Controlling ^{222}Rn ingress in the SNO+ detector

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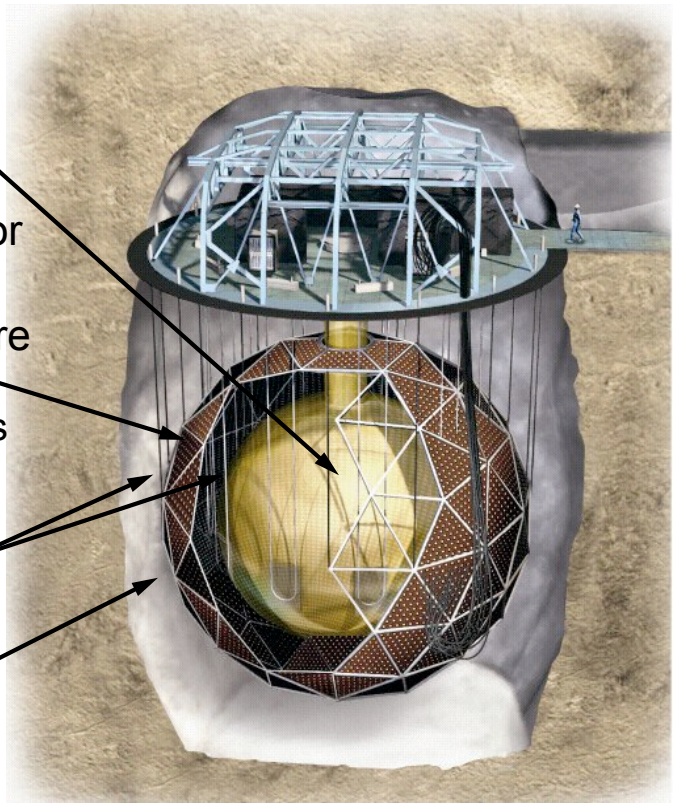
CAP 2014, 20 June 2014

SNO+ Physics



Neutrinoless double beta decay

Low energy solar neutrinos

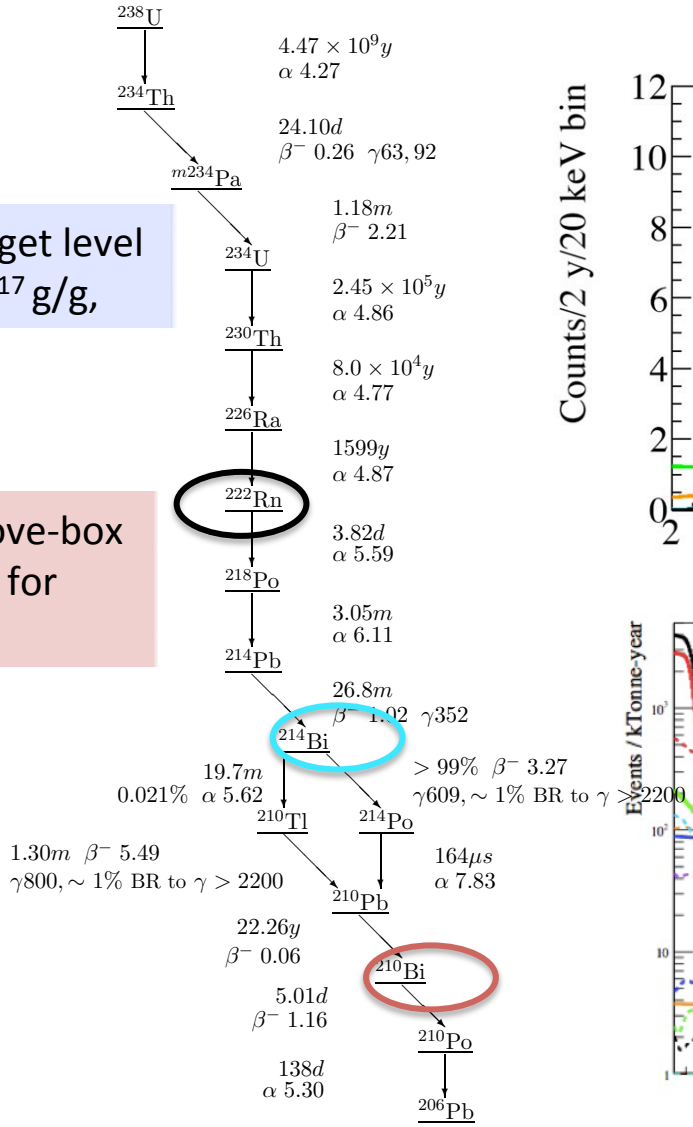
Reactor/geo anti-neutrinos

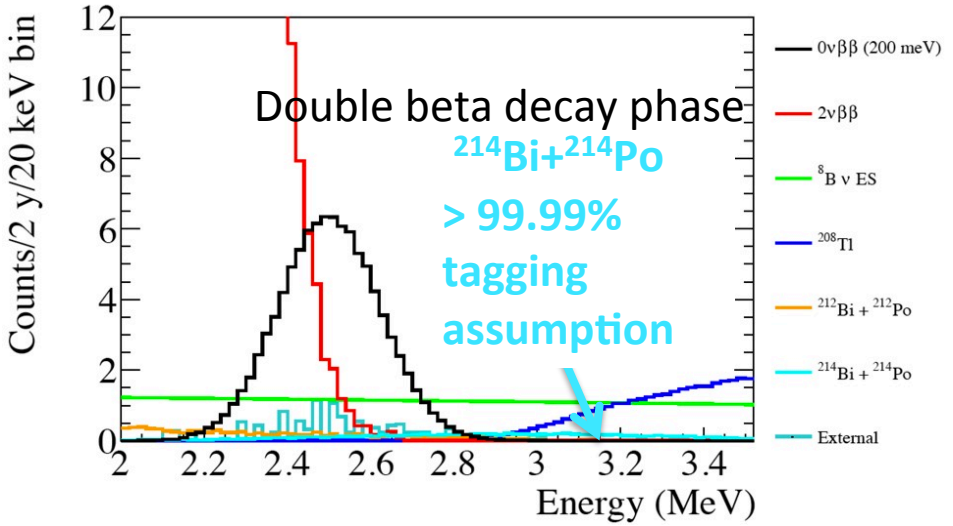
Supernova neutrinos

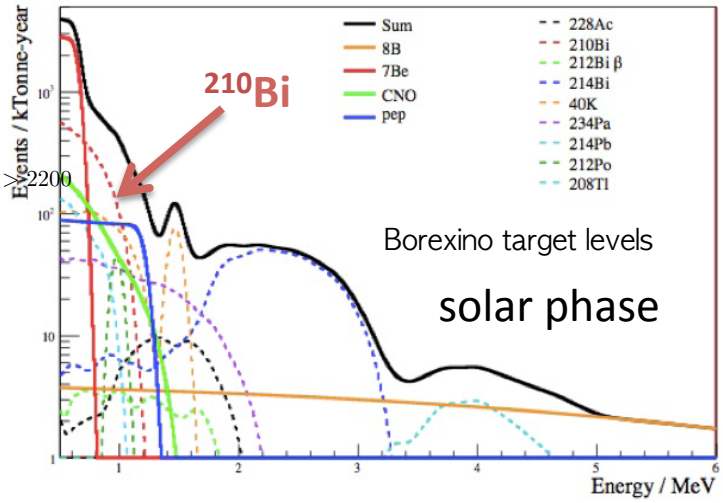
Backgrounds from ^{222}Rn

Liquid scintillator target level (Borexino): ^{238}U ~10^{-17} g/g,

New radon-sealed glove-box and cover gas system for ^{222}Rn reduction





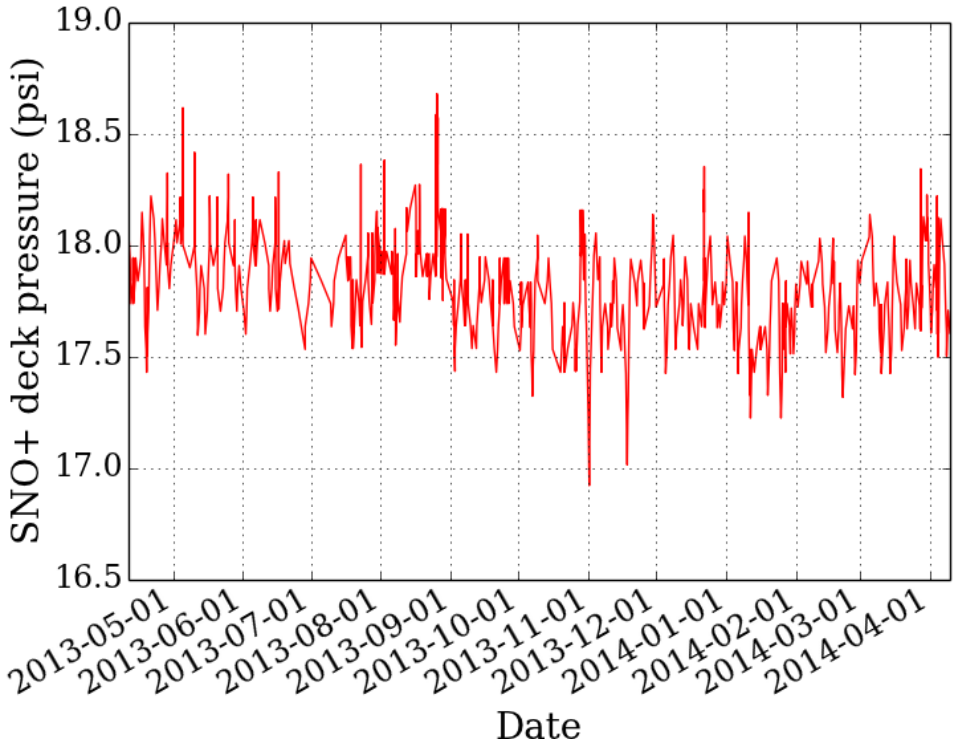


^{222}Rn control

- SNOLAB radon level is ~ 6 x10^7atoms/m^3
- Acrylic vessel (AV) neck provides between factor of 50 to 100 radon reduction
- Target radon ingress inside the detector < 5000 atoms/year (5.5 atoms/m^3)
- Top of the AV needs to be filled with Nitrogen (cover gas) to provide factor of ~ 10^5 reduction factor
- Target radon level inside of the cover gas is 650 atoms/day (270 atoms/m^3)

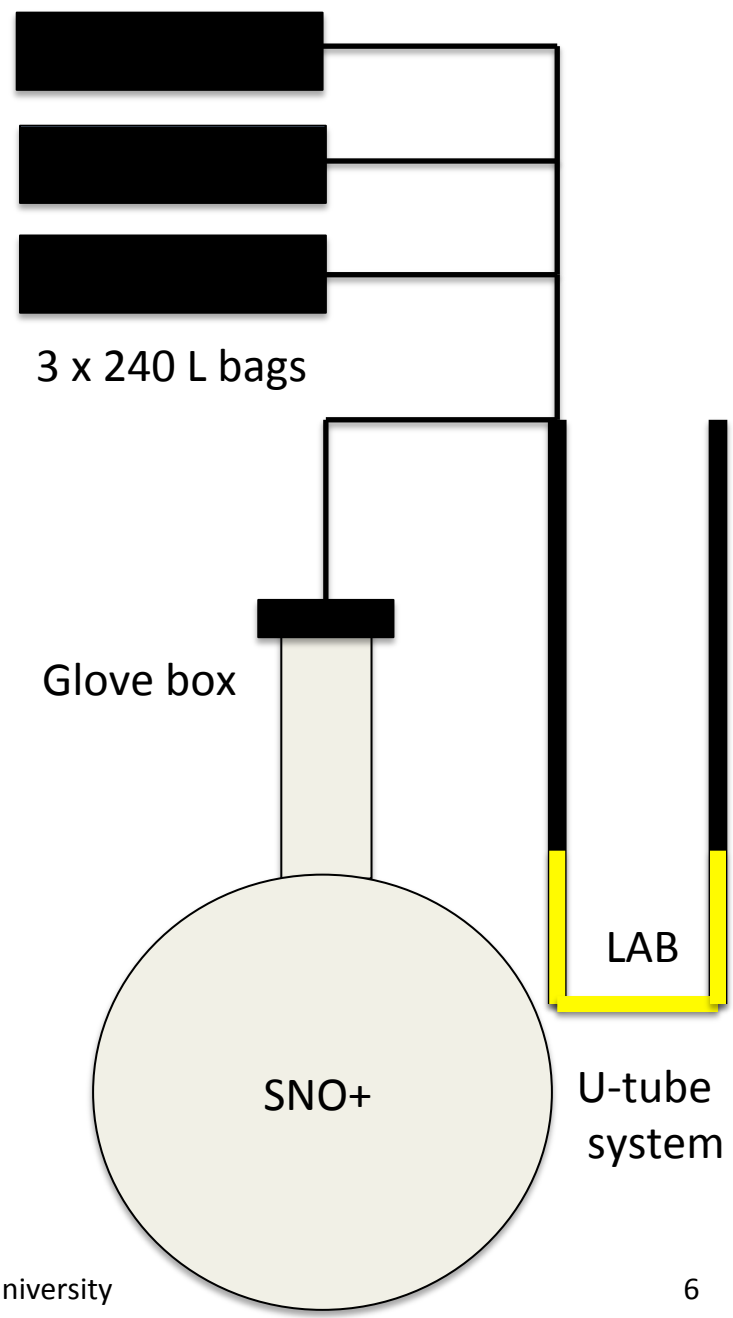
Design approaches

- Flow through system: Most experiments (including SNO) flow the cover gas over the volume
  - Pressure fluctuation in the mine (6%) can change the radon level in the cover gas
  - Does not make the SNO+ radon requirement
- Sealed system
  - Radon ingress from the mine can be zero
  - The system is subject to pressure swings
  - All the components have to have low radon emanation/permeation



SNO+ sealed system

- Designed and built by Queen's and is the first such system
- Adapt to ambient pressure swings
- Minimize radon ingress
- Main components
  - Flexing bags (3 x 240 L)
  - Failsafe (pressure relief) system
  - Electro polished stainless steel tubing (5 cm diameter)



Bags radon emanation, flexing and over pressure tests

- Material from DuPont (inside to outside: nylon, aluminum, thin layer of low density polyethylene)

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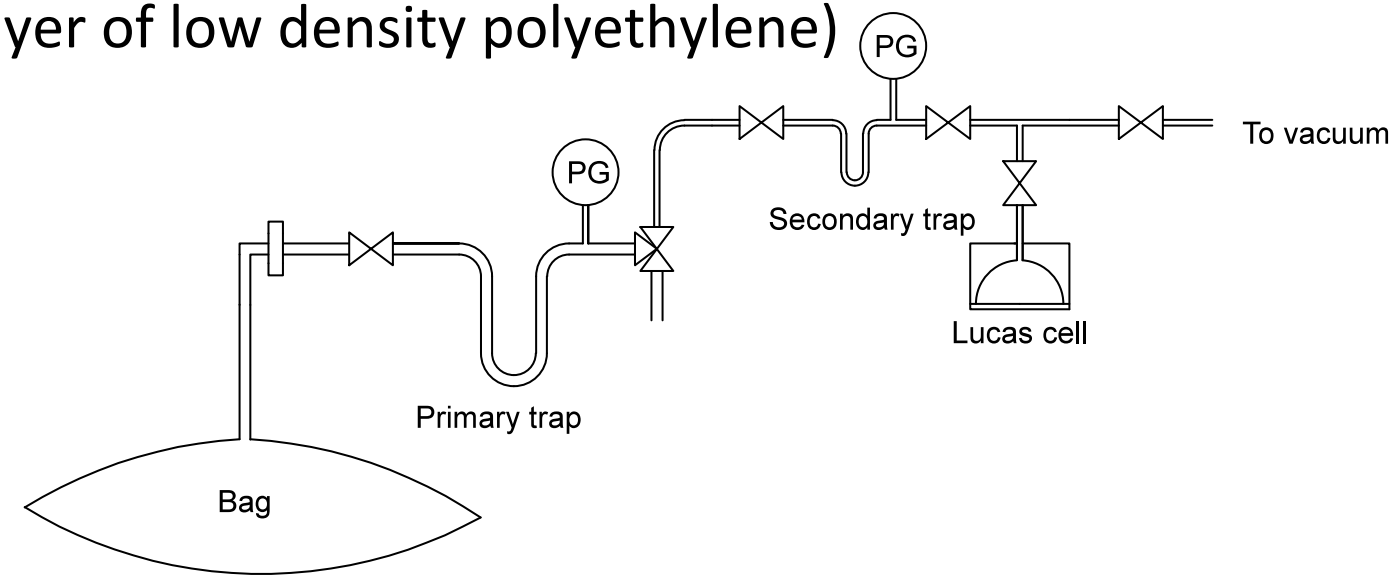
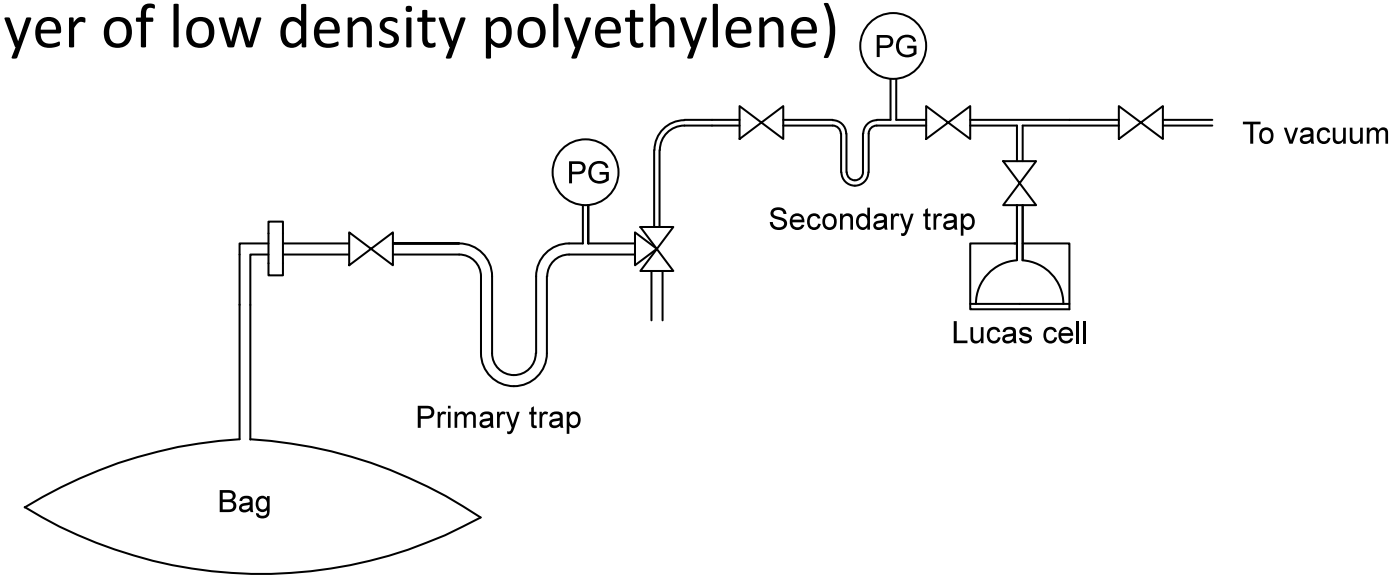


- A bag was filled with helium and left for 3 half-lives of radon
- The emanated radon atoms were trapped by liquid nitrogen and extracted to a Lucas cell (ZnS scintillator)
- Radon decays observed with a PMT.

Bags radon emanation, flexing and over pressure tests

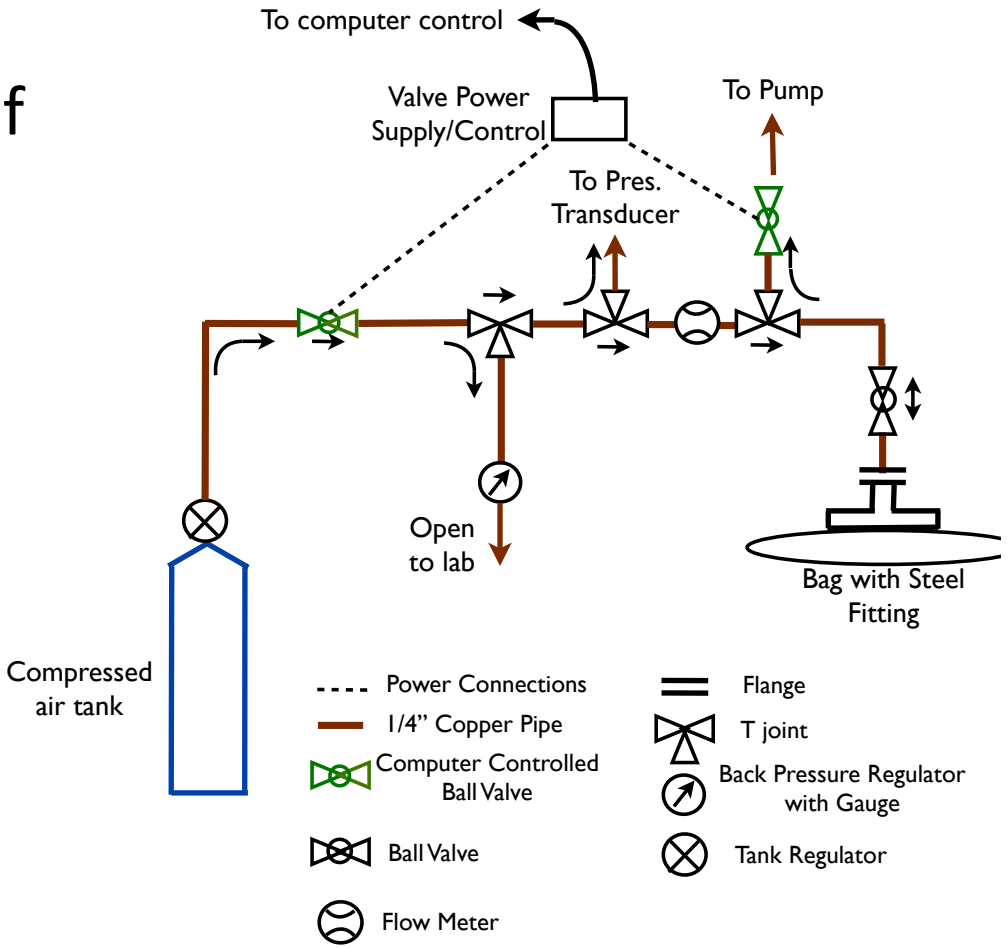
- Material from DuPont (inside to outside: nylon, aluminum, thin layer of low density polyethylene)



Radon emanation from 3 bags:
230± 83 atoms/day

- A smaller size bag was inflated/deflated for total of 1500 times and leak checked for pin holes
  - Leak < 1 x 10^{-7}mbarL/s

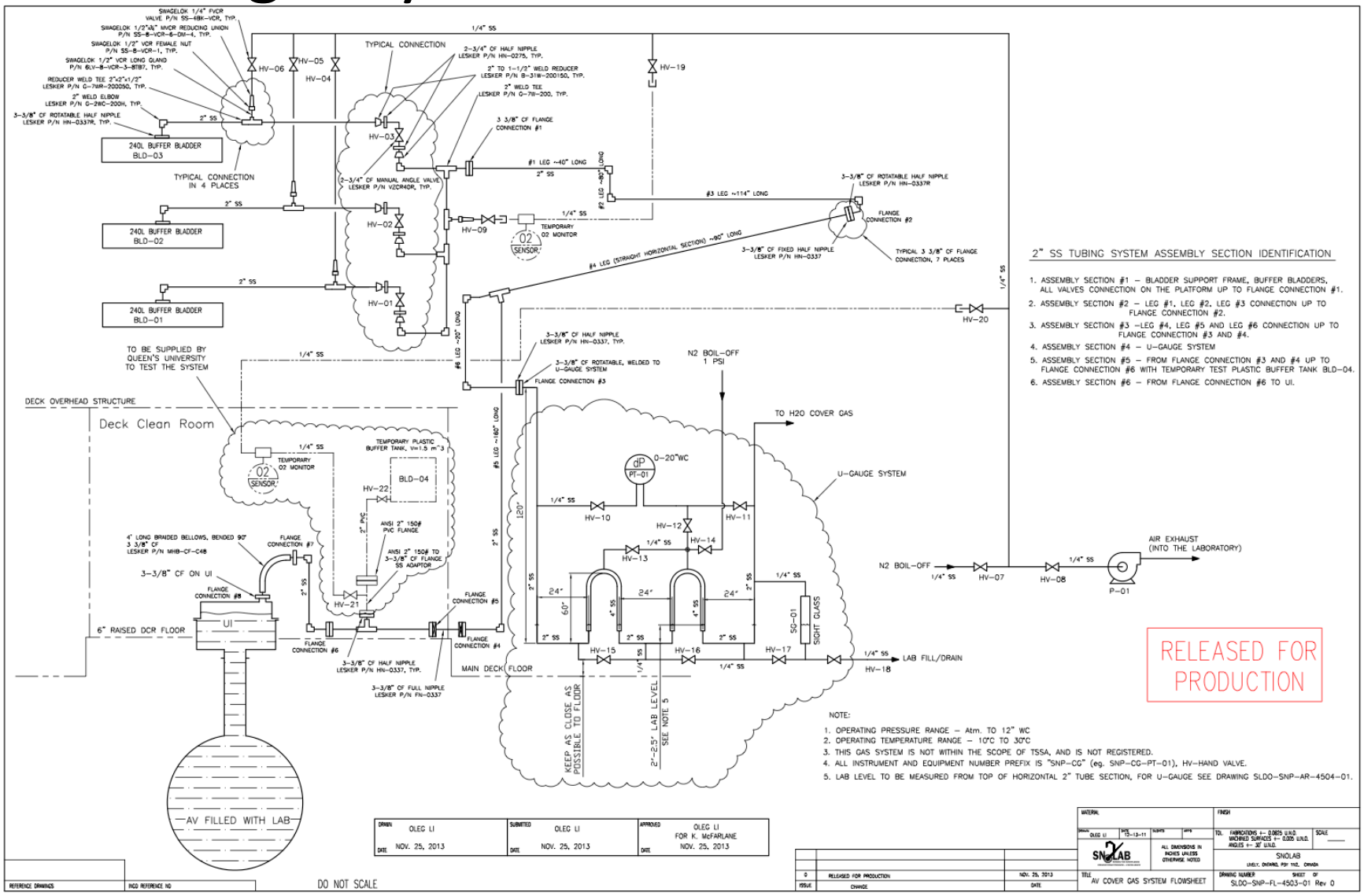
- A full bag was over pressurized up to 0.4 psi (failsafe system gets activated at 0.26 psi)

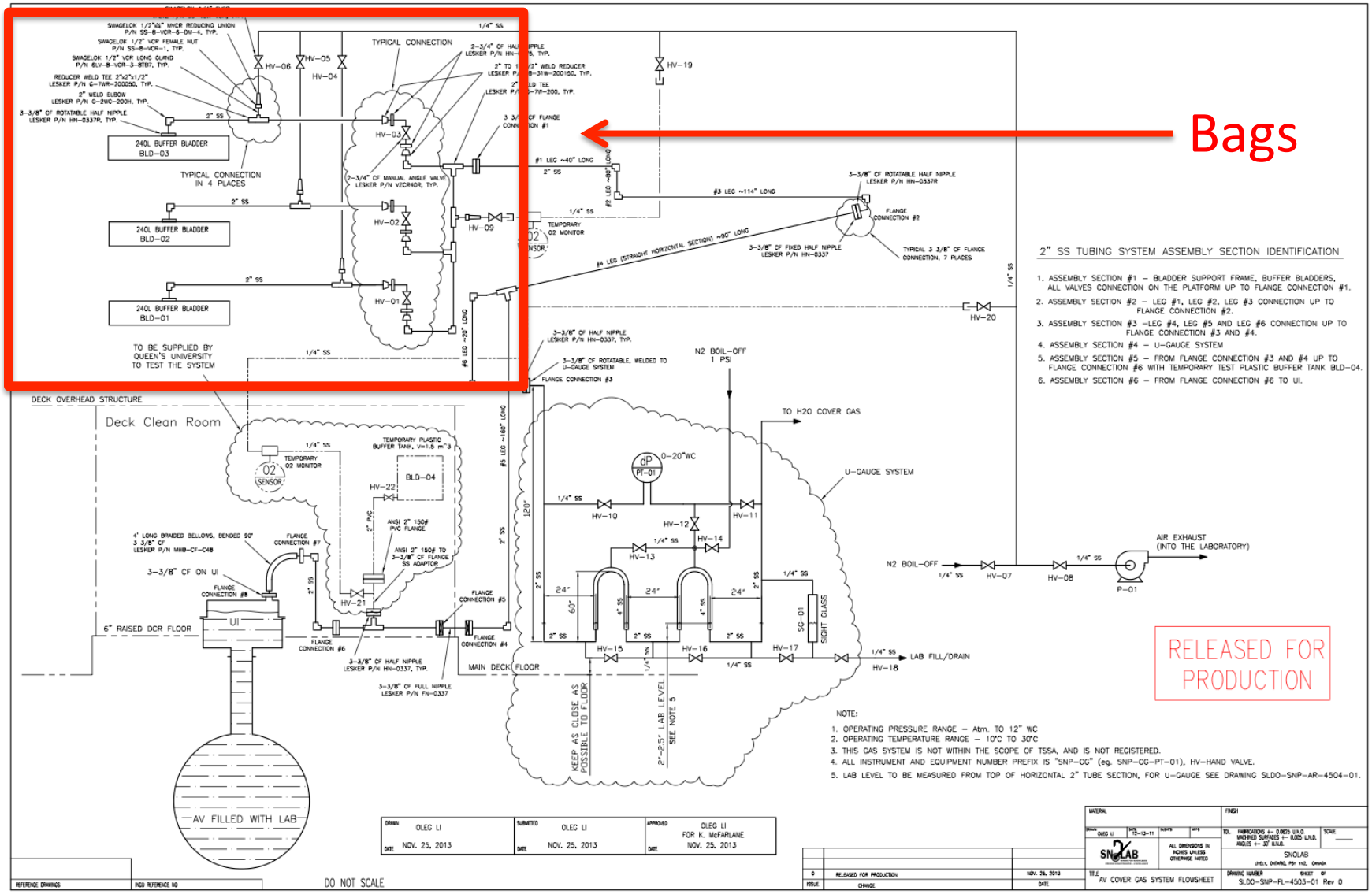


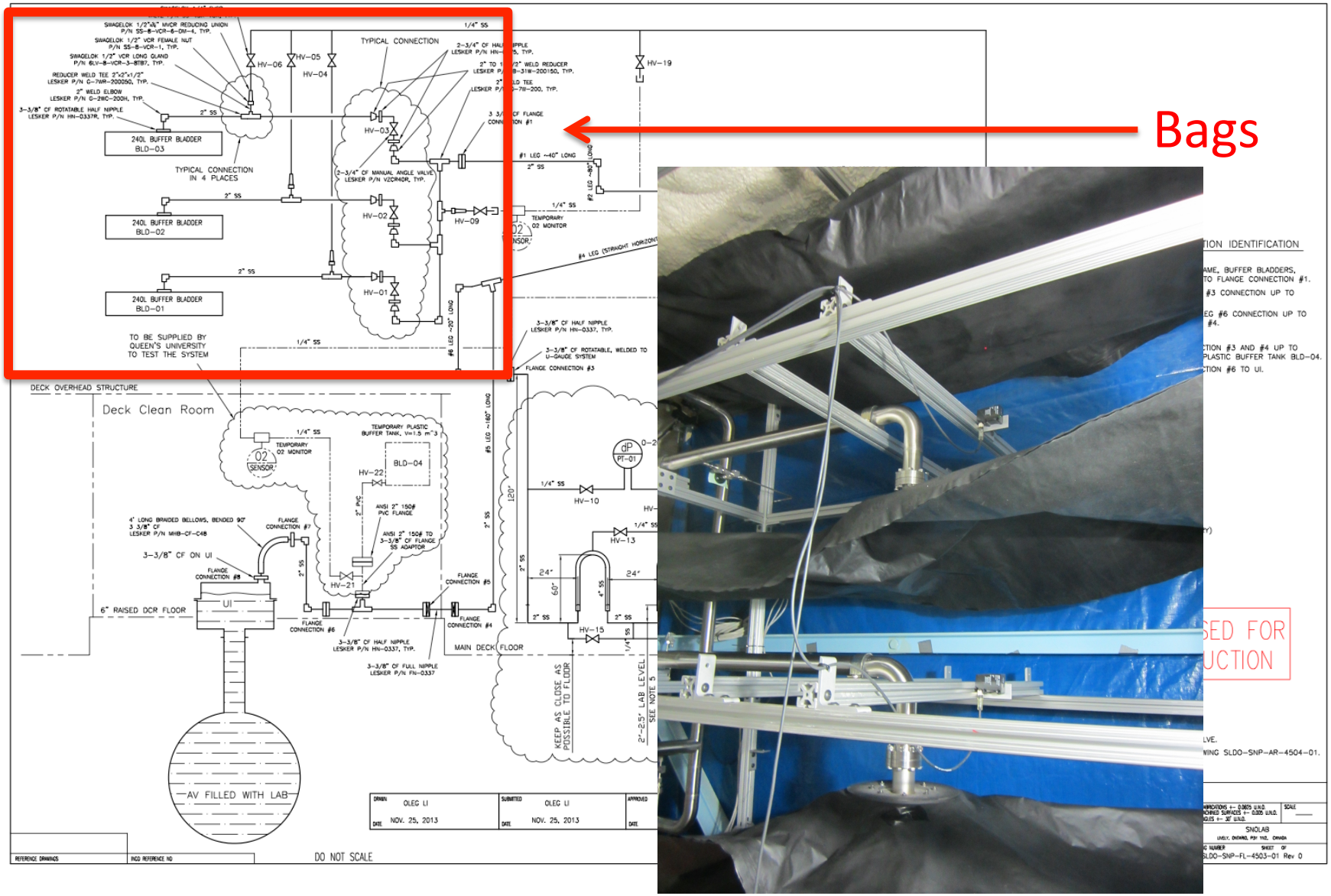
Bags fabrication

- Bags were made using a heat sealer
- They were sprayed with rubberized material for protection against pin holes
- Bags were leak checked once at Queen's and once at SNOLAB
  - Leak rate: < 1 x 10^{-7}mbarL/s

Cover gas system installation




Bags
2" SS TUBING SYSTEM ASSEMBLY SECTION IDENTIFICATION
1. ASSEMBLY SECTION #1 – BLADDER SUPPORT FRAME, BUFFER BLADDERS, ALL VALVES CONNECTION ON THE PLATFORM UP TO FLANGE CONNECTION #1.
2. ASSEMBLY SECTION #2 – LEG #1, LEG #2, LEG #3 CONNECTION UP TO FLANGE CONNECTION #2.
3. ASSEMBLY SECTION #3 –LEG #4, LEG #5 AND LEG #6 CONNECTION UP TO FLANGE CONNECTION #3 AND #4.
4. ASSEMBLY SECTION #4 – U–GAUGE SYSTEM
5. ASSEMBLY SECTION #5 – FROM FLANGE CONNECTION #3 AND #4 UP TO FLANGE CONNECTION #6 WITH TEMPORARY TEST PLASTIC BUFFER TANK BLD–04.
6. ASSEMBLY SECTION #6 – FROM FLANGE CONNECTION #6 TO UI.
TYPICAL CONNECTION
TYPICAL CONNECTION IN 4 PLACES
240L BUFFER BLADDER BLD–03
240L BUFFER BLADDER BLD–02
240L BUFFER BLADDER BLD–01
TO BE SUPPLIED BY QUEEN'S UNIVERSITY TO TEST THE SYSTEM
DECK OVERHEAD STRUCTURE
Deck Clean Room
6" RAISED DCR FLOOR
MAIN DECK FLOOR
TEMPORARY PLASTIC BUFFER TANK, V=1.5 m^3
TEMPORARY O2 MONITOR
BLD–04
N2 BOIL–OFF 1 PSI
TO H2O COVER GAS
U–GAUGE SYSTEM
dP PT–01 0–20"WC
AIR EXHAUST (INTO THE LABORATORY)
N2 BOIL–OFF
P–01
LAB FILL/DRAIN
SIGHT GLASS
UI
AV FILLED WITH LAB
KEEP AS CLOSE AS POSSIBLE TO FLOOR
2"–2.5" LAB LEVEL SEE NOTE 5
NOTE:
1. OPERATING PRESSURE RANGE – Atm. TO 12" WC
2. OPERATING TEMPERATURE RANGE – 10°C TO 30°C
3. THIS GAS SYSTEM IS NOT WITHIN THE SCOPE OF TSSA, AND IS NOT REGISTERED.
4. ALL INSTRUMENT AND EQUIPMENT NUMBER PREFIX IS "SNP–CG" (eg. SNP–CG–PT–01), HV–HAND VALVE.
5. LAB LEVEL TO BE MEASURED FROM TOP OF HORIZONTAL 2" TUBE SECTION. FOR U–GAUGE SEE DRAWING SLDO–SNP–AR–4504–01.
RELEASED FOR PRODUCTION
DRAWN OLEG LI NOV. 25, 2013
SUBMITTED OLEG LI NOV. 25, 2013
APPROVED OLEG LI FOR K. McFARLANE NOV. 25, 2013
DO NOT SCALE
AV COVER GAS SYSTEM FLOWSHEET
SNOLAB
SLDO–SNP–FL–4503–01 Rev 0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HV-19
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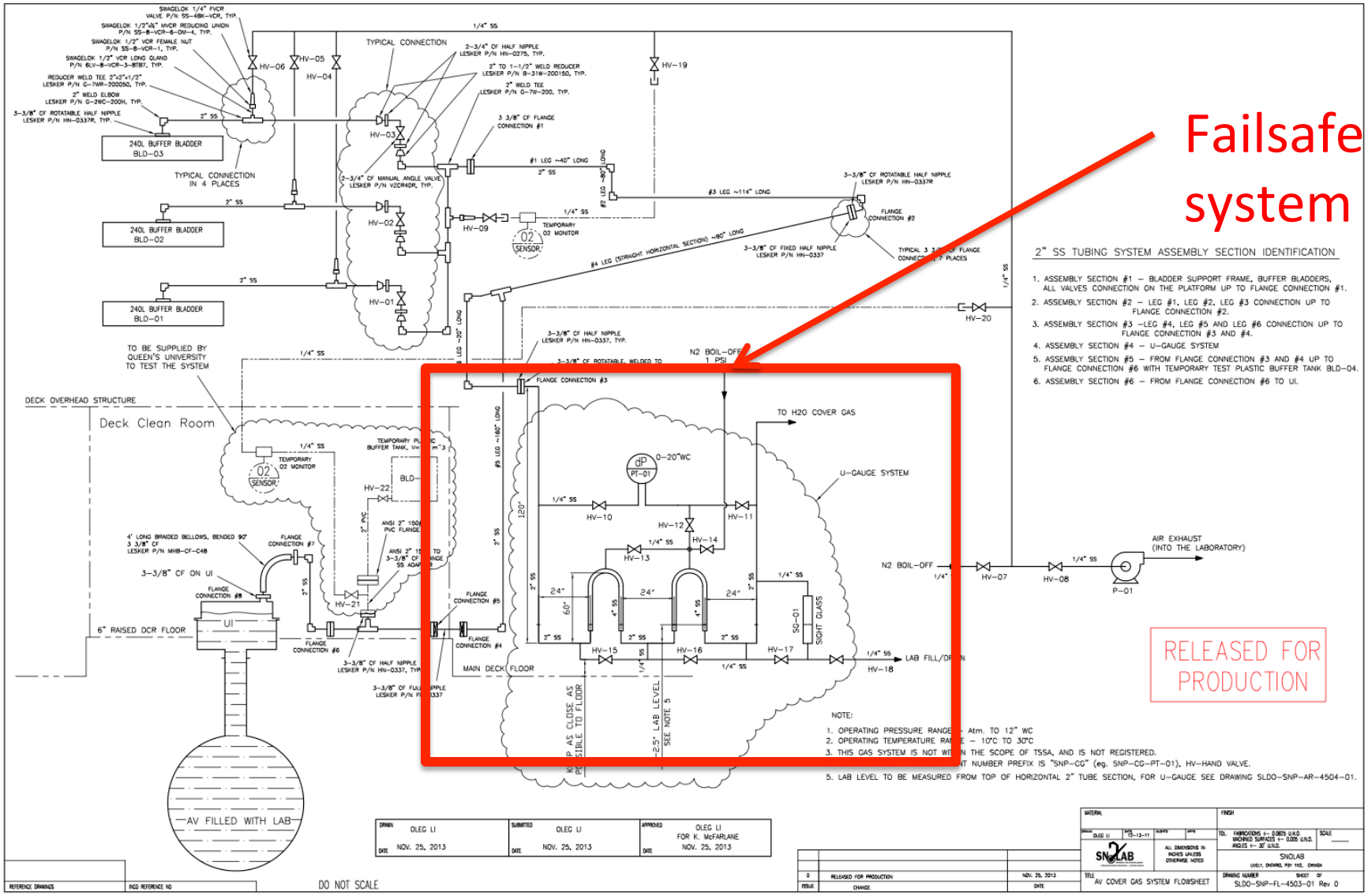
Failsafe system
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HV–13
HV–14
HV–15
HV–16
HV–17
HV–18
HV–19
HV–20
HV–21
HV–22
FLANGE CONNECTION #1
FLANGE CONNECTION #2
FLANGE CONNECTION #3
FLANGE CONNECTION #4
FLANGE CONNECTION #5
FLANGE CONNECTION #6
FLANGE CONNECTION #7
FLANGE CONNECTION #8
#1 LEG ~40" LONG
#2 LEG ~80" LONG
#3 LEG ~114" LONG
#4 LEG (STRAIGHT HORIZONTAL SECTION) ~90" LONG
#5 LEG ~160" LONG
#6 LEG ~20" LONG
120"
60"
24"
2" SS
1/4" SS
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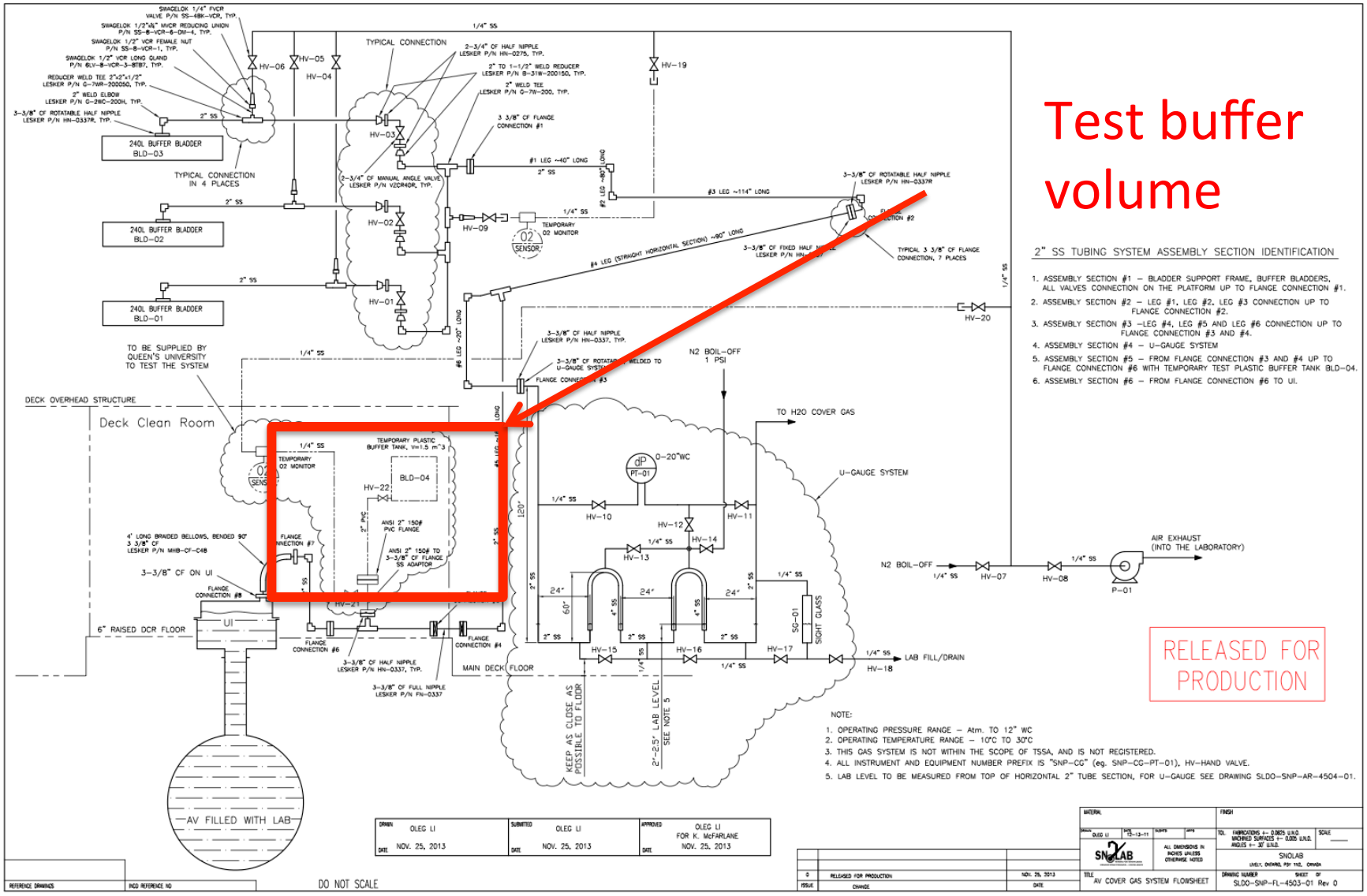
SNOLAB
SLDO–SNP–FL–4503–01 Rev 0

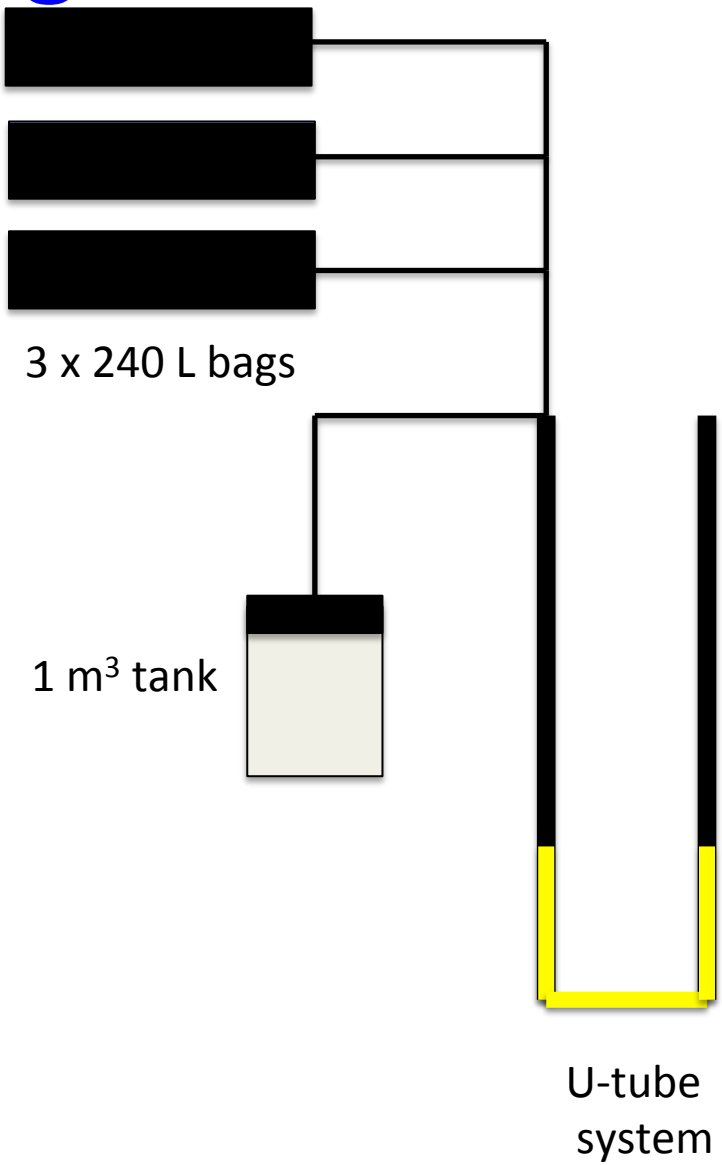
- Pressure release device
- Filled with LAB which bubbles when the dP between AV cover gas and H2O cover gas > 0.26 psi (AV design specification)

Test buffer volume



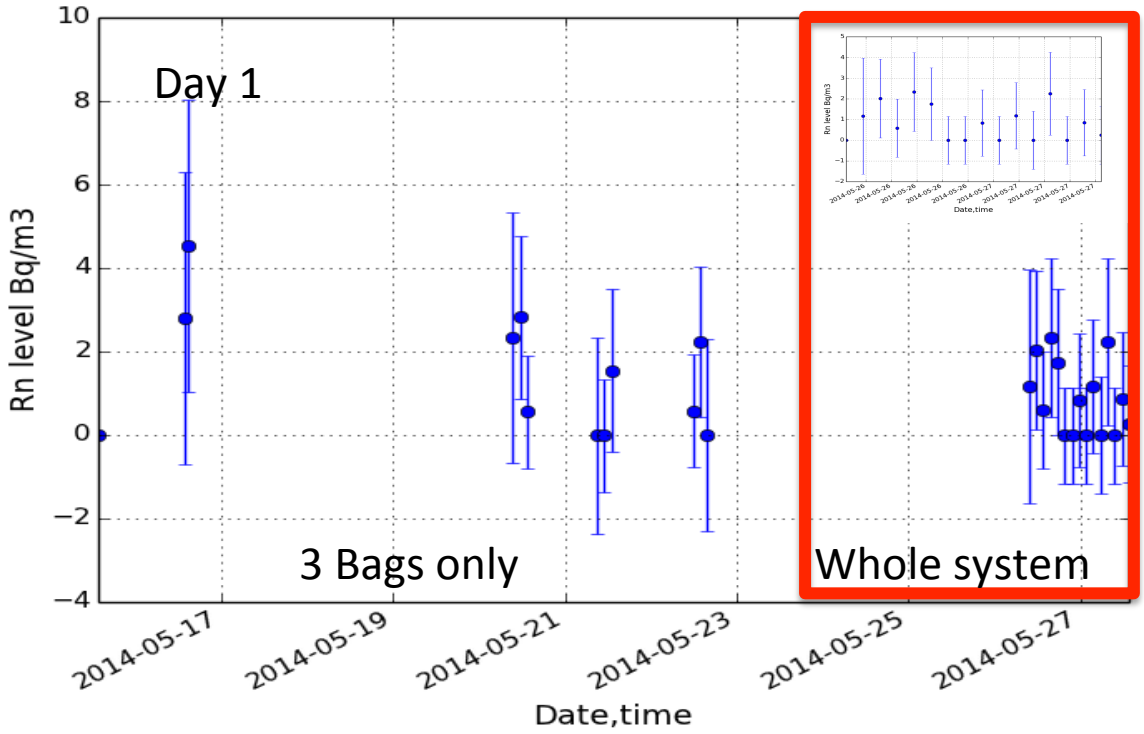
Commissioning tests

- The system was filled with N_2 and radon level and pressure change response was tested



Radon measurement

- Rn level was measured by RAD7 unit (sensitivity: factor of 100 lower than mine air)



Position sensors and Pressure

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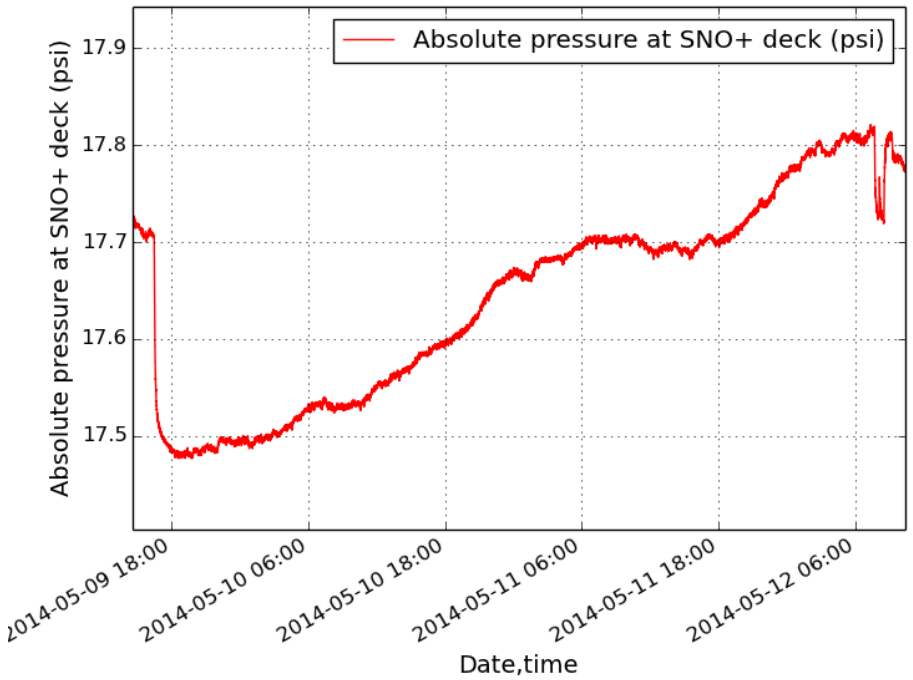

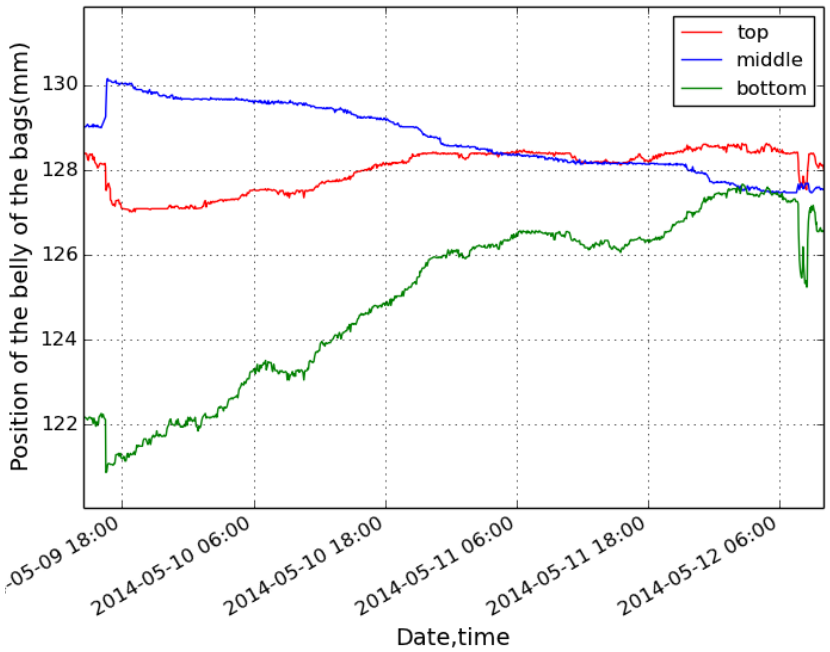

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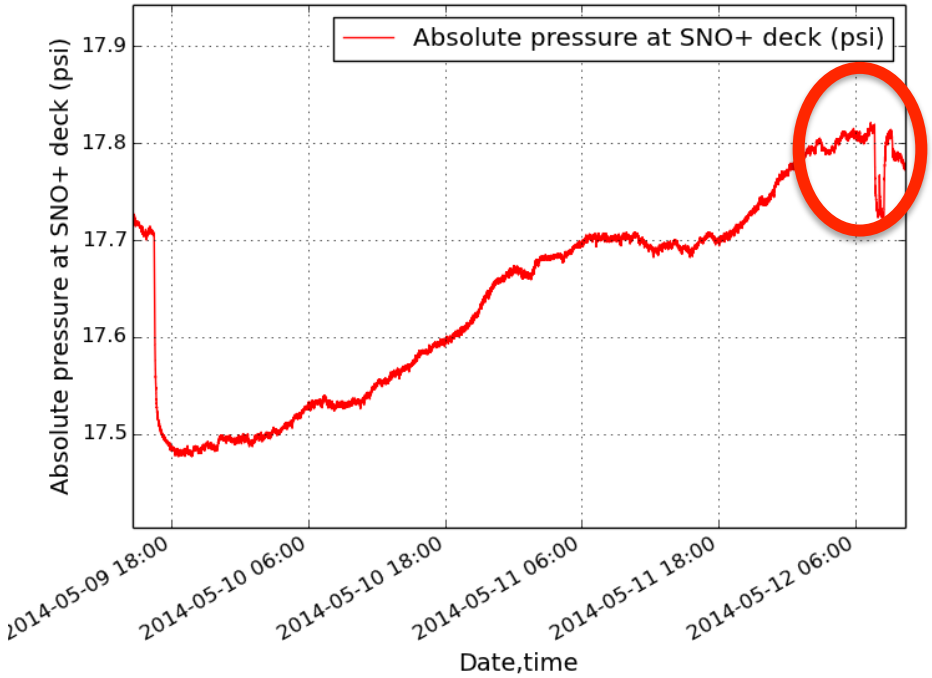

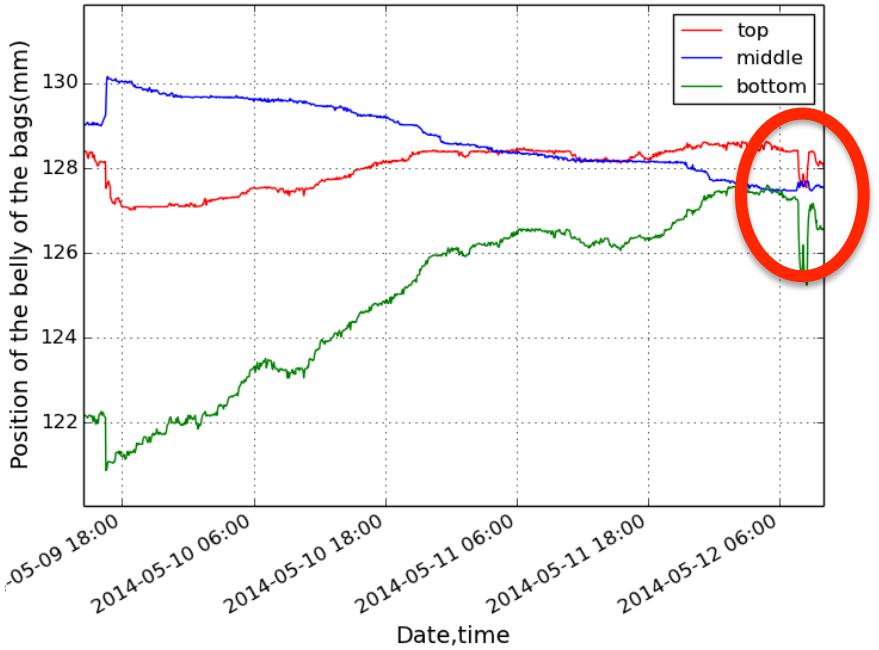

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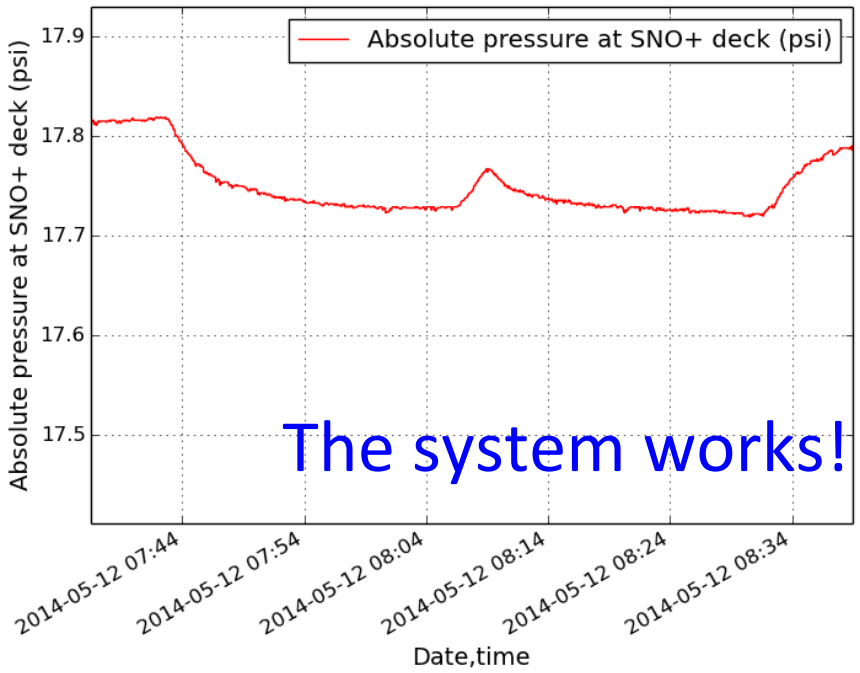

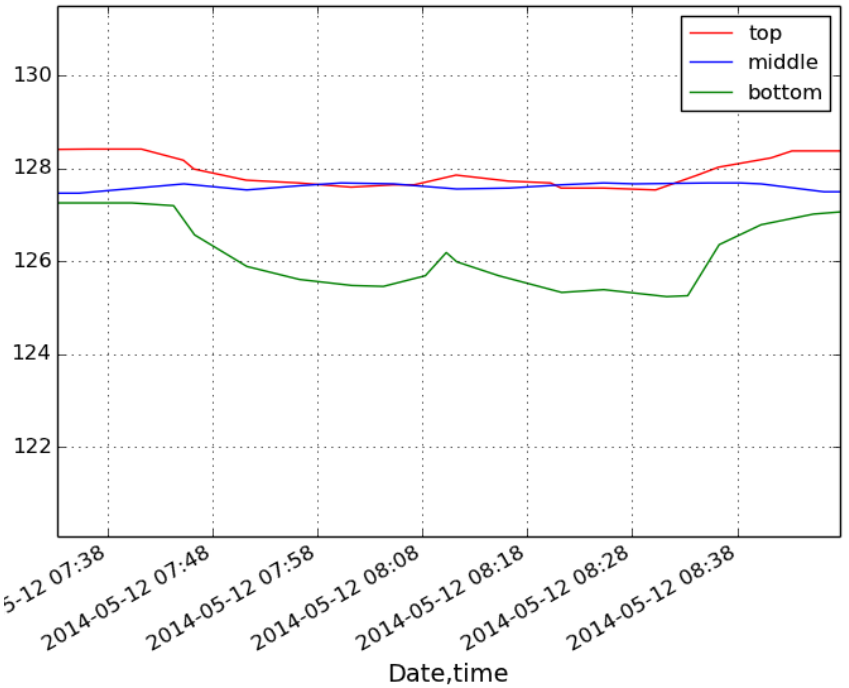

Summary and current status

- SNO+ novel cover gas system is designed and installed to prevent radon ingress in the detector
- The cover gas bags were radon emanated before installation and make the low radon requirement (<650 atoms/day)
- The commissioning with the buffer tank system has been successful
- The system is going to be attached to AV for further tests during the H_2O phase