Neutron Shield/Muon Veto (WBS 1.3)
and
Underground Installation Issues (WBS 1.6)

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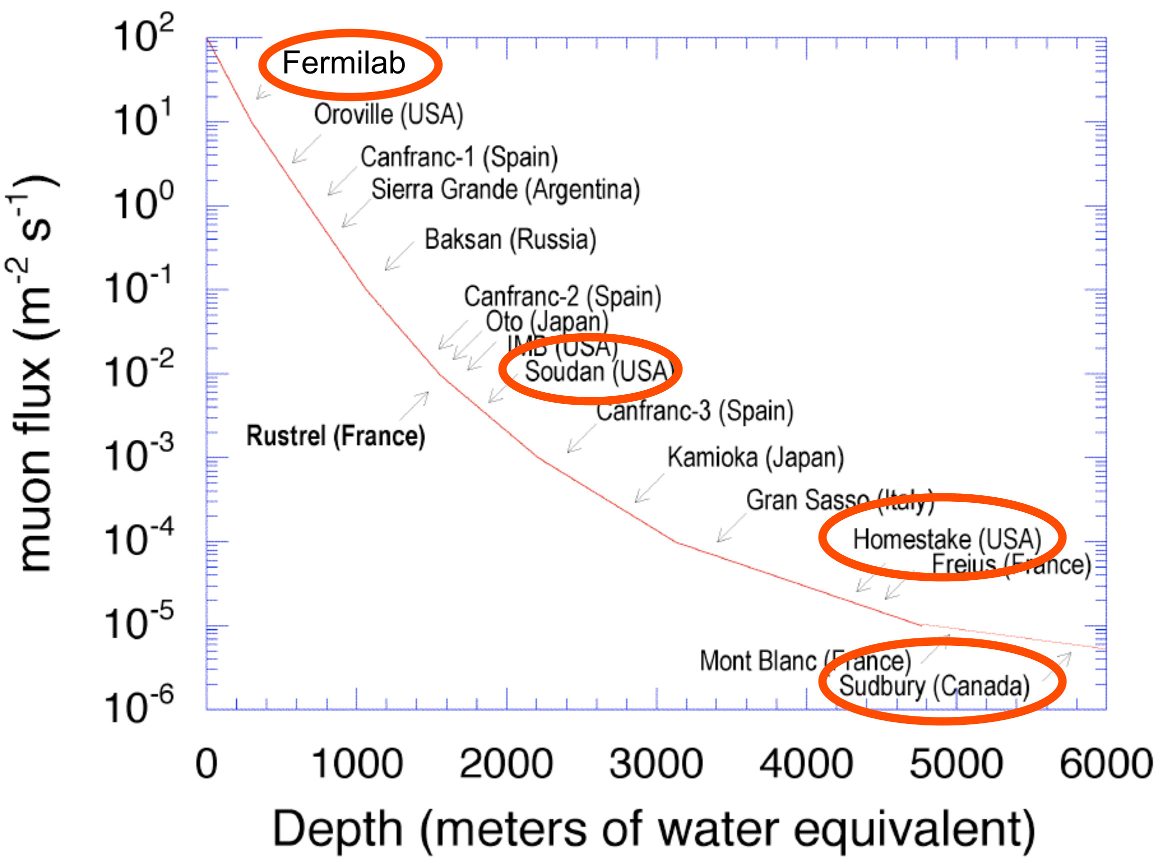
Why a shield, why a veto, and why go underground?

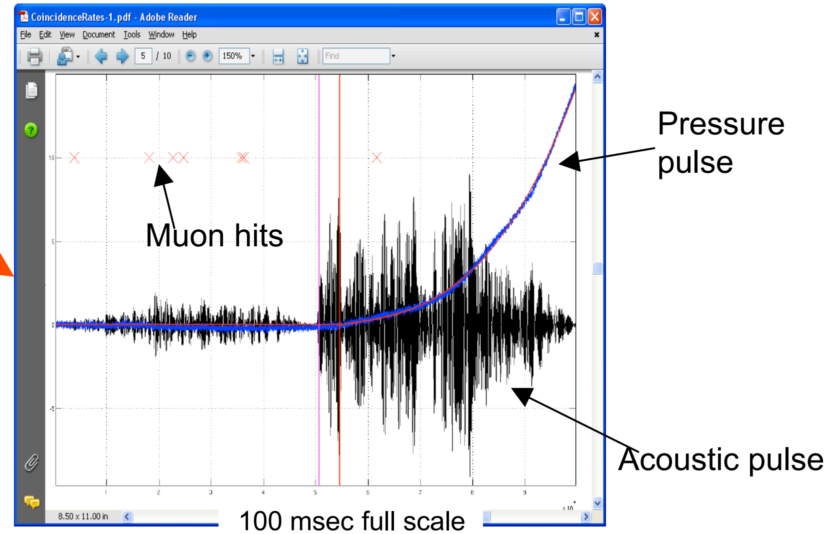
- At the surface, there are more than 100 muons per square meter per second traversing the detector. In addition, there is a large flux of hadrons, including neutrons.
- It is predicted that this stream of particles would cause thousands of nuclear recoils per day in our 60 kg detector. This would challenge the efficiency of any veto system.
- Thus we need to shield the detector and go underground to reduce this background.

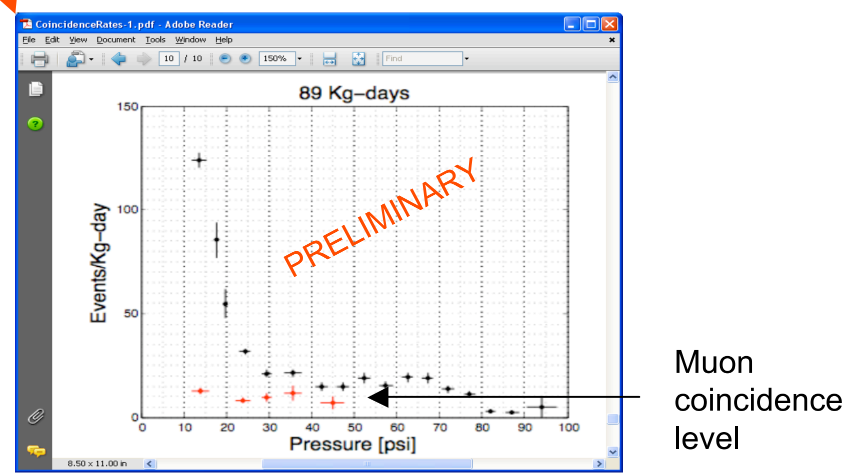


Muon veto requirement

- In the MINOS tunnel, for the 2 kg chamber, we observed about 5-10 events/kg/day in coincidence with the muon veto.

- Then, for a typical run of the 60 kg chamber, for 200 days:
  - **At MINOS**: this translates to ~100,000 cosmic background neutrons in this type of run. **No realistic veto will work.**
  - **At Soudan**, we would expect a reduction of about 10^3 in rate, or ~50-100 cosmic ray induced events in the run. (CDMS results are consistent with this background estimate.) **A cosmic ray veto is necessary and most solutions will work.**
  - **At SNOLAB**, the cosmic ray rate is reduced to irrelevancy- less than 1 event in 200 days. **No cosmic ray veto is necessary.**





Neutron shielding requirement

- Neutrons also arise from spontaneous fission and (α,n) reactions in surrounding materials such as the rock walls. This occurs at the level of 15 events/kg/day.
- Shielding with 50 cm of hydrogenous material can reduce this by a factor of x1000.
- However, shielding with polyethylene could become a dominant environmental background.
- Our default choice is to use water for shielding

COUPP-Proposal.pdf - Adobe Reader

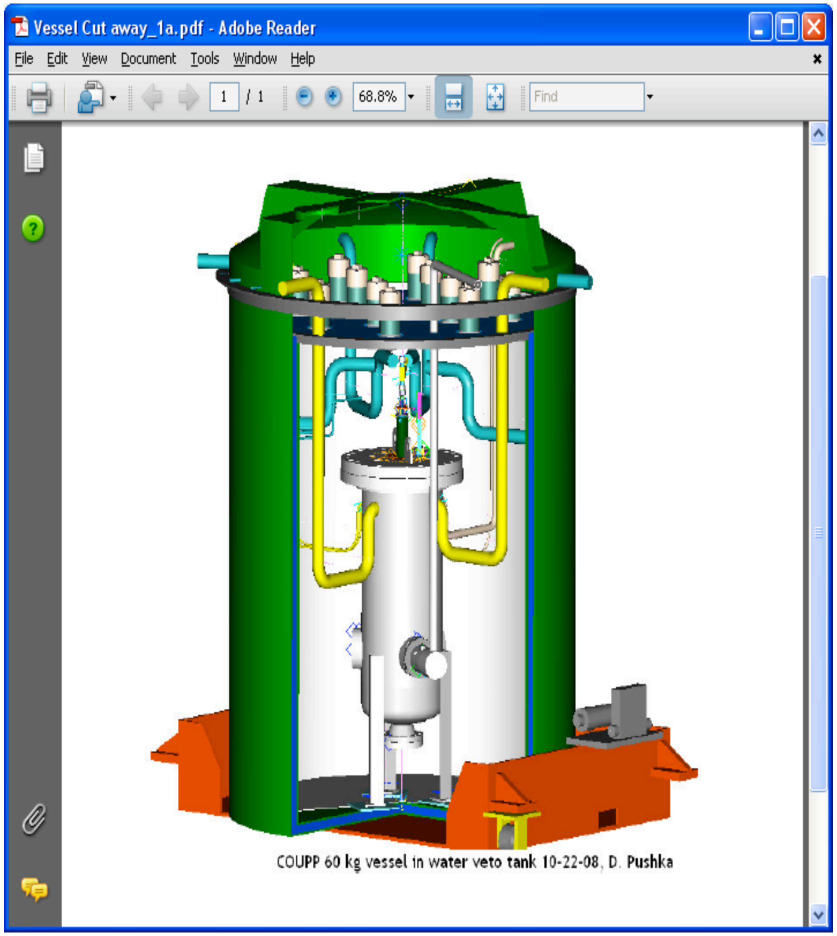
	Poly. (α,n)	Poly. (SF)	Steel (α,n)	Steel (SF)	Min. oil	Quartz
U,Th (ppb)	10	10	2	2	$<10^{-4}$	0.01
Mass (kg)	1.06×10^{4}	1.06×10^{4}	250	250	75	10
Alphas/day	1.06×10^{9}	n.a.	5×10^{6}	n.a.	<75	10^{3}
Yield (n/α)	1.7×10^{-7}	n.a.	4×10^{-9}	n.a.	1.7×10^{-7}	2.5×10^{-7}
n's / day	180	120	2×10^{-2}	0.56	$<1.3\times10^{-5}$	2.5×10^{-4}
(1) Events /50 kg /day	0.07	0.012	7.7×10^{-4}	0.01	$<1.5\times10^{-6}$	9.1×10^{-5}
(2) Singles /50 kg /day	0.016	3.1×10^{-3}	1.9×10^{-4}	2.8×10^{-3}	$<3.7\times10^{-7}$	2.3×10^{-5}
(3) Singles in Fiducial Vol. /50 kg/day	3.9×10^{-3}	5.2×10^{-4}	3.4×10^{-5}	5.0×10^{-4}	$<7.3\times10^{-8}$	3.5×10^{-6}
(4) Irreducible rate /100 kg-yr	8.5	1.2	0.075	1.1	$<1.6\times10^{-4}$	7.7×10^{-3}

Table I: Expected neutron backgrounds due to internal radioactivity. This table shows the results of a Monte- Carlo simulation of an array of 5 x 50 kg CF_3I bubble chambers surrounded by 50 cm of polyethylene. Contributions to the neutron flux from

From COUPP proposal (2006)

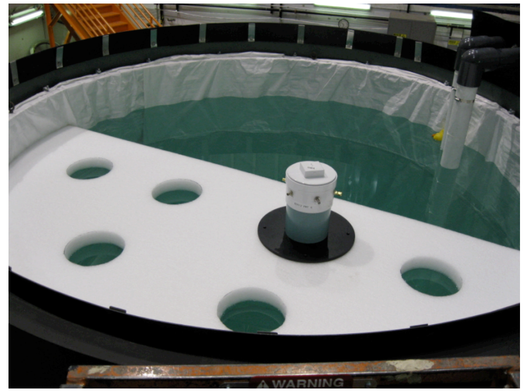
A Water Tank Veto/Shield for E961

- We decided to go with an inexpensive solution - a solid polyethylene water tank with Tyvek liner that would act as:
  - Neutron shielding
  - Cerenkov muon detector
  - Heat bath for controlling the temperature of the experiment.
- This tank cannot fit down either the Soudan or SNOLAB shaft.
- An engineering note has been written outlining a design for a water tank that can be assembled from thin steel sheets, which are narrow enough to fit down a mine shaft.

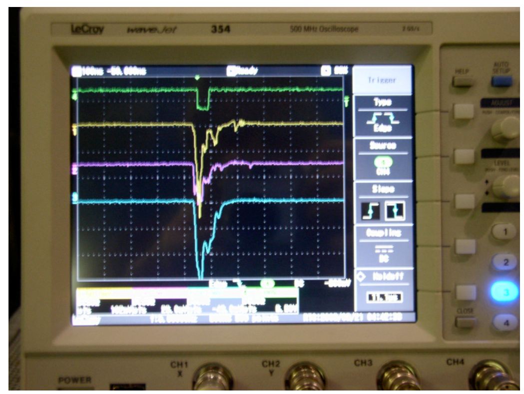


First cosmic ray observations in the E961 water shield

The tank was in operation with three PMT's and at desired temperature (40 C) for several weeks



The full system has twelve 9" PMT's and a floating raft to hold them. Readout will be with a CW digitizing base

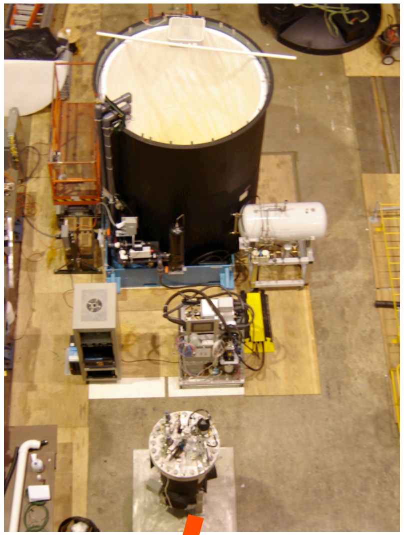


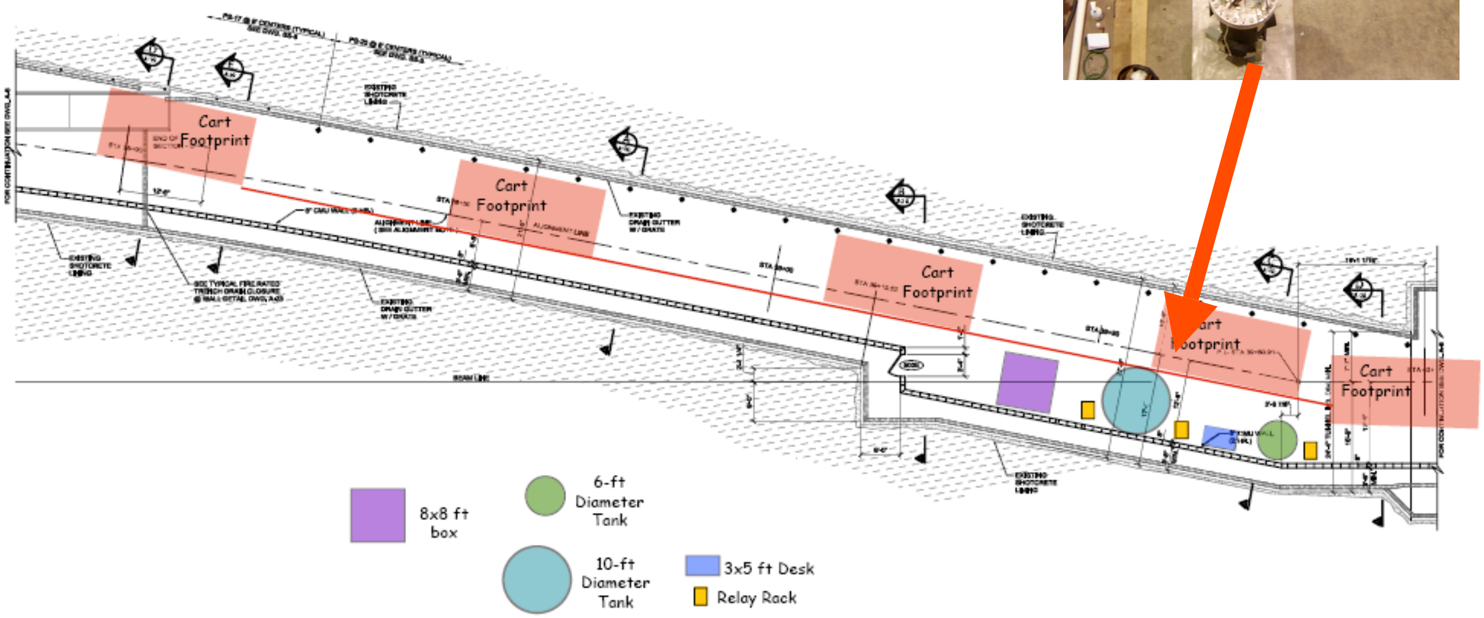
Pulses in the 3 PMT's, with a scintillator telescope trigger selecting for muons crossing the tank.

- Light yield of >10 p.e. per tube is what was predicted from a smaller test chamber
- The light yield should improve as we learn how to keep the water pure.
- One unknown is whether the detector will shadow the light from reaching the PMTs

MINOS Tunnel Installation

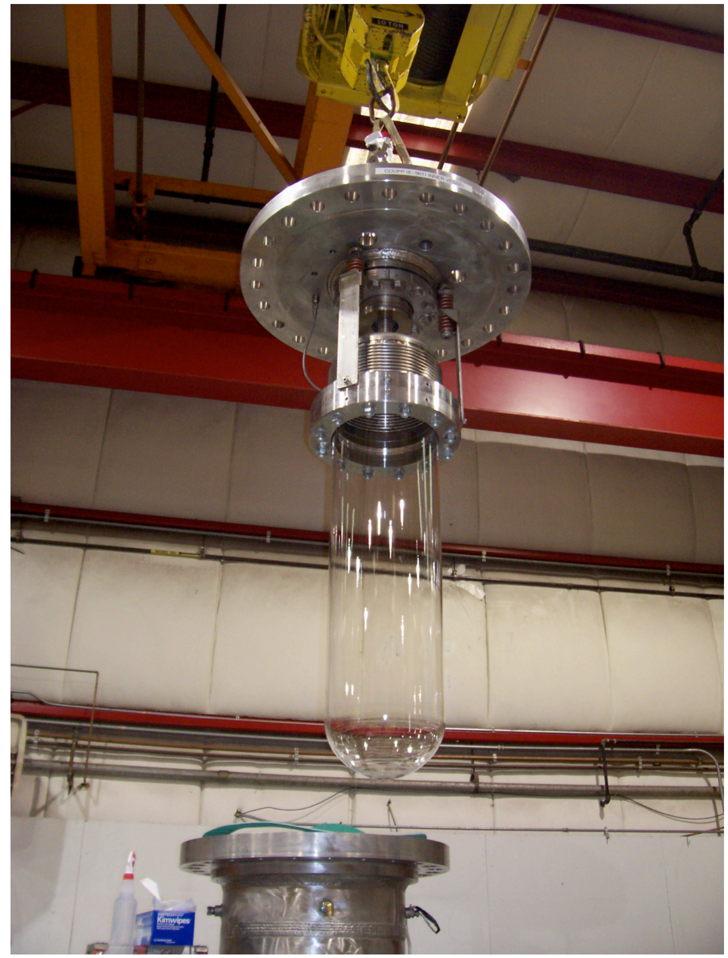
- We have arranged for space in the MINOS tunnel at Fermilab, at a depth of 300', for our initial run.
- We are beginning to address safety issues in the tunnel that likely will translate to a deeper site.





Assembly requirements

- There are three significant installation steps for the 60 kg detector:
  - Cleaning of inner vessel.
  - Assembly of clear vessel with flange and bellows.
  - Insertion of vessel assembly
- We are sending out the pieces for cleaning.
- We have a class <100 clean room for assembly of the vessel with the bellows.
- The insertion stage for the MINOS location will be above ground, but for a deep site, it will be at the final detector location.
- This requires a minimum of about 17 feet hook height, with a gantry or monorail crane.



Infrastructure requirements

- A water tank of approximately 10’ diameter and 10’ high needs to be assembled underground.
- Height requirement:
  - Minimum hook height requirement >17’ for installing the inner vessel into the outer vessel.
  - A hook height of >20’ would allow the inner vessel to be removed from a water tank.
  - A hook height of >23’ would allow the removal of the full bubble chamber from a water tank, without disassembling it.
- A monorail crane or gantry is required for moving the vessel and detector short distances.
- The footprint for the detector and associated electronics is approximately 12’ x 20’
- Power requirements:
  - One 240V, 50A circuit, for the water pump and heater.
  - Three 120V, 20A circuits
- A compressed air line is required.
- Safety infrastructure to meet site requirements
- Networking: Offsite access to our server is required
- Detector accessibility: besides normal day shift access to lab and underground, we need emergency access to be available.

Deep underground site options

- Operating solely in the MINOS tunnel would require a hermetic muon veto with at least 10^{-4} inefficiency. This difficulty can be circumvented by going to a deep underground site.

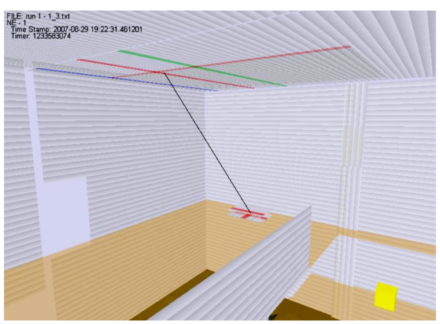
- There are 3 options that we have contemplated
  - Soudan Underground Lab
  - SNOLAB
  - Homestake

- COUPP collaborators have visited each site and we have begun conversations with lab personnel at Soudan and SNOLAB

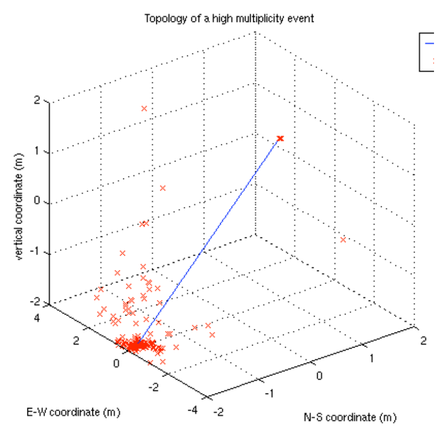
Soudan Underground Lab

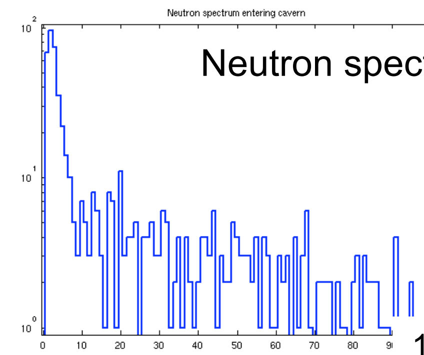
- The Soudan cavern is 100’ x 35’ x 40’, contains an overhead crane, and is surrounded by a wire proportional tube muon tracking system. This space is currently available.

- The wire tracker has been under study and is being compared to a Monte Carlo simulation for cosmic ray muons and the neutrons they generate:



Real event display

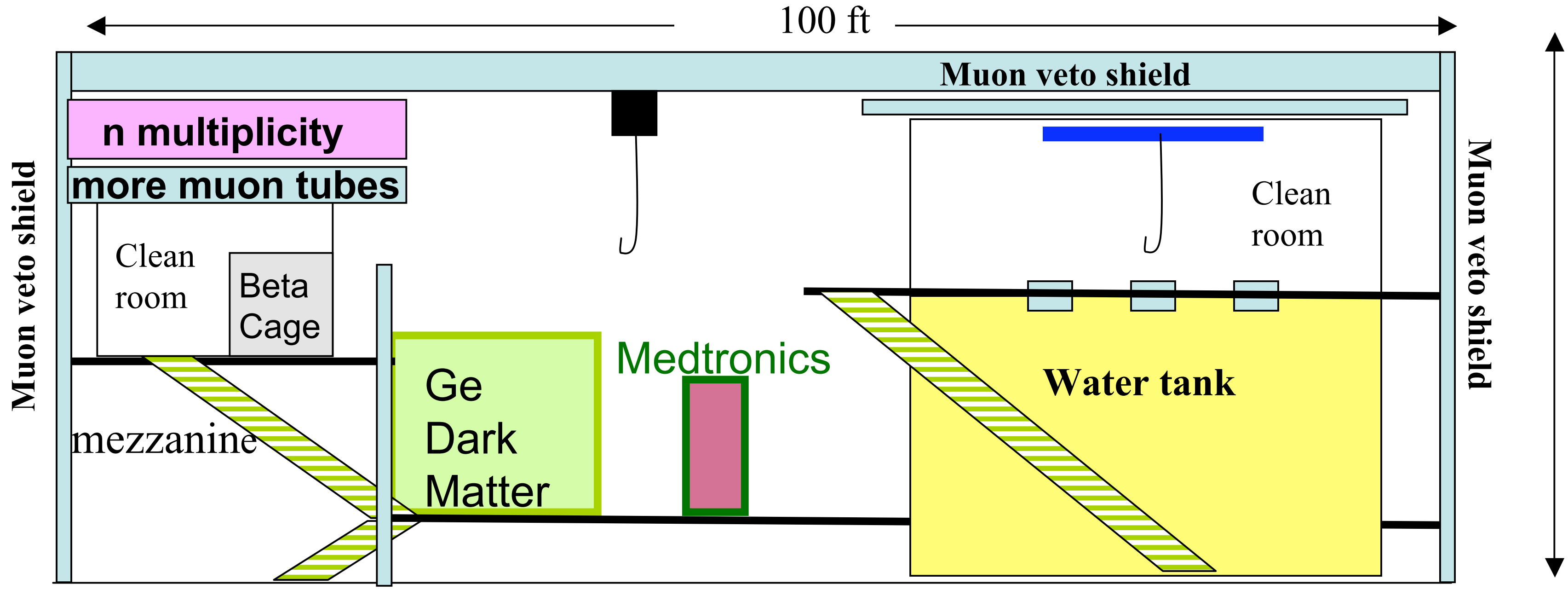




Monte Carlo results

SOUDAN Upgrade

- A proposal has been made to install a large water tank in the hall to generally support experiments that need shielding.
- It is unlikely this would be appropriate for COUPP because we use our water for thermal regulation.



SNOLAB Facilities

- A visit was made to SNOLAB in December, 2008.
- Discussions for possible SNOLAB installation have been made with Tony Noble, director.
- We were visited by chief engineers in May, 2009

Purified water facility

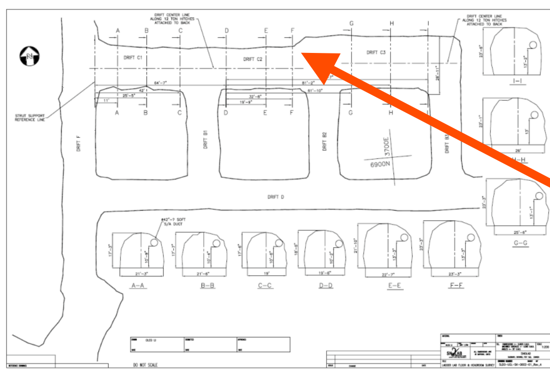
Air lock for deliveries

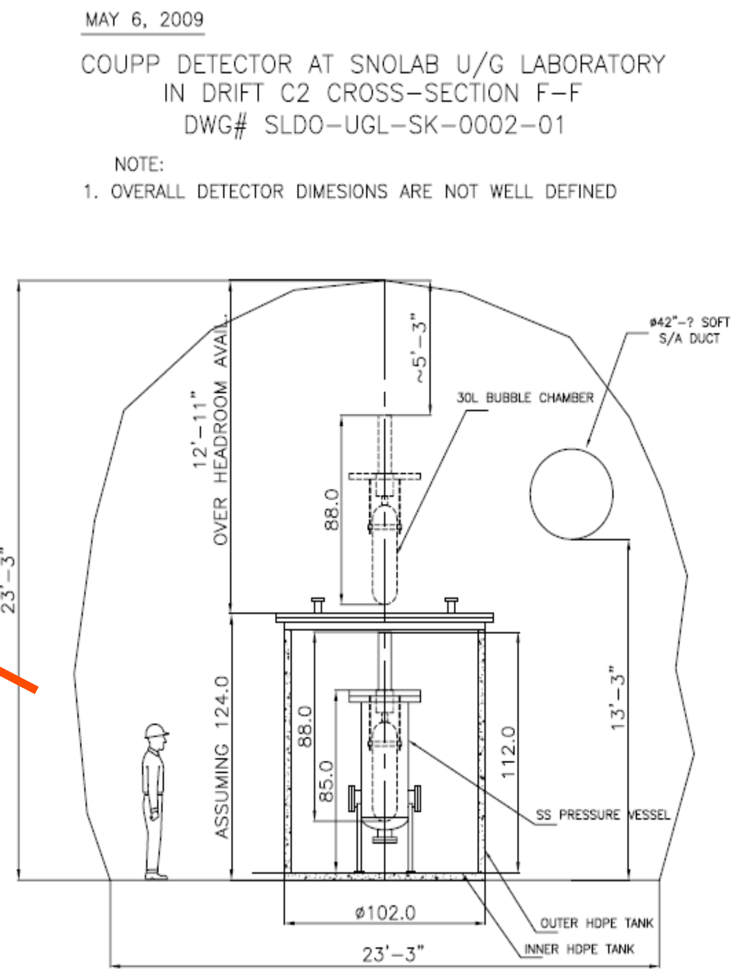
Surface clean rooms

Radon counting facility

SNOLAB Ladder Lab location

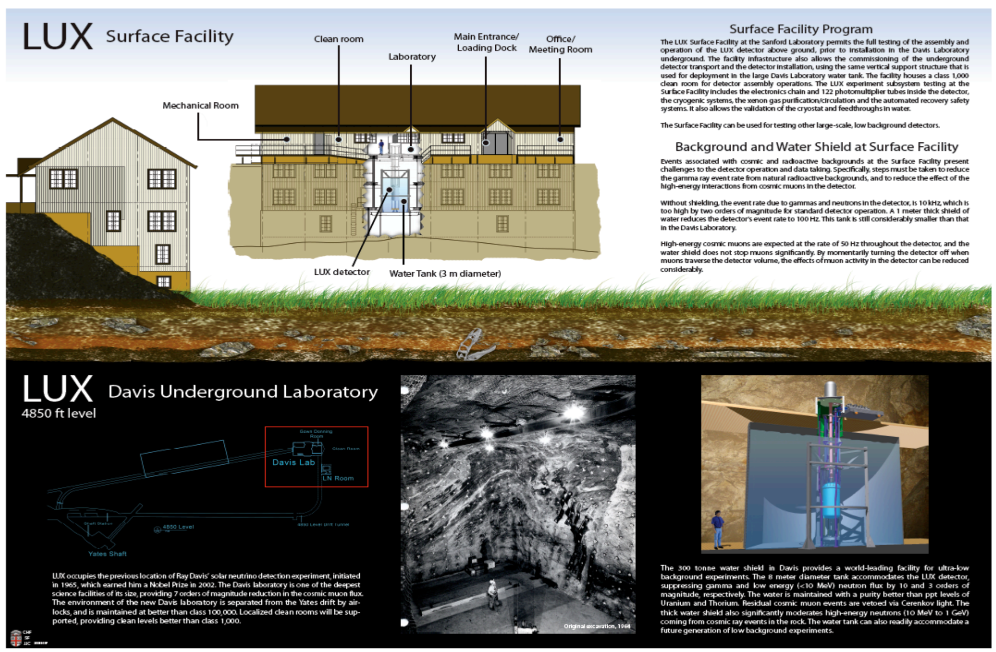
- Consultations with SNOLAB engineering staff have resulted in a possible layout in one of the 'ladder lab' locations.
- Size of water tank might be constrained in this location, but this would not impact physics.
- Pure water is available for filling tank.
- Utilities have not been installed yet.





Homestake

- 4850’ level (Davis cavern) is almost pumped out
- Assessment of safety status will begin after the Davis cavern is clear.
- LUX will be the first dark matter experiment at Homestake – They plan on a run above ground in Fall, 2009.
- LUX will have a very large water tank (8 meter diameter) for their detector. This tank will fill the Davis cavern.
- We believe that the time scale for installation in Homestake is not appropriate for the next stage of COUPP.



Basis for comparison for deep site installation

- Utility installation as needed
- Safety equipment installation
- Underground construction of water tank
- Transportation of detector to site
- Move detector underground
- Operations cost
- Technician cost
- Travel
- Other?

A comparative report for Soudan and SNOLAB will be available in mid-July