NuMI experience with Tritium

Overview:

When NuMI turned on, saw more Tritium in target hall air
than expected from tritium production in target pile air.
Further, Tritium in air coupled more strongly to sump water then expected
and Tritium to sump continues long (months) after beam is turned off
Believe extra Tritium comes from evaporation from steel shielding etc.
By adding dehumidification, intercept majority of tritium, evaporate it to air

Have done a few tests to investigate tritium transport in NuMI, for instance:

- *Borings of concrete decay pipe shielding*
- *Sampling of target pile steel*
- *Sampling of decay pipe helium*
- *Sampling of target volume helium*

NuMI Tritium Production and Release

Ci / 10^20 POT	Produced in
50	target pile steel
20	decay pipe concrete
9	decay pipe steel
1.1	chase air
0.12	decay pipe helium
??	absorber
??	horns
??	Target

MARS Monte Carlo of Tritium production

(note work in progress)

6.0 Measured Release 2008 – 2011 Ci per 10^20 POT

So release was 5 times that expected from the chase air production, and ~ 5% of the total tritium produced

Of the 6.0 Ci / 10^20 POT release:

4.5 Ci was intercepted by the new dehumidification systems

1.5 Ci went to NuMI sump water, then pumped to surface

Compare to regulatory limits

Tritium from dehumidifiers is evaporated to outside air. Sump water is injected into Fermilab cooling water system, ending up mostly evaporating from cooling ponds.

Concentrations

Limit for surface water release is 1900 pCi/ml.

Tritium concentration in NuMI sump water has varied from a few pCi/ml (during shutdowns) to 60 pCi/ml (when dehumidification systems were impaired).

So main concerns are to not contaminate groundwater (Illinois limit: do not degrade, EPA limit: 20 pCi/ml), or cause public relations problem.

Total emissions

0.1 mrem/year limit to Maximum Exposed Offsite Individual (MEOI) from air emissions
translates into a 3000 Ci / year release of tritium

But tighter limit of 2000 Ci / year comes from air release of all radioisotopes

NuMI maximum was 20 Ci / year of Tritium

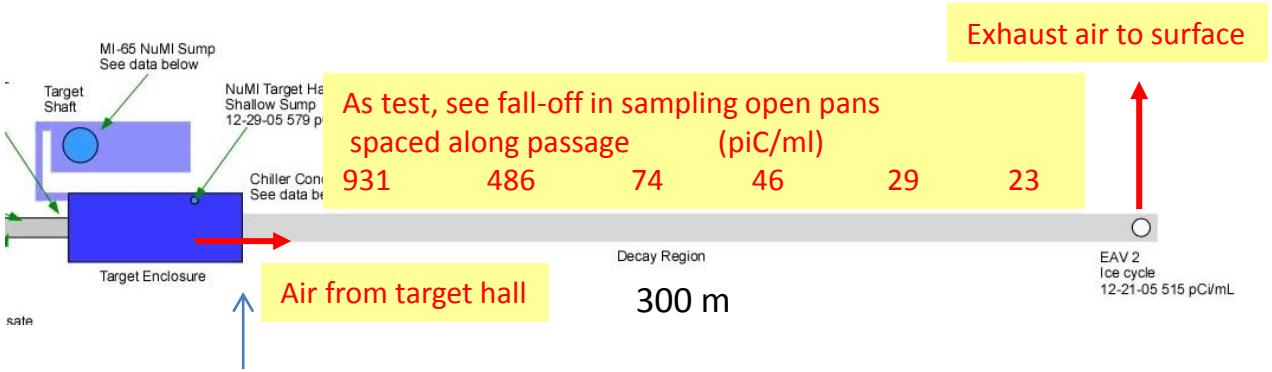
5 Ci / year limit into water sanitary sewer by Federal Regulation

Some NuMI Tritium measurements indicate Tritium is pretty mobile

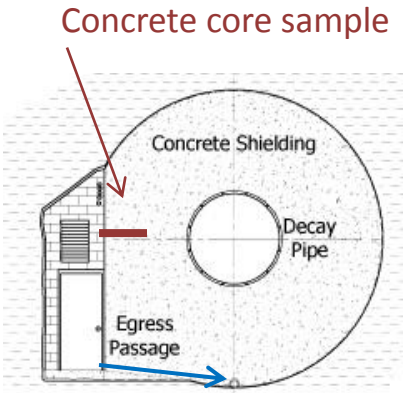
Tests:

- Cut off steel from plug in **target pile shield**, soak and measure tritium release
  - Tritium extraction had several month time constant
  - Significant release, but seemed somewhat below that needed to explain "extra tritium" (but sample was "good steel", not the poor quality blue blocks)
- **Target canister helium** sample
  - Tritium found in helium was six or seven orders of magnitude less than probably produced in the target - - hence suspect there was good transport through aluminum target canister, release into target pile air
- **Decay pipe helium** sample
  - Suspected that decay pipe steel tritium could evaporate into helium, like target pile release, and this could dominate. (Production is 9 Ci/1e20 POT in steel versus 0.1 Ci/1e20 POT in helium).
  - Sample after 16 months of running; found Tritium level in Helium gas was a factor of five below even the direct production from helium.
  - Does Tritium escape through upstream decay pipe window (1.6 mm thick Aluminum), and contribute to the "extra Tritium" ? Or absorb to steel?

Tritium from Target hall air deposited in decay passageway even at constant temperature/humidity



Mitigation: add dehumidifiers



Tritiated water deposited from air in passage goes to gutters to main drain to sump

Model that fits tritium deposition in passageway:

Assume water exchanges with walls and thus

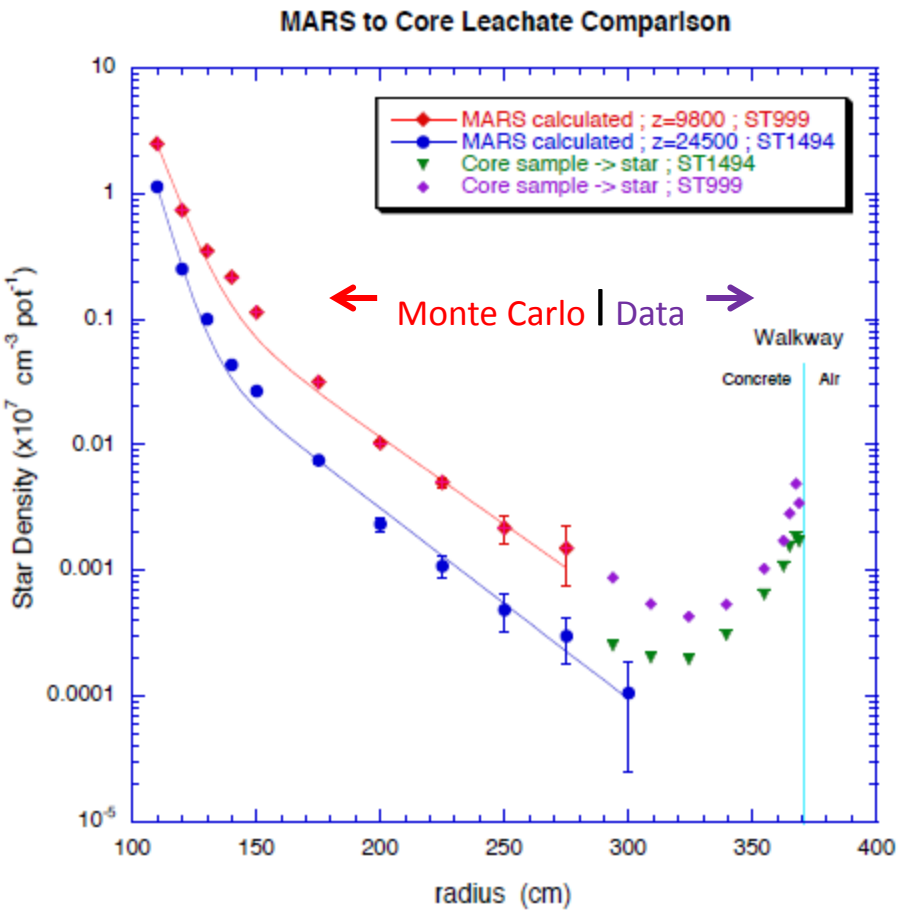
Tritium deposition is proportional to:

C	concentration in water	(pCi/ml)
h	humidity	(ml/cf)
a	wall area	(sq ft)
f	fraction of wall area that is damp	
t	time	(minutes)

Free parameter: k (deposition constant) ~ 0.1 (ft/min)

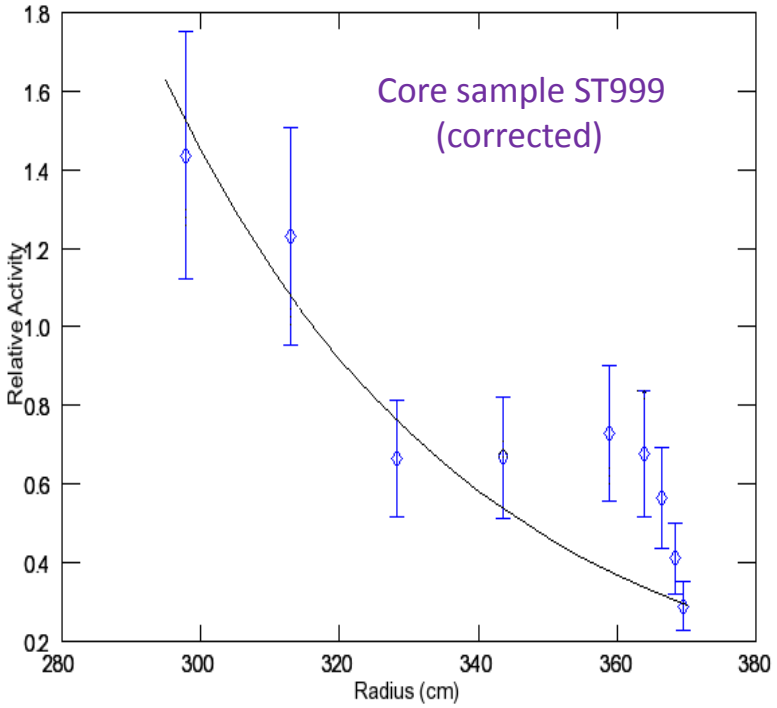
Target hall dehumidification reduced tritium to sump by a factor of 4

Saw deposited tritium also penetrate into concrete shield – but substantially reduced after dehumidification installed



BEFORE Dehumidification

Core samples taken by drilling into passageway concrete

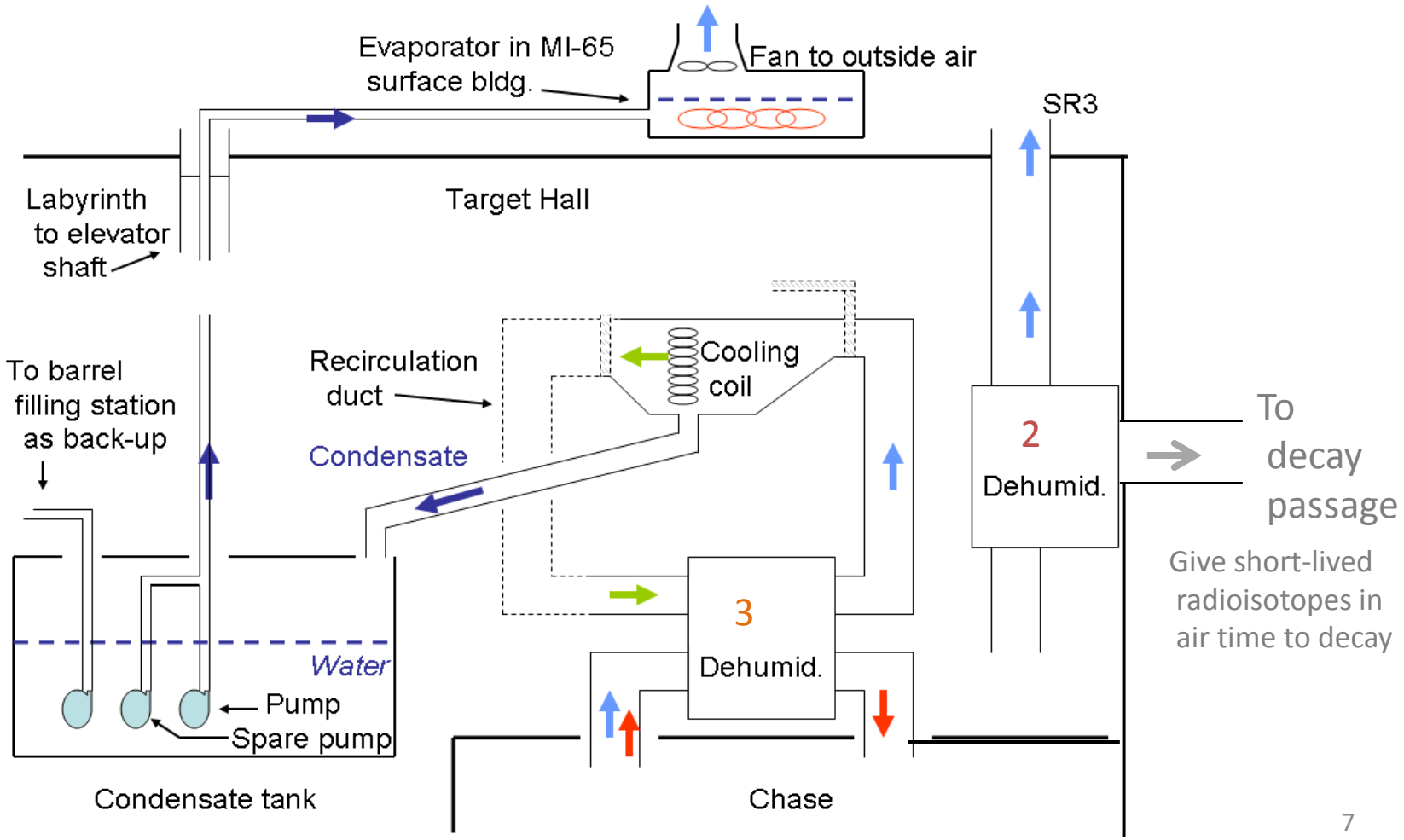


AFTER Dehumidification

(not normalized)

Systems to remove tritiated humidity

1) Collect Target pile air chiller condensate
2) Dehumidify Target hall air exhaust to decay passageway
3) Dehumidify chase (target pile) air recirculation system
4) Dehumidify absorber area, and air to passageway from that end



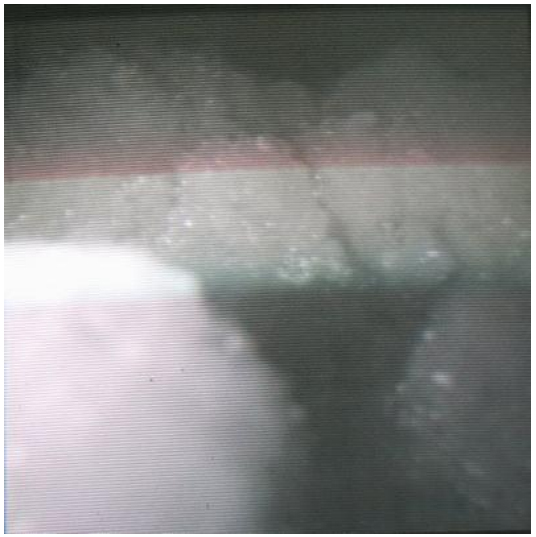
Some NUMI drainage systems are not directly accessible for cleaning

With drains partially clogged, extra water,
NuMI dehumidification systems less effective

Bio-slime in drains - can too much shielding be a bad thing?*

- Not enough radiation to kill the bio-slime

Don't have time to show the boroscope movie,
but the stuff jiggles and some floats around in the water flow



Used Sodium Hypochlorite to eliminate bio-slime in drain (improved water flow)

Planning to use vinegar to de-calcify drain, try to further improve flow

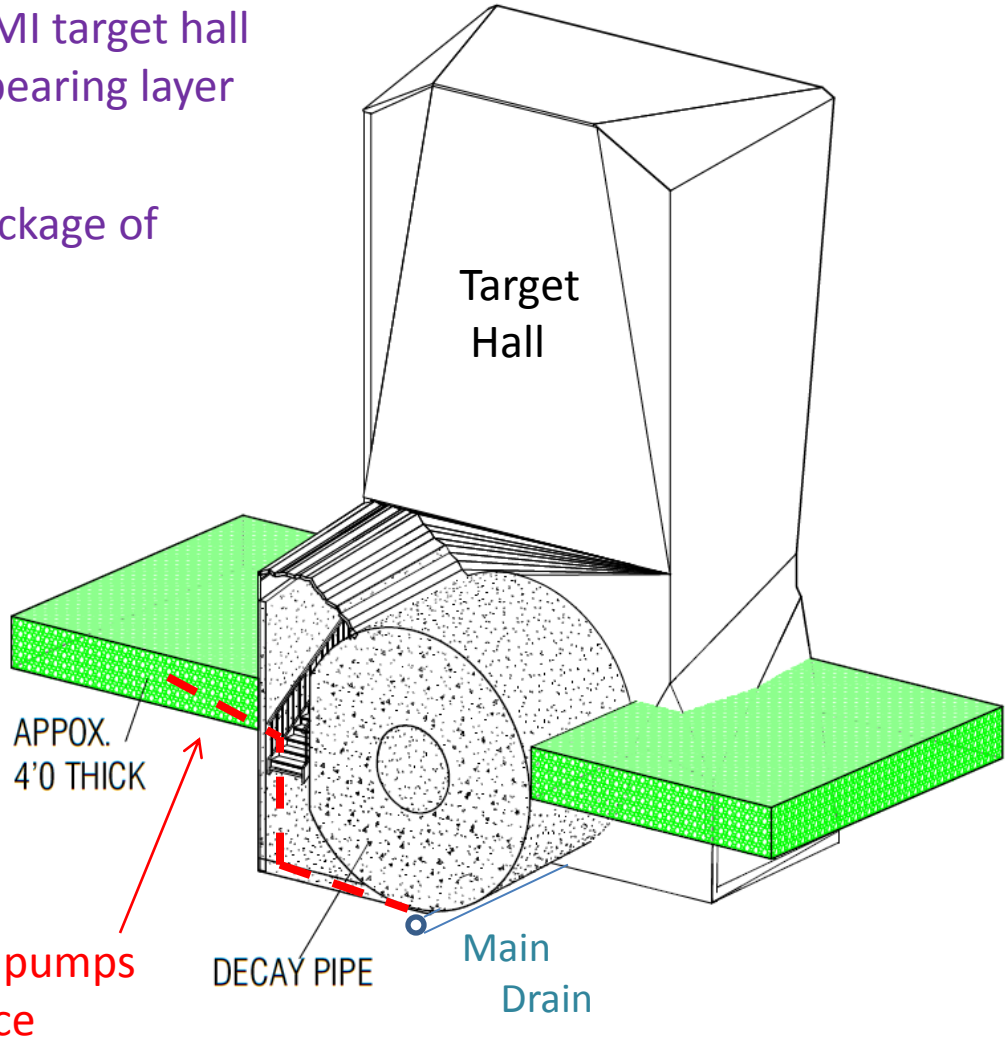
*(meant to be a bad physics joke)

Under consideration for reducing NuMI tritium transport to sump

Reduce water pressure around NuMI target hall by giving drainage path for water-bearing layer

(crudely, compensate for some blockage of drain system)

water-bearing layer that has higher hydraulic conductivity than rest of surrounding rock



Drill a few holes, route water to gutter/sump that already pumps 140 gallon/minute to surface

Note on target hall air

Radiation + humid air -> nitric acid, ozone, …

The dehumidification & cooling systems have taken a fair amount of maintenance

Condensing/cooling coil with aluminum fins after a few years

-> replaced with stainless steel

NuMI Tritium experience

Some lessons learned:

- tritium evaporates from steel and other solids
  - (and transports through aluminum DK window?)
- NuMI could have used one more layer in the target pile onion;
  - for LBNE design: added a geo-membrane
- should design drains that have adequate access for maintainability
- damp passageway can be tritium sieve
  - For LBNE design: exhaust of air will be through drier area