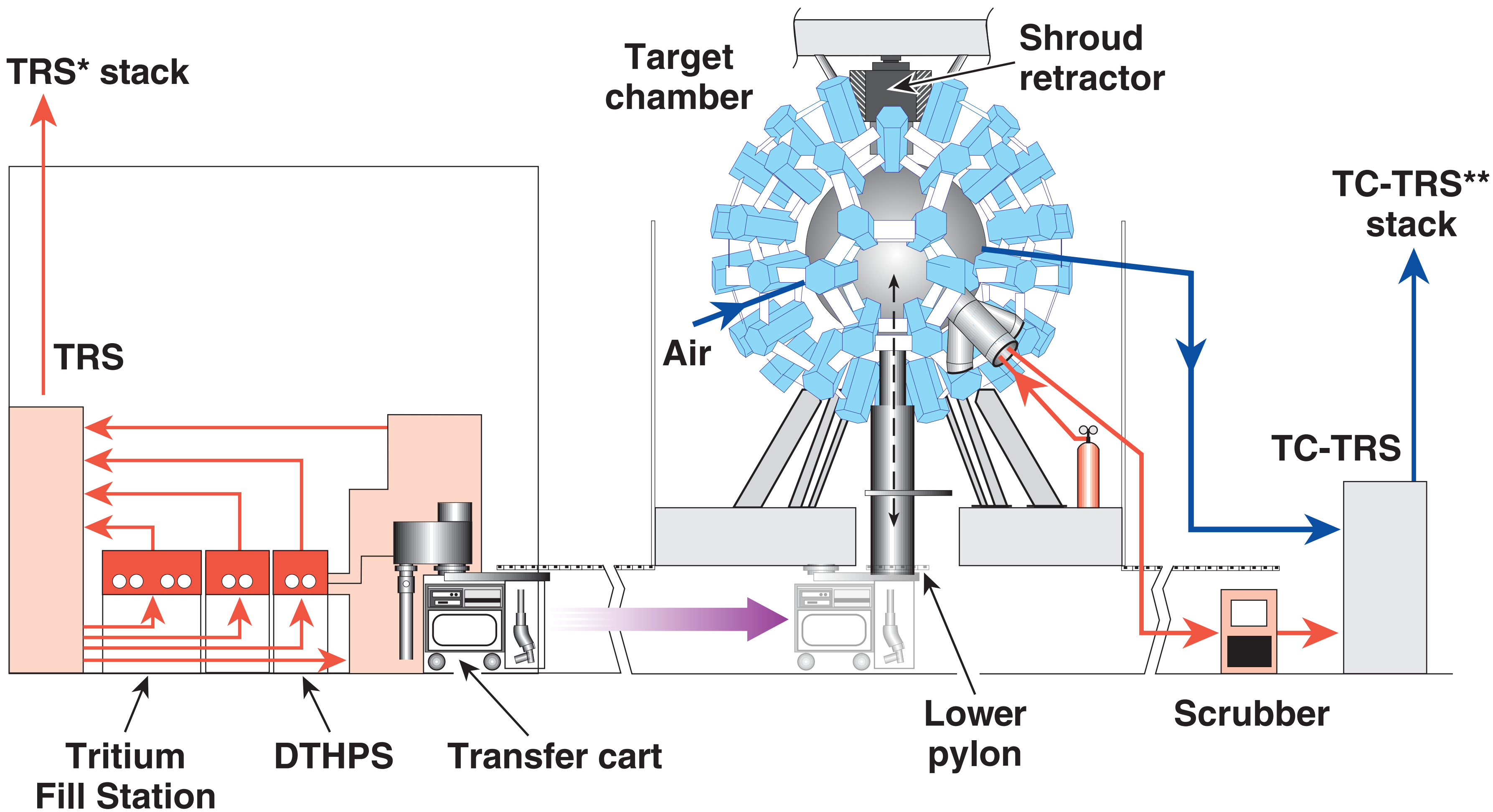
E13091b

DT gas-filled (warm) targets are transported to the TC in sealed plastic containers



E11597I

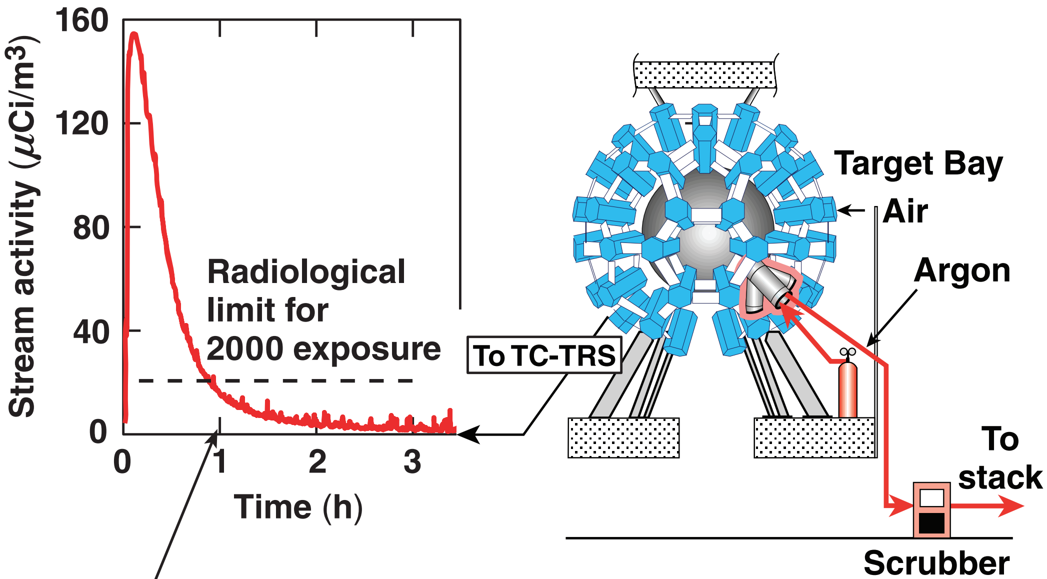
Cryogenic targets are transferred to and held at target chamber center under vacuum and at 17 K until shot time



*TRS = Tritium Removal System
**TC-TRS = Target Chamber Tritium Removal System

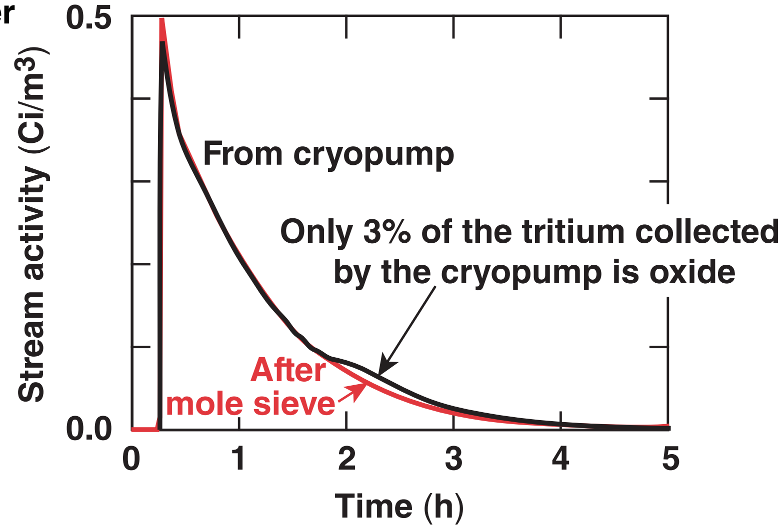
E11598j

The TC cryopumps collect ~75% of the DT fielded; the balance adsorbs on the TC wall as DTO

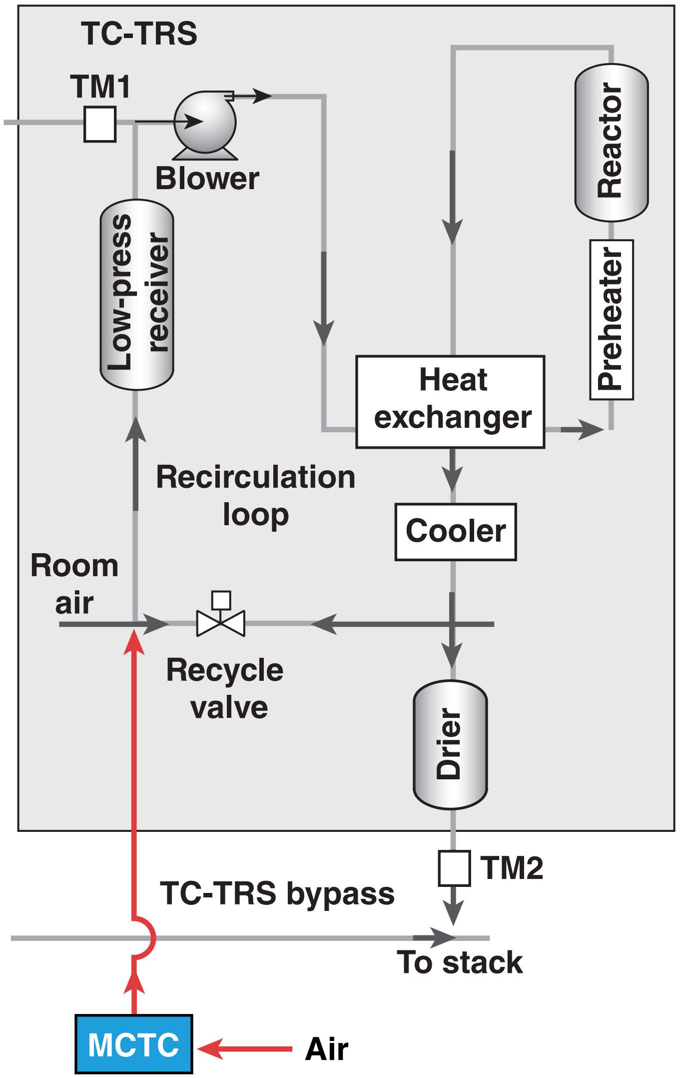


A 200-mCi (7.4-GBq) DT cryo target will deposit ~48 mCi (1.7 GBq) on the TC walls.

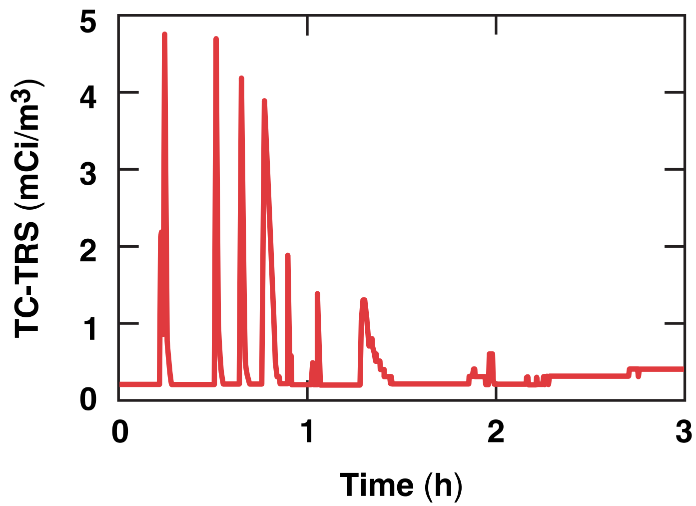
Room-temperature, moist air purges decontaminate the TC interior to negligible dose levels within 2 h for gas targets and within 4 h for DT cryo targets.



The TC-TRS is based on classical "burn-and-dry" technology



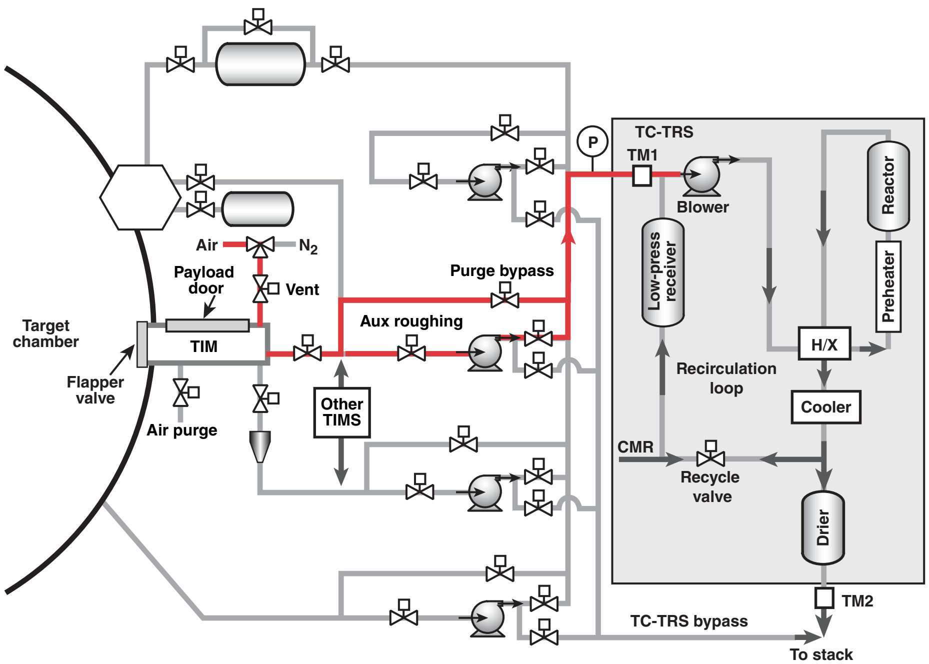
- All tritiated air streams are sent to the TC-TRS

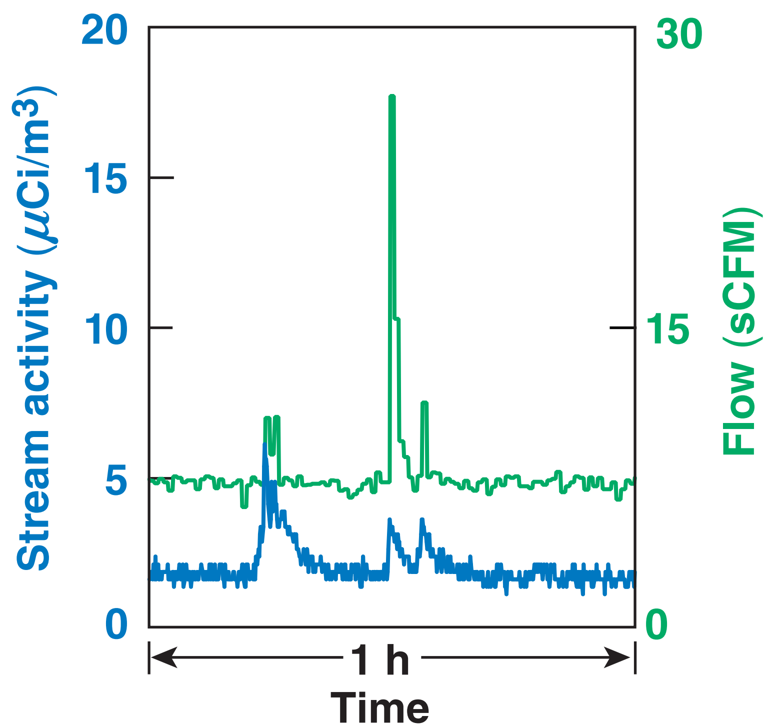


- MCTC's are decontaminated before maintenance to reduce outgassing and dose uptake

T2515c

Each TIM* is purged with air before it is opened to prevent a "tritium puff"



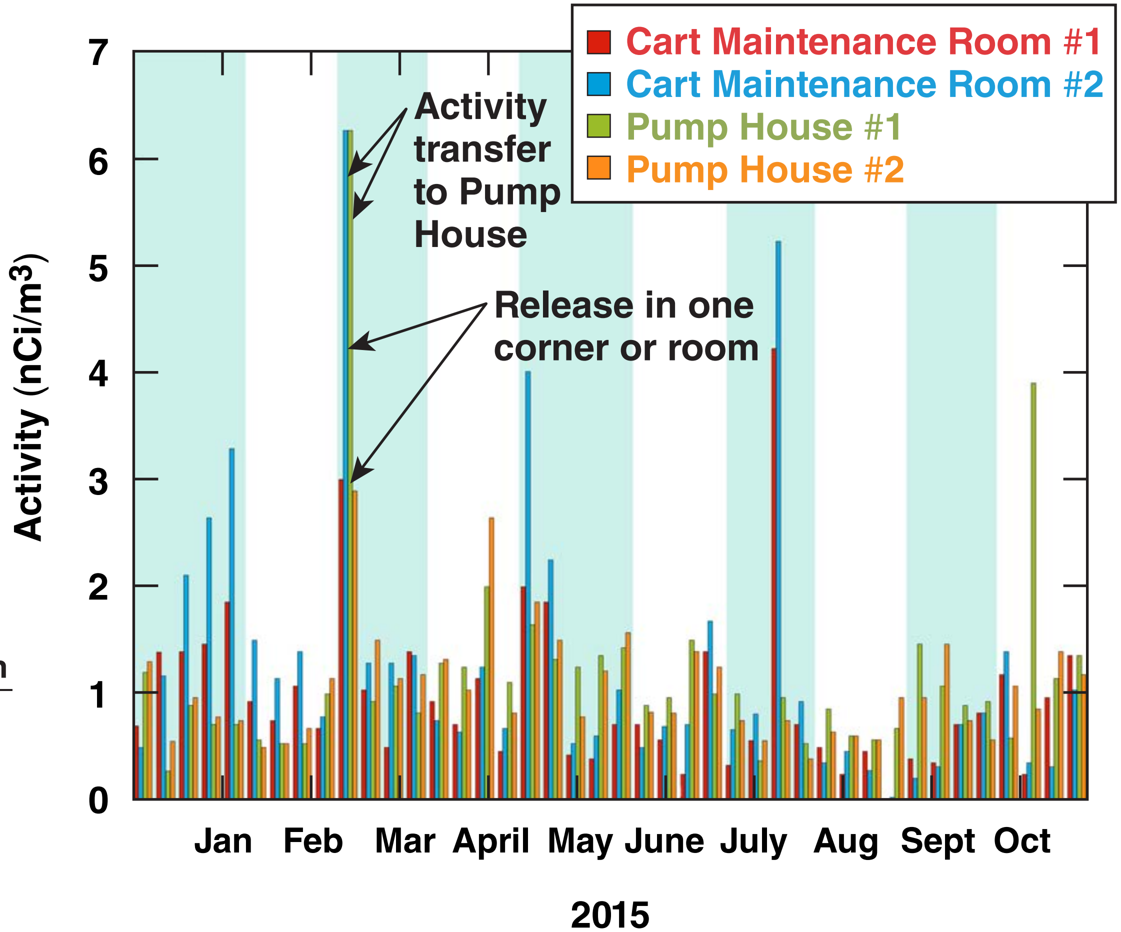


- **Each TIM is decontaminated overnight following any DT campaign**

T2513b

*TIM = ten-inch manipulator

Chronic, low-level releases can be identified with a Stephenson diffusion cell

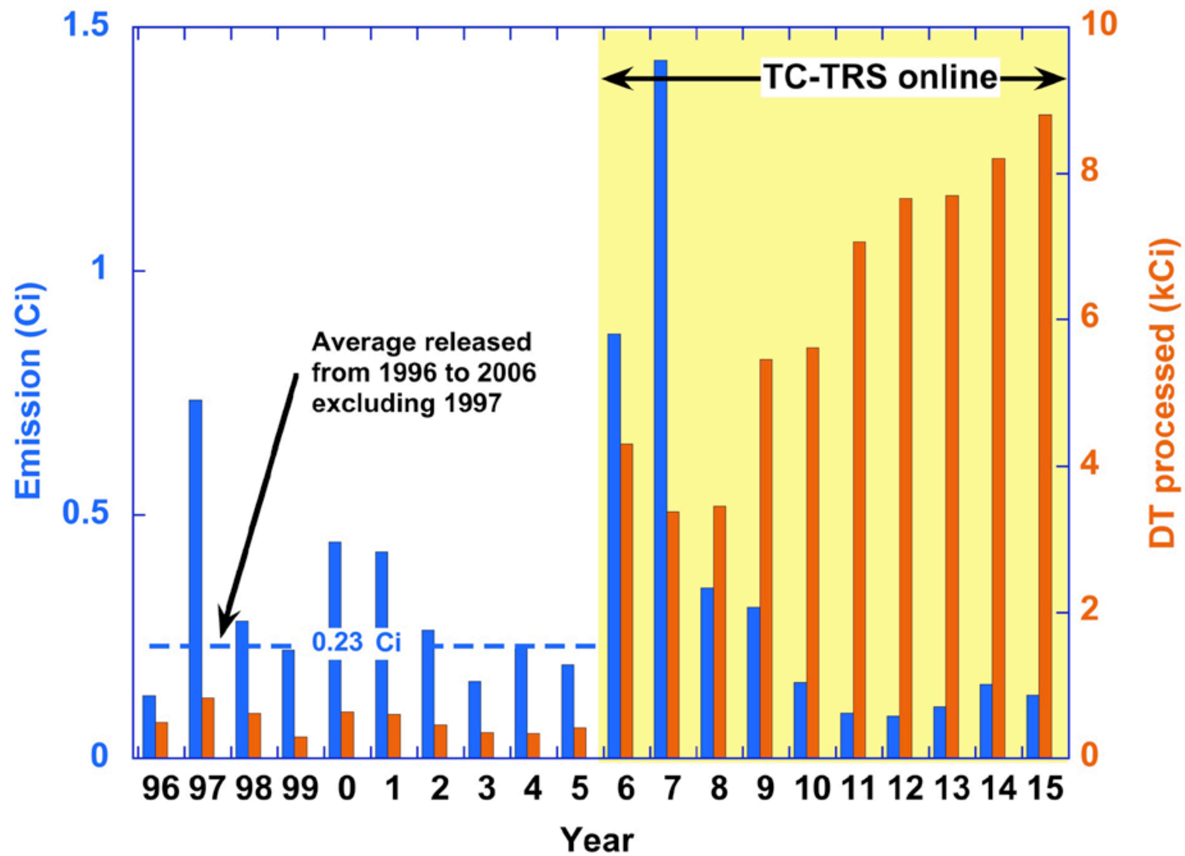


$$\text{Airborne activity}^{\dagger}\left(\frac{\text{nCi}}{\text{m}^3}\right) = 2 * \frac{D_{\text{dpm}}}{T_{\text{h}}}$$

† 7.5 mm-diam-orifice

E24710

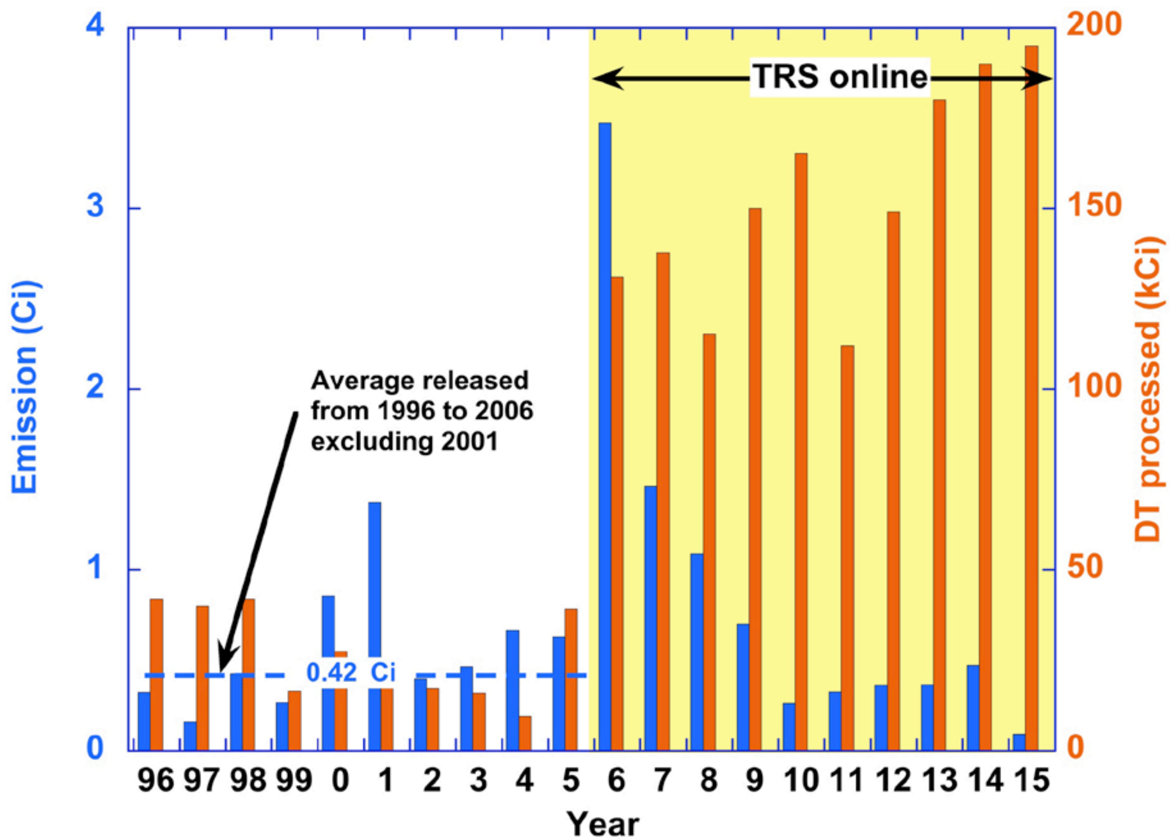
Tritium throughput has increased 15-fold since 2005, while emissions from the OMEGA stack have dropped twofold



- **The OMEGA stack is permitted to discharge up to 2.2 Ci/year**

E24652

Tritium throughput has increased fivefold since 2005, while emissions from the Tritium Facility stack have dropped continuously



- **The Tritium Facility stack is permitted to discharge up to 4 Ci/year**

E24653

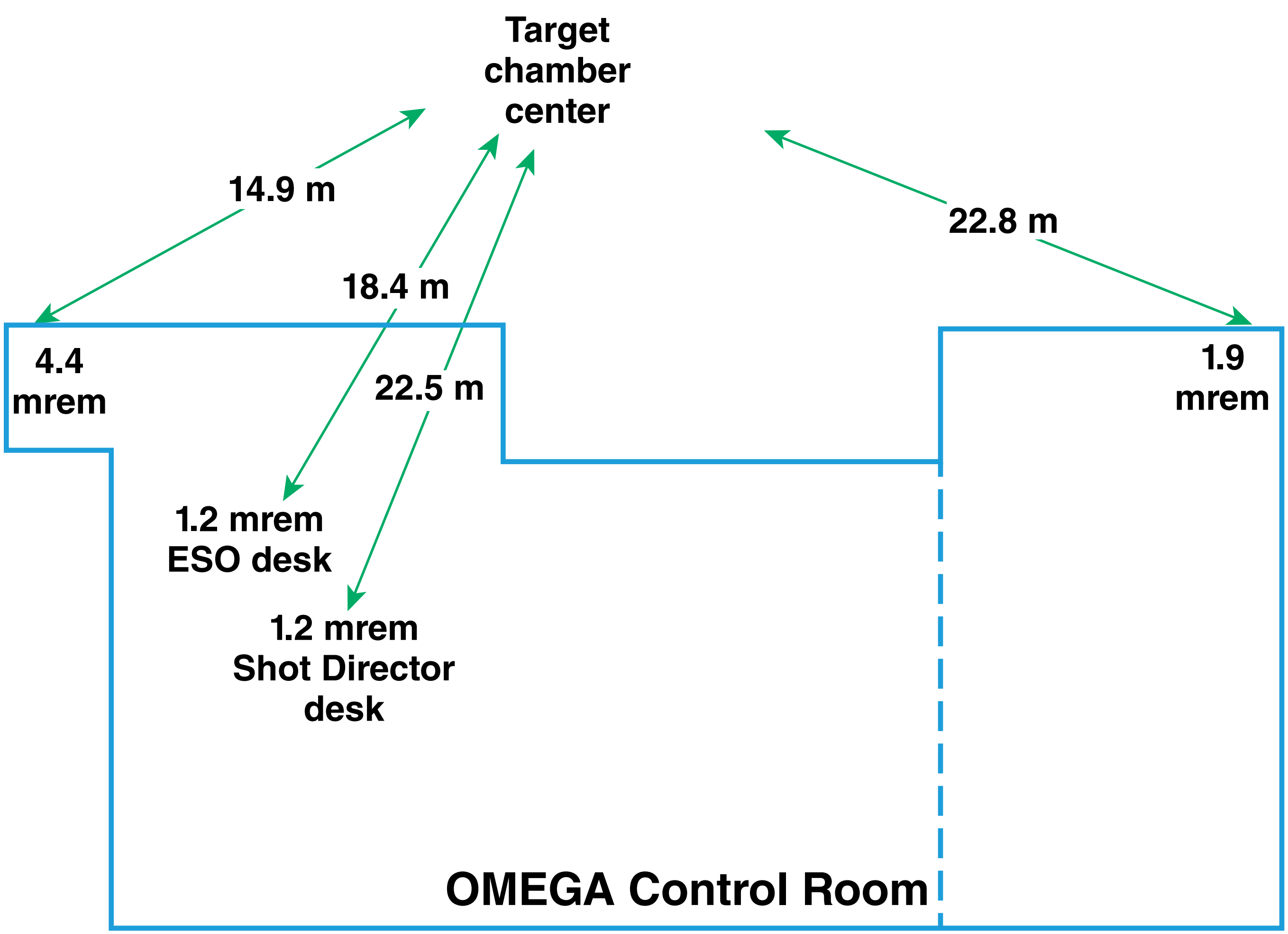
The OMEGA neutron shield is performing satisfactorily

Point no.	Location	Integrated dose[1] (mrem)	Dose for max. cred. yield[2] (mrem)	Shield design (mrem)
1	Experimental System Operator station	<10	<10	7
2	TB anteroom	318	42	21
3	Stairway opposite TB entrance	378	57	40
4	TB north emergency exit	119	2	<1
9	Room 134 damage test lab. north	<10	<10	1
10	LaCave darkroom	10	2	<1
11	LaCave/Capacitor Bay wall	<10	<10	<1
12	Control Room conference room	12	3	30
13	Rod amplifier room east wall	<10	<10	40
14	Amplifier test and assembly area	20	5	27
15	Amplifier test and assembly area	20	5	20
16	Laser Bay north wall, center	70	16	36
17	LaCave below TC for type-6 shots	<10	<10	<1[3]
18	Laser Bay west wall	10	2	1
19	Laser Bay south wall, center	30	7	17
20	Laser Bay south wall, east	40	9	30

[1] Dose for 1995 to 2015 for integrated neutron yield of 2.22×10^{16}.
[2] Extrapolated dose for maximum credible neutron yield of 3×10^{15} per shot.
[3] Badge 17 was put in place to determine if there was any exposure risk from hard electrons when the area below the target chamber was accessible. The result indicates that there is no risk.

G6712b

Average low-energy neutron dose at various locations per 10^{14} neutrons produced in OMEGA



E24529

Summary

- Engineered systems have been robust against emissions to the environment despite increased throughputs
- No reportable doses to radiation workers from tritium or activated materials
- Tritium contamination outside the radiological areas less than 1000 DP/100 cm^2
- Emissions from all stacks below 10% of the authorized New York State (NYS) Department of Environmental Conservation (DEC) – Part 380 discharge limit