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Mu2e Remote Handling Review Radiological Issues

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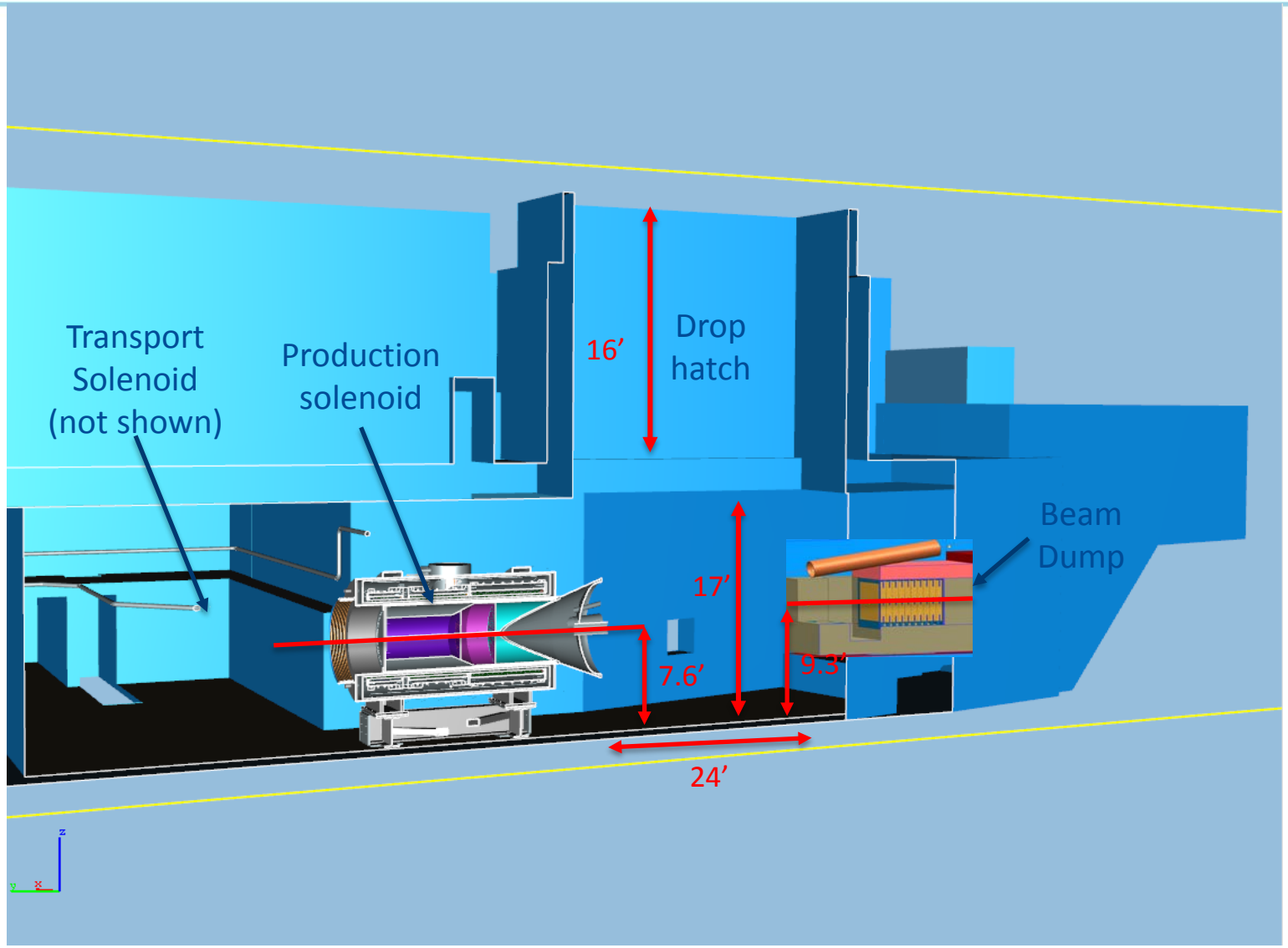
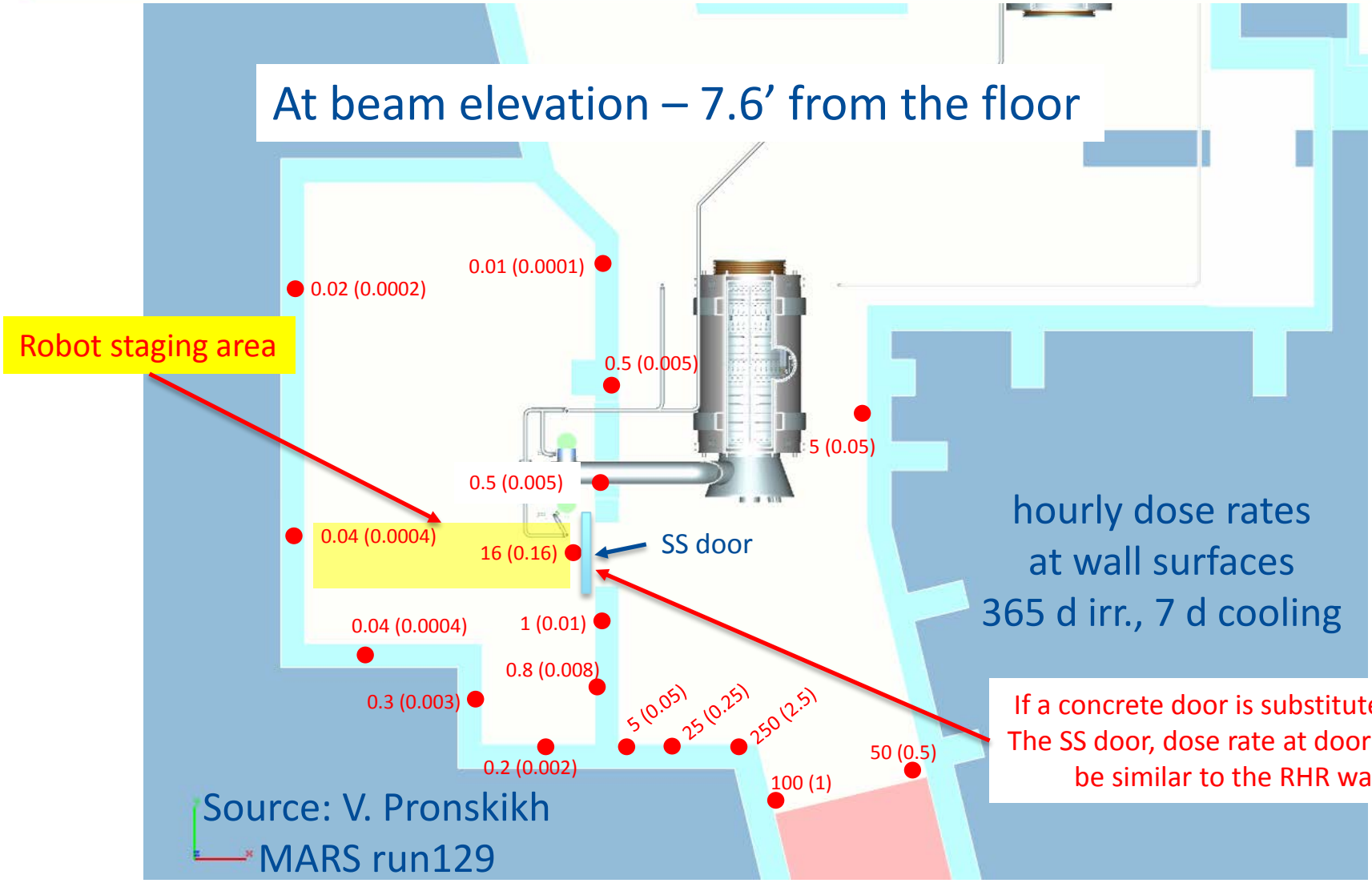
Outline

- Facility radiation dose rates (sans major sources)
  - PS Room
  - Remote Handling Room
- Major radiation sources
- Air flow
  - During operations
  - During remote handling operations
- Contamination sources
- Radiation Protection – entry controls
- Operating notes
- Summary
- **Note: All radiation dose units are in the format mrem/hr (mSv/hr)**

Elevation View



Plan view - Facility radiation dose rates (sans major sources)



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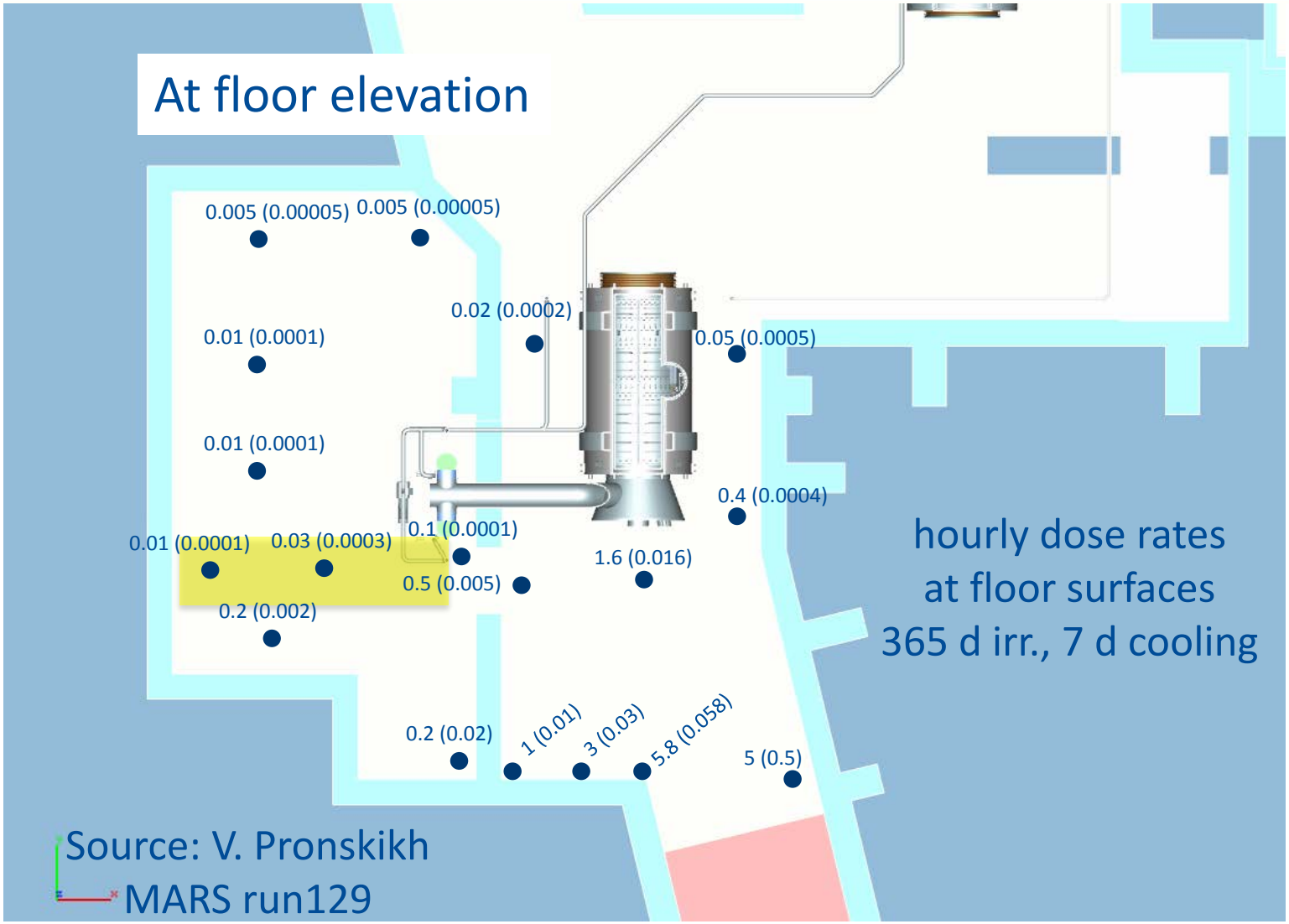

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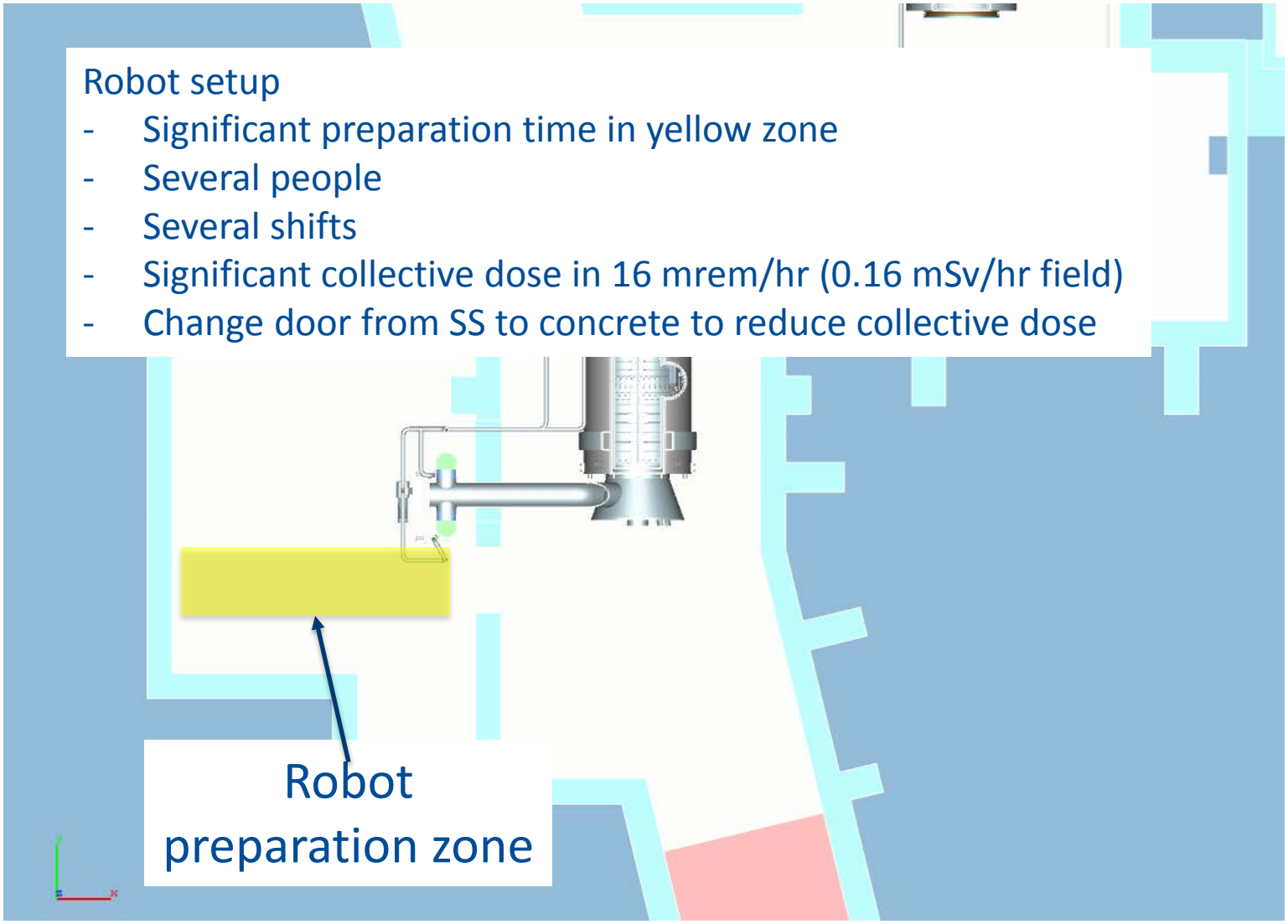
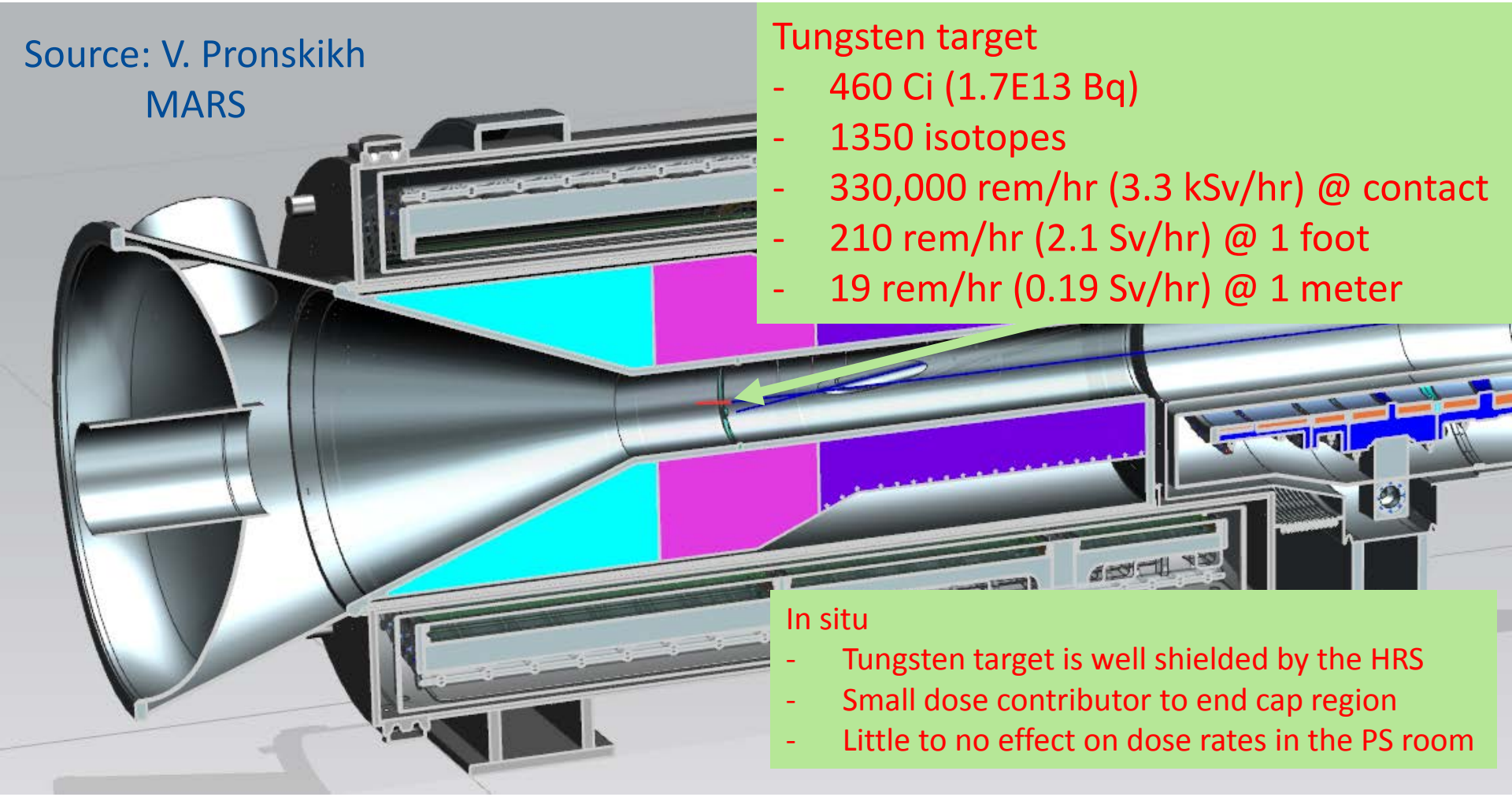


Major Sources – tungsten target



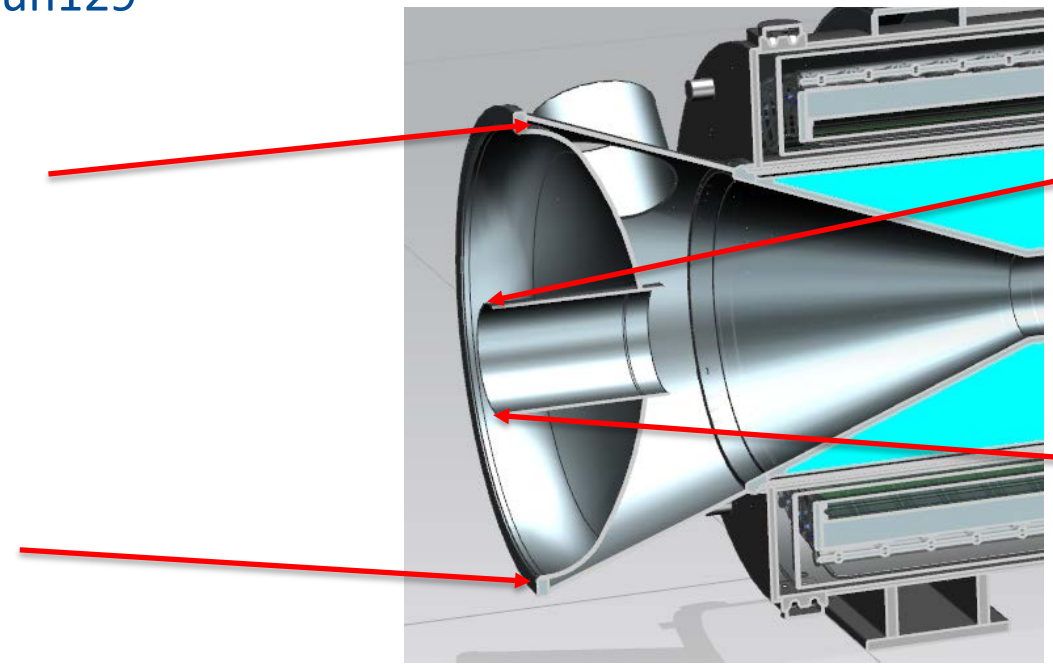
Source: V. Pronskikh
MARS

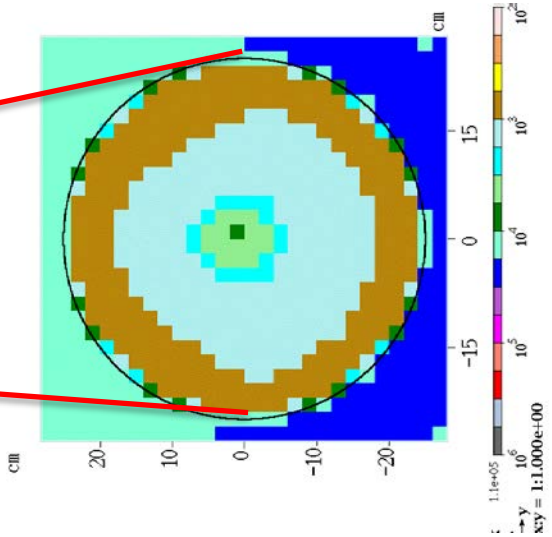
Tungsten target
- 460 Ci (1.7E13 Bq)
- 1350 isotopes
- 330,000 rem/hr (3.3 kSv/hr) @ contact
- 210 rem/hr (2.1 Sv/hr) @ 1 foot
- 19 rem/hr (0.19 Sv/hr) @ 1 meter

In situ
- Tungsten target is well shielded by the HRS
- Small dose contributor to end cap region
- Little to no effect on dose rates in the PS room

Major sources – end cap & vacuum window

Source: V. Pronskikh
MARS run129



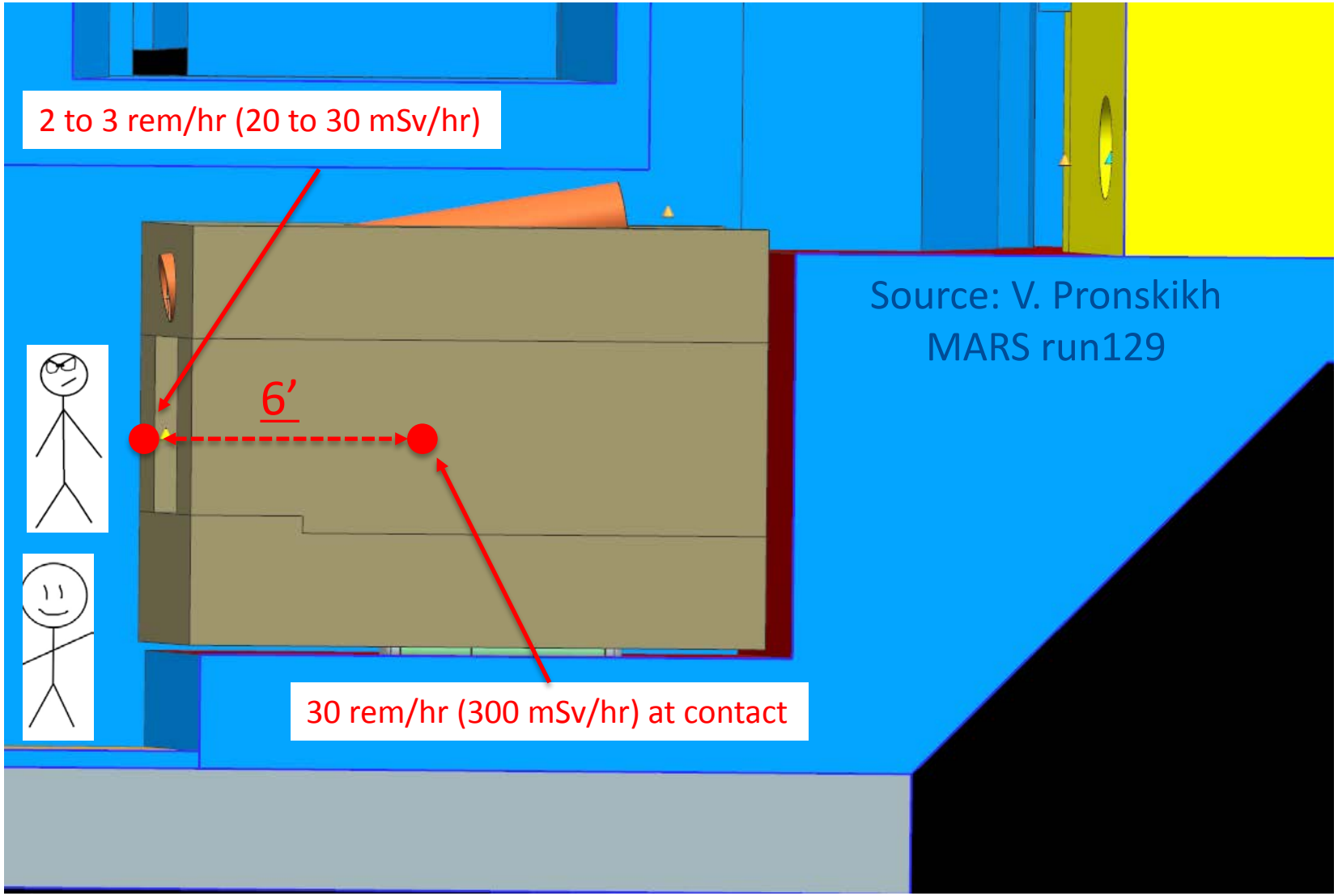


In situ end cap @ contact
32 rem/hr (321 mSv/hr)

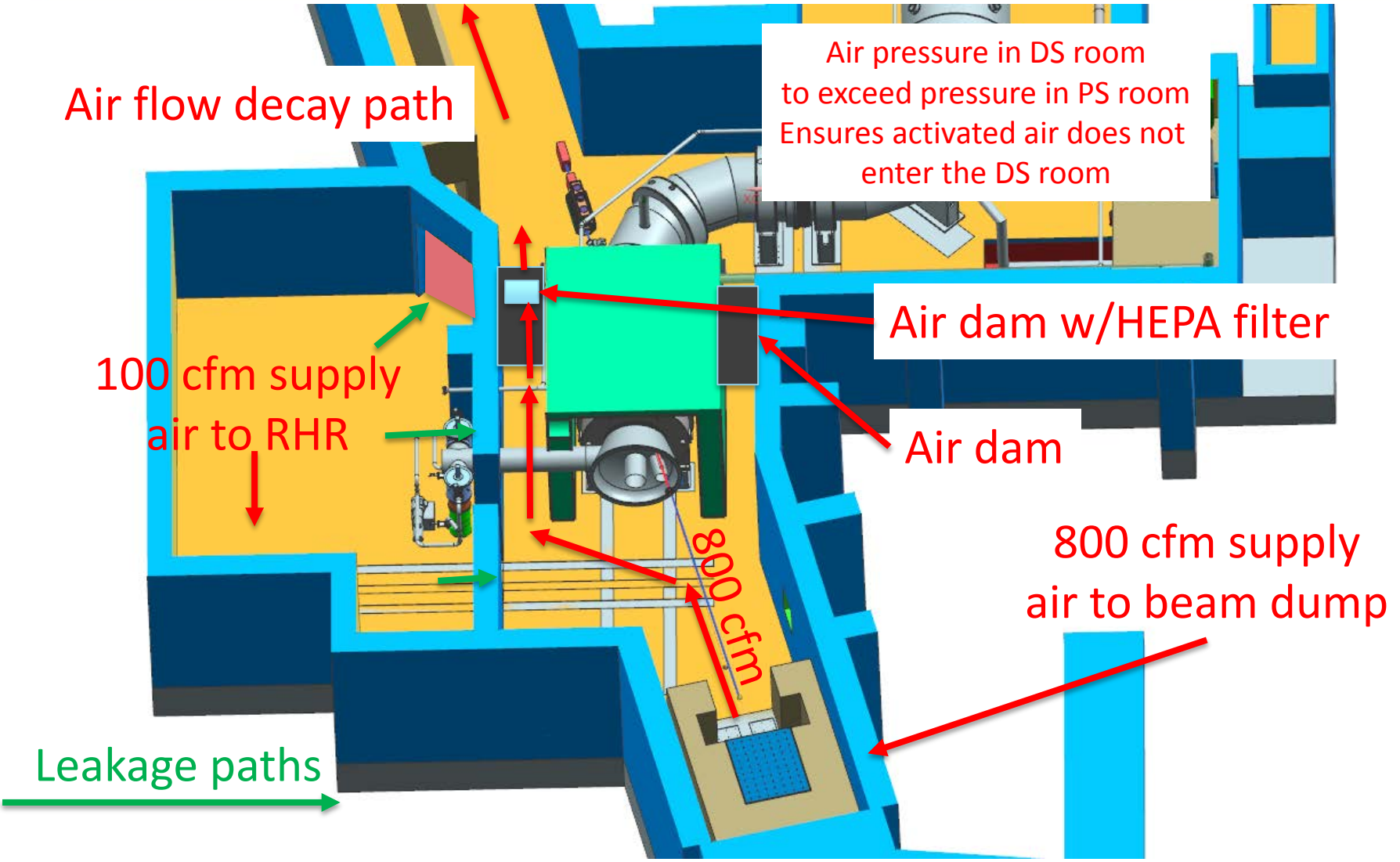
Vacuum window @ contact
Separated from PS
1 to 7 rem/hr
(10 to 70 mSv/hr)

Preliminary results based upon a previous end cap design
The latest design has 10 x thinner windows
Vacuum window dose rate should be lower!

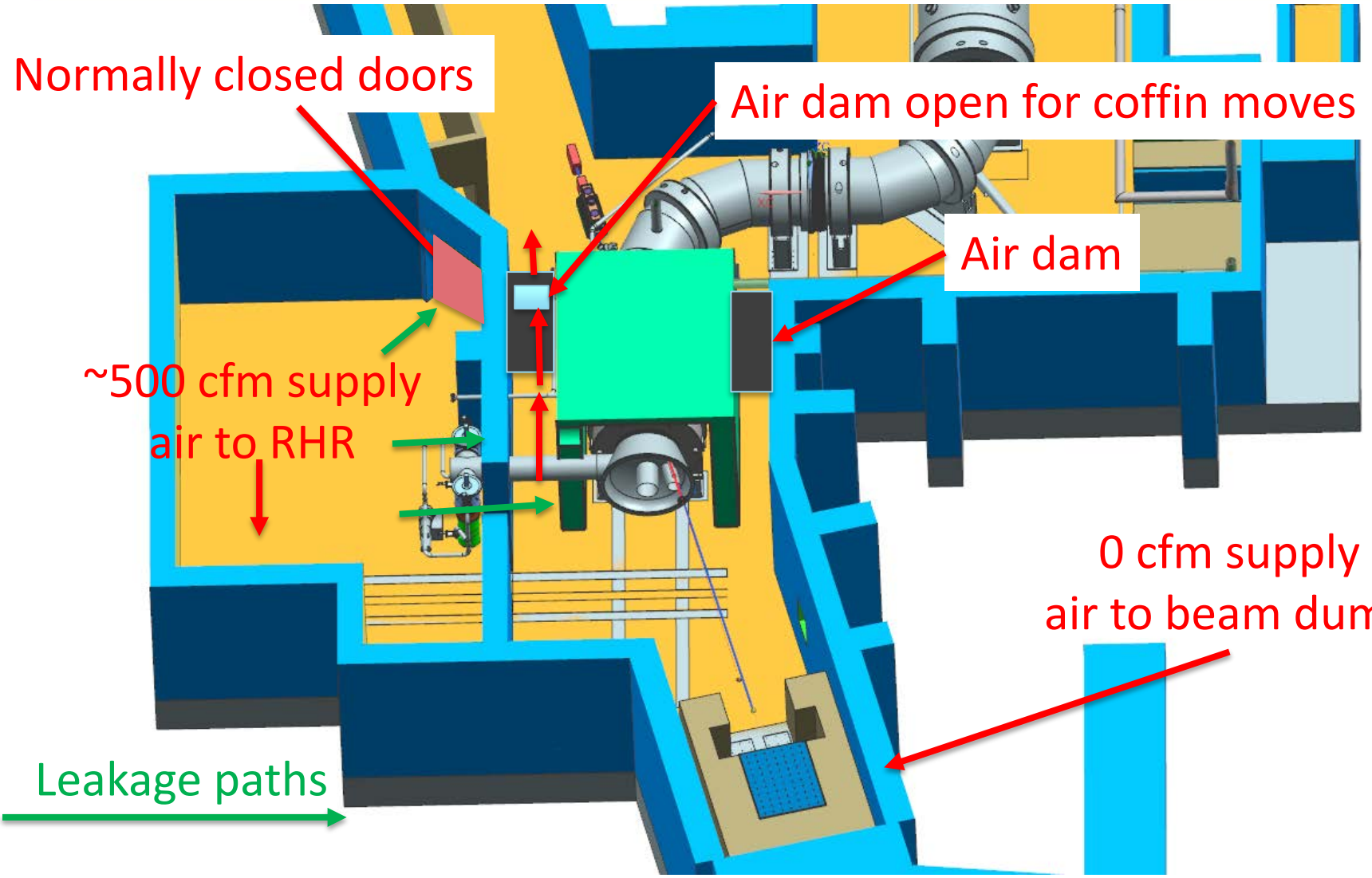
Major Sources – beam dump (beam entrance face)



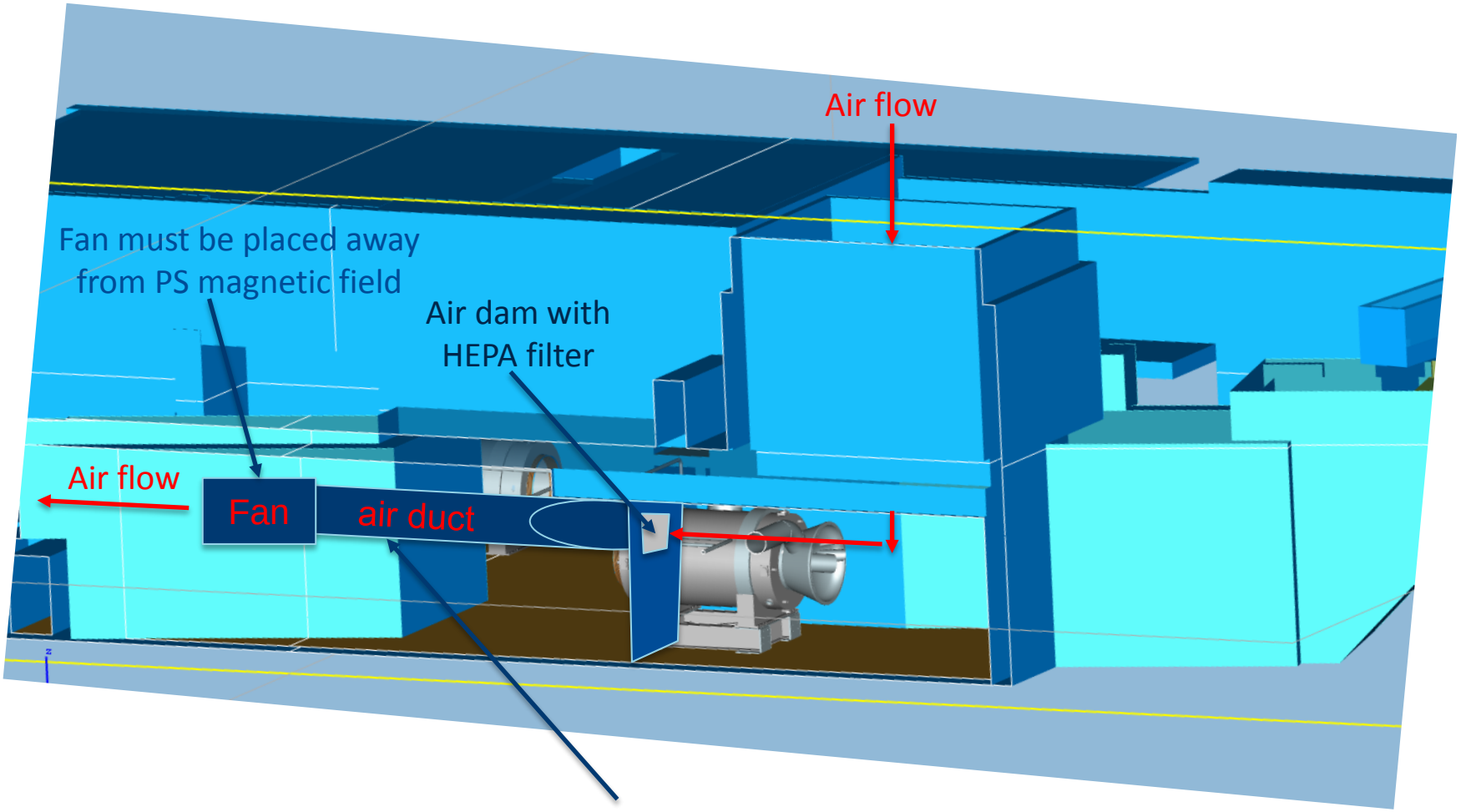
Air flow during operation – supply air comes from a common source



Air flow during target change out – horizontal scheme



Air flow during target change out – vertical scheme



Control of air flow for the vertical scheme requires this additional fan and duct. The duct could also be employed for the operational mode and the horizontal scheme.

Surface Contamination Sources – RHR

- Contamination issues in the Remote Handling Room are very unlikely unless the robot tracks it in
  - Engineered controls for ventilation limit activated air infiltration from the PS room
  - Used targets and vacuum window should never be returned to the RHR
  - AD ES&H department radiation protection group will monitor/control traffic between the PS and RH rooms to prevent spread of contamination

Surface Contamination Sources – Production Solenoid Rm

- PS room surfaces
  - 0.5 to 250 mrem/hr
  - Experience-based relationship exists between:
    - the possibility of surface contamination on walls and floors and
    - residual dose rates of those surfaces
  - AD checks for surface contamination on floors when residual dose rate exceed 100 mR/hr (1 mSv/hr) @ 1 foot from beam line components
  - Measureable contamination is nominally not expected until ~500 mR/hr (5 mSv/hr) @ 1 foot from components
  - Expect mild contamination at the west wall surface at 7.6’ from floor (~nCi/100cm^2)

Surface Contamination Sources – beam dump

- Supply air is filtered and dried
- Exhaust air velocity 33 ft/min (10 m/min)
- Air cooling flow is around the outside surfaces of the 1.5 m x 1.5 m x 2 m mass
- Air mixing between steel plates is not prevented
  - Main air flow is over surfaces with lowest specific activity
- Dump steel is to be painted, no rusted surfaces
- Peak temperatures should not lead to thermal degradation of paint
- Paint on entrance surface could eventually become radiation damaged
- Albedo trap should provide fallout region for any air-entrained particulates

Surface Contamination Sources – beam dump

- Primary emission for exhaust should be
  - C11
  - N13
  - O15
  - Other short-lived isotopes
  - Ar41
- Be7 will be produced as spallation product in air
  - Primarily deposited in HEPA filter at air dam
- Other gaseous isotopes will pass through the HEPA filter
  - Directed to exhaust stack for decay during transit time
- Expect contamination in the albedo trap, but contributes very little to general surface contamination in the PS room

Surface Contamination Sources

- End cap and vacuum window
  - Expect surfaces to be contaminated
    - Multiple nCi/100 cm^2
  - Would not expect contamination from these surfaces to spread except by physical contact

Surface Contamination Sources

- Target
  - 460 Ci (1.7E13 Bq) after 1 year of operation
  - Expect extremely contaminated target surface
  - Extreme care required for target handling
  - Post operation surface condition is difficult to predict
    - Could range from reasonably intact to friable
    - Target coatings could
      - increase emissivity
      - Reduce target temperature
      - Reduce impact of poor vacuum
    - PS vacuum
      - Major factor

Target coating	Yes	No	No	Yes
PS vacuum quality*	Good	Good	Poor	Poor
Severity of contamination	bad	worse	Really awfully bad	worse to TBD

*poor vacuum > 1E-5 Torr > good vacuum

Surface Contamination Sources

- Target handling considerations
  - **prevent physical shock & rough handling**
  - provide robust containment for target outside of PS
    - containment should accommodate a broken target, spokes, etc.
    - Catch basin, e.g., plastic bag, SS box, sticky pad, or similar to capture target detritus
    - Minimize air movement
  - move target into full containment as soon as practicable
  - Move target/containment to target coffin
- Target coatings are promising, however
  - Coating degradation could eventually lead to
    - Target hot spots
    - accelerated corrosion
  - Good vacuum quality remains a high priority

Radiation Protection - Entry controls for the PS Room

- Once mu2e beam operations begin, entry into the PS room will be under the exclusive control of the AD ES&H department radiation protection group
- Work will be controlled by radiation work permit
- Work is planned by target station engineers
- Approval of work is by AD RSO, or in exceptional cases, by the Fermilab Senior Radiation Safety Officer
- Pace of work is controlled by AD ES&H personnel
  - ES&H ensures adherence to:
    - radiological check points
    - radiation dose control
    - contamination control

Operating Notes - Aisle for coffin loading

- The dose rate in the aisle for the coffin position < 1 mrem/hr
- Staging/manipulating target/window coffins in the aisle is completely feasible for the horizontal scheme

Operating Notes – robot storage during operation

- Majority of the robot structure may reside in RHR
  - Absorbed dose calculation is Si sample is 60,000 to 230,000 rad/year (0.6 to 2.3 kGy/y) (V. Pronskikh, MARS)
  - We typically assume service life degradation at 10,000 rads (100 Gy) for electronics
  - Radiation resistant LVDTs and resolvers remain on the machine
  - Electronic components are removable by quick disconnect cables prior to beam operation

Operating Notes – PS Room Access

- It should be possible to shield the major sources in the PS room to allow personnel access
  - Stack shielding across PS window
    - Lift truck
    - 3’ X 3’ X 6’ C blocks
  - Stack concrete shield in front of beam dump entrance
  - Such temporary shield arrangement would permit
    - PS alignment
    - Other off normal maintenance/repair activity
    - robot assistance

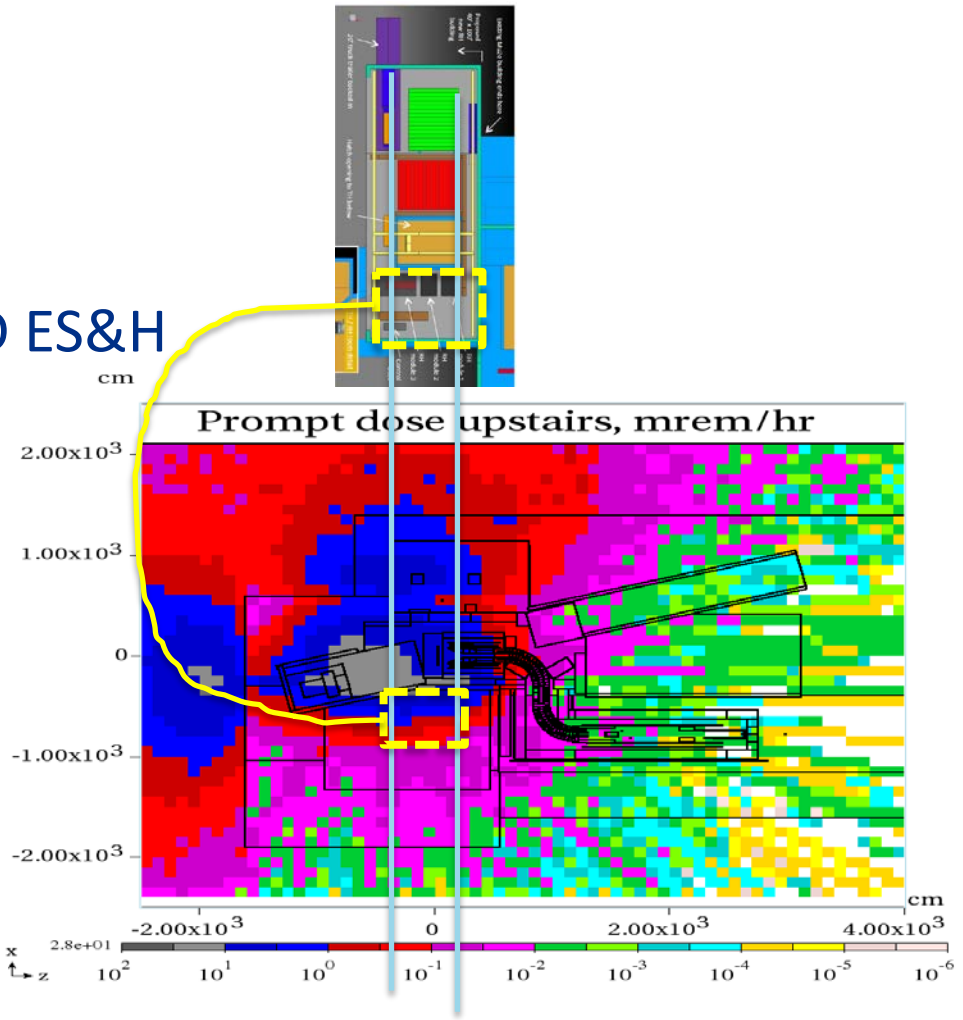
Operating Notes – vertical scheme service building access

Yellow box indicates remote handling equipment service area

Prompt dose rate 0.1- 3 mrem/hr

Occupancy at the discretion of AD ES&H

Requires radiation work permit



Summary

- Radiological parameters for the mu2e facility are within the range of experience and expertise of the Fermilab staff
- Handling of the irradiated tungsten target will require extraordinary care considering its activity (460 Ci) and potentially fragile nature
- Application of concrete shields at the PS window and beam dump should permit personnel access to the PS room under supervision of AD Radiation Protection Personnel