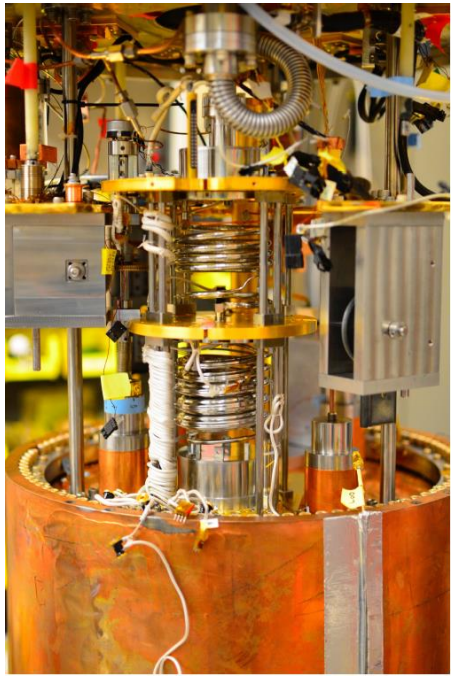


ADMX Dilution Refrigerator

Jihee Yang

2020/11/16

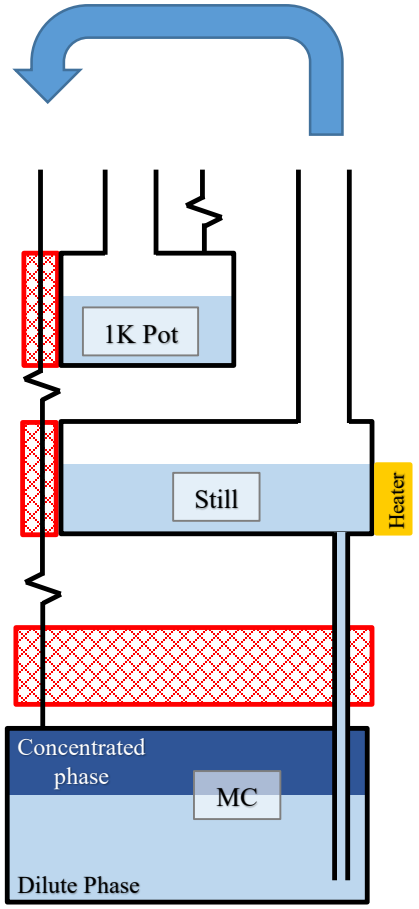
ADMX Collaboration Meeting

Outline

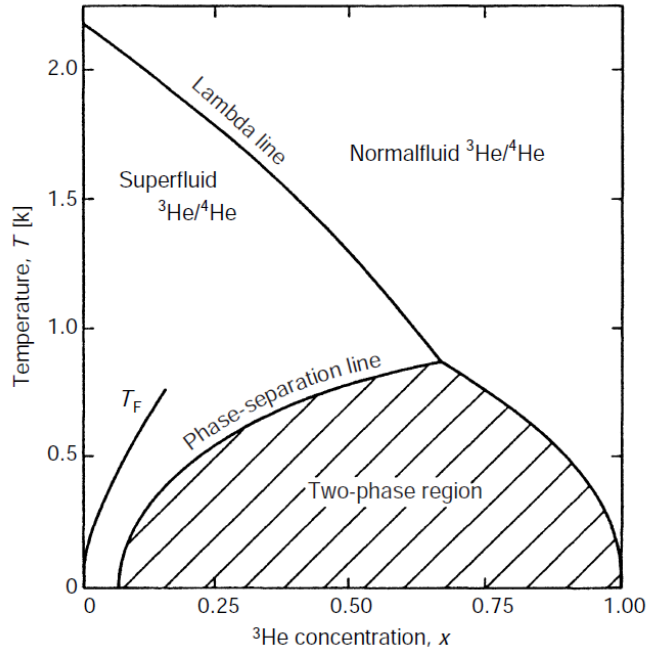
- Introduction
  - Dilution refrigerator (DF)
  - ADMX DF
- DF in Run1C
  - Timeline & status
  - Improvement & issues
  - Solutions
- Summary

Dilution Refrigerator

- Dil fridge (DF)
- 3He and 4He mixture
- Heat of mixing (Mixing chamber (MC))
- Continuous cooling
  - Vacuum pump
  - Still heater
- Cool low as 2 mK



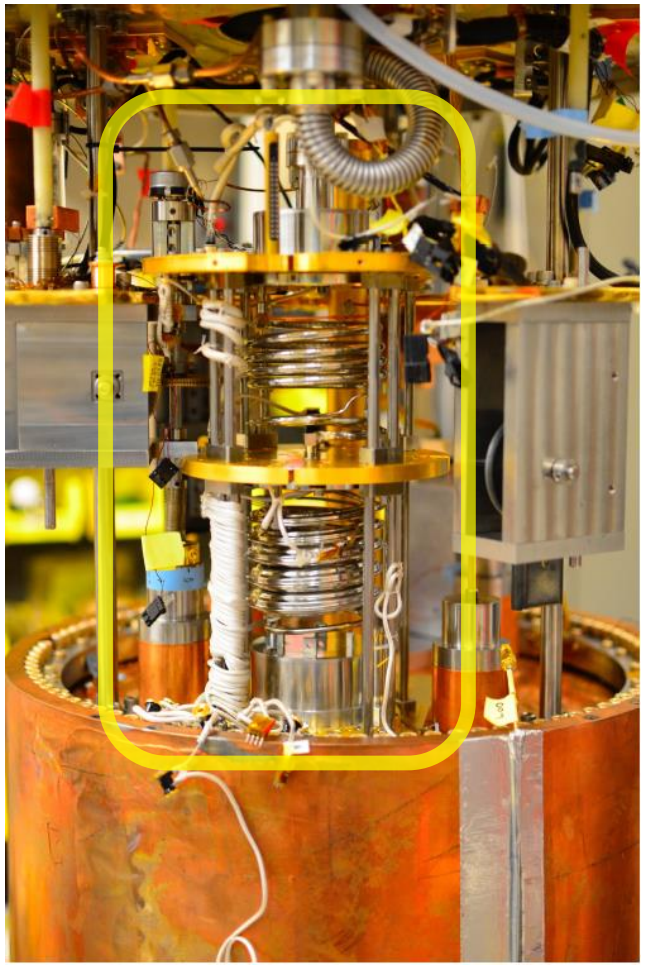
Adapted from R. Ottens slides



"Matter and Methods at Low Temperatures", Frank Pobell, Springer

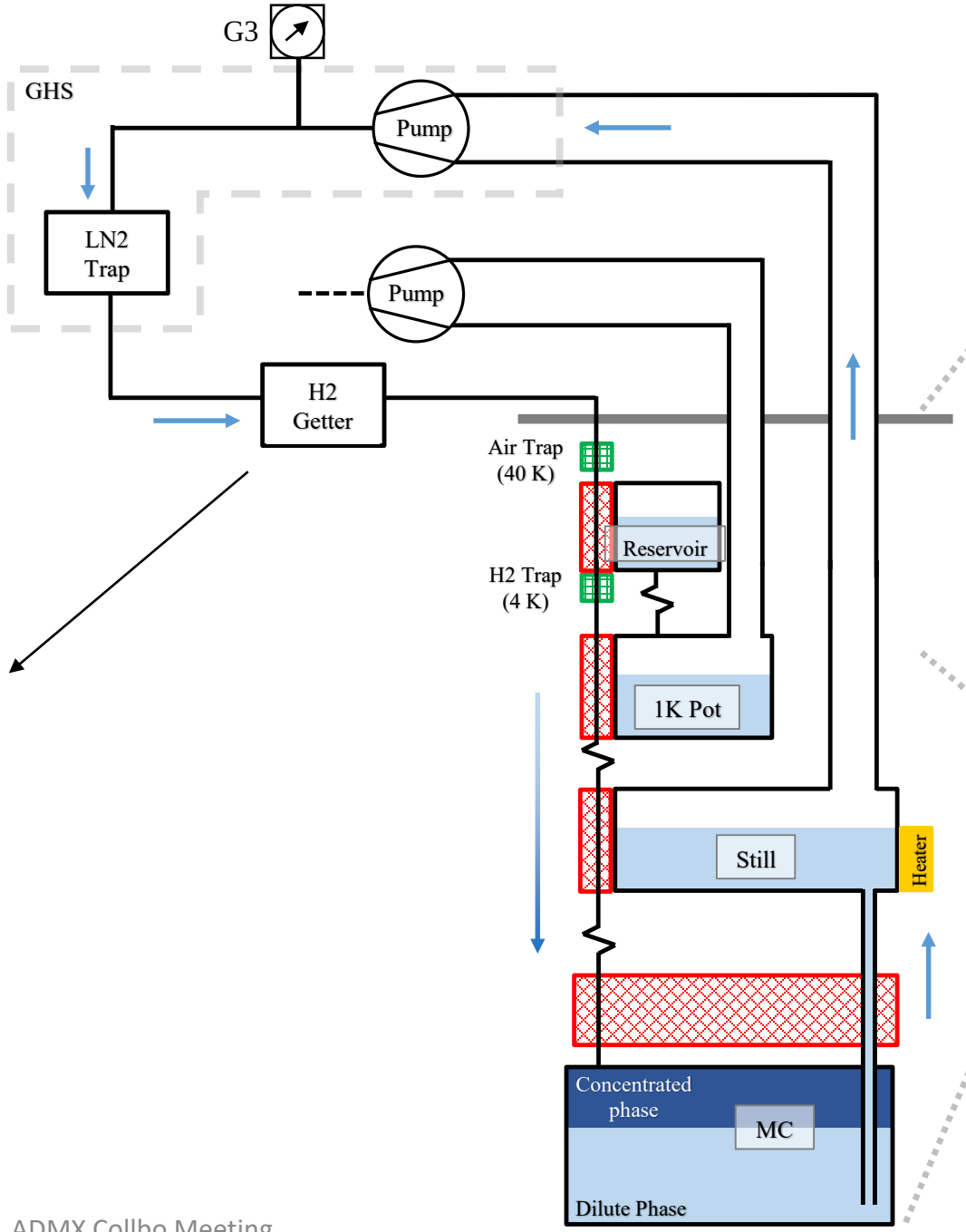
ADMX Dilution Refrigerator

- Made by Janis Research
  - Customized to ADMX
- 800 uW at 100 mK
- Small 1K pot : Cooling mixture
  - c.f. Big 1K pot : cooling shield, wires, gearbox
- Installed on insert (2016/05)
  - Gen2 operations (Run1A, 1B, 1C)
  - DFSZ sensitivity



JACoB
(GHS control box)

Getter Panel



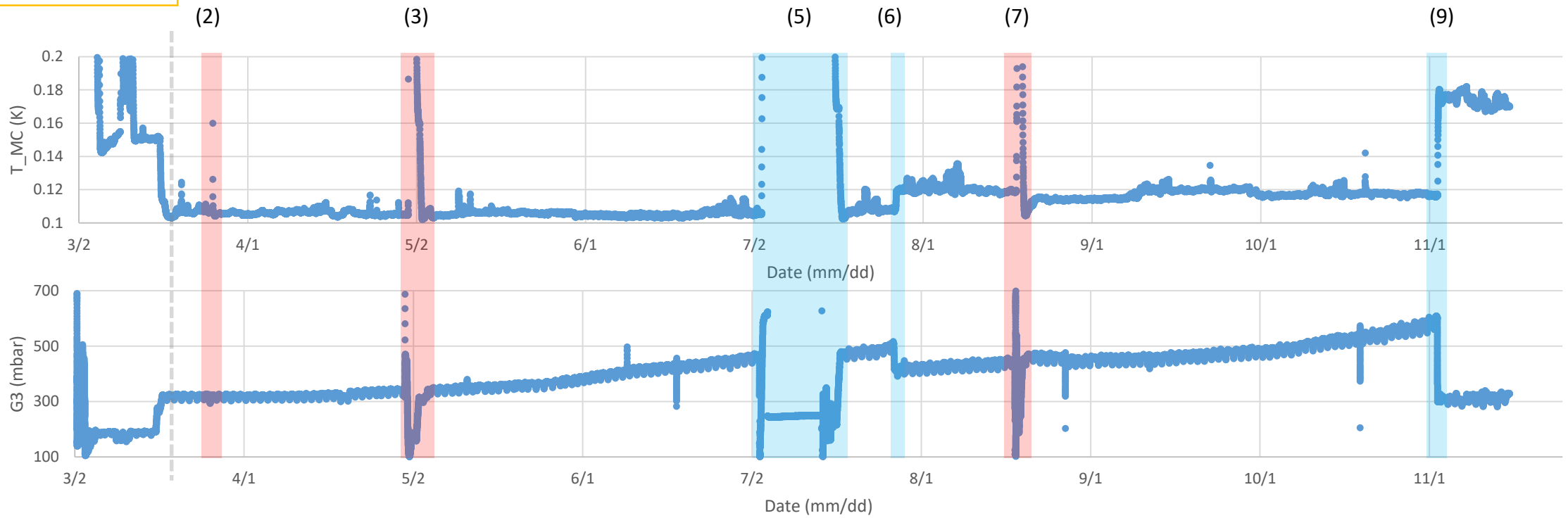
ADMX DF System

DF Status in Run1C (2020)

- Improvement
  - Small 1K pot stability
    - Low flow rate
    - Less disturbing LHe transfer to reservoir
    - Pressurizing during cooldown

- Issues
  - JACoB (cRIO) error
  - Heat dump (BC quench, sidecar piezo overdrive)
  - Impedance buildup

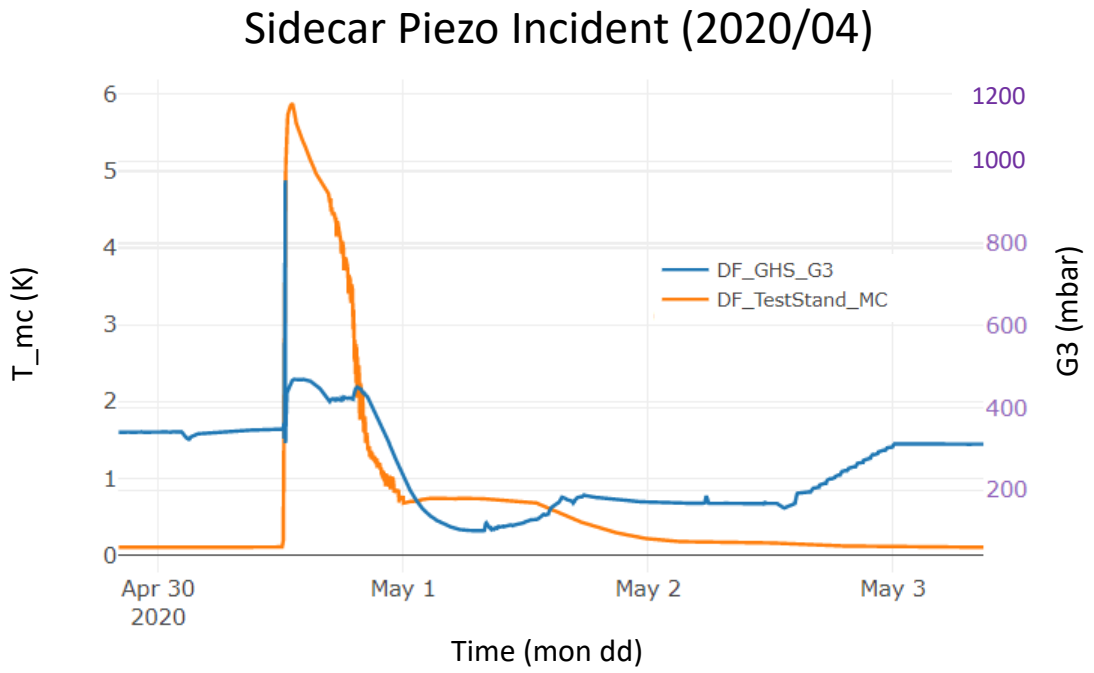
Run1C (2020) Timeline



#	Date	DF Procedure	Heating	T_MC (base)	T_MC (peak)
(1)	02/20	Insert into the bore			
(2)	03/26		BC quench	105 mK	160 mK
(3)	04/30		Sidecar piezo overdrive		6 K
(4)	06/09	H2 getter bypass test			
(5)	07/08	DF line leak check & tightening			4.2 K
(6)	07/27	Still heater lowered			
(7)	08/18		JPA heating study	120 mK	3 K
(8)	09/09	H2 getter swap			
(9)	11/02	Still heater off		175 mK	

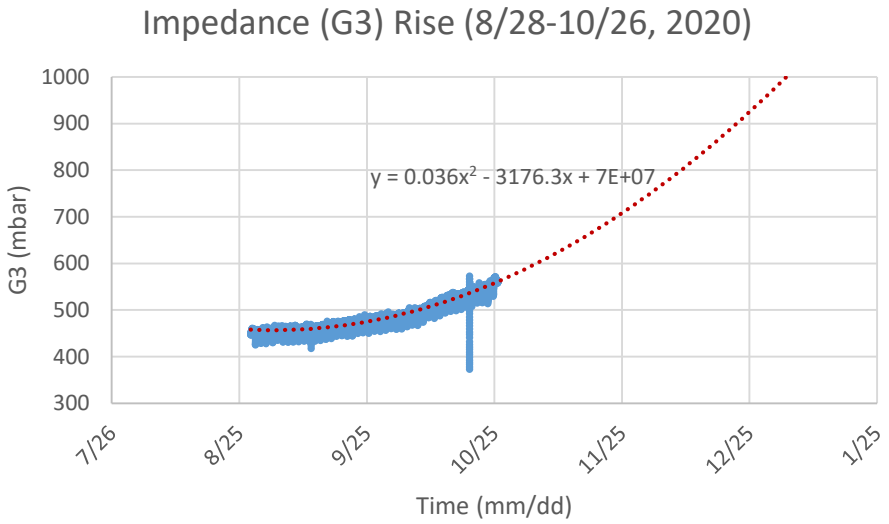
Issues & Solutions

- JACoB (cRIO) error
  - Limiting remote access
  - Resolved by power cycling
- BC quench
  - 50 mK jump
  - Repaired magnet controller
- Sidecar piezo overdrive
  - 6 K jump (runaway)
  - Implemented fail safe measures



Issue : Impedance Buildup

- When impedance in return side of DF increases, G3 pressure rises (non-linear)
- G3 limits
  - 800 mbar : during operation
  - 950 mbar : GHS directs mixture into the dump
  - 1000 mbar : GHS directs mixture into the dump & turns off pumps
- G3 rise
  - 320 => 610 mbar (in 7.5 months)
- Source?
  - H2 leak
  - Air leak (leaky connections, diffusive o-rings)



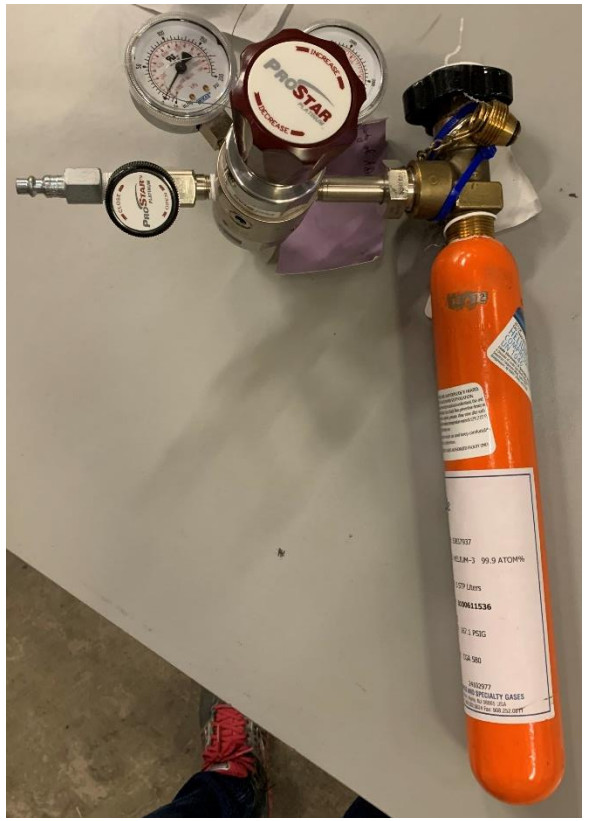
Impedance Buildup : Possible Solutions

- Tried
  - LN2 trap swap
  - Getter swap
  - Leak checking & joint tightening (4.2 K warm-up)

- Plans
  - Impedance cleanup (20 K warm-up) + Leak checking & joint tightening
  - Extraction (300 K warm-up)

DF Further Upgrade Plans

- 3He addition
  - Mixture : 163 L (in 2016) => 157 L (in 2020)
  - 4He addition (2 stp liters) in 2016/09
  - Can improve DF stability
- 1K pot pump upgrade
  - Separating pumping of big & small 1K pots
  - Isolation
  - Lower pot temps => lower insert temps
- GHS upgrades
  - O-rings : viton => neoprene
  - Metal seals



Regulator & 3He bottle (5 stp liters)

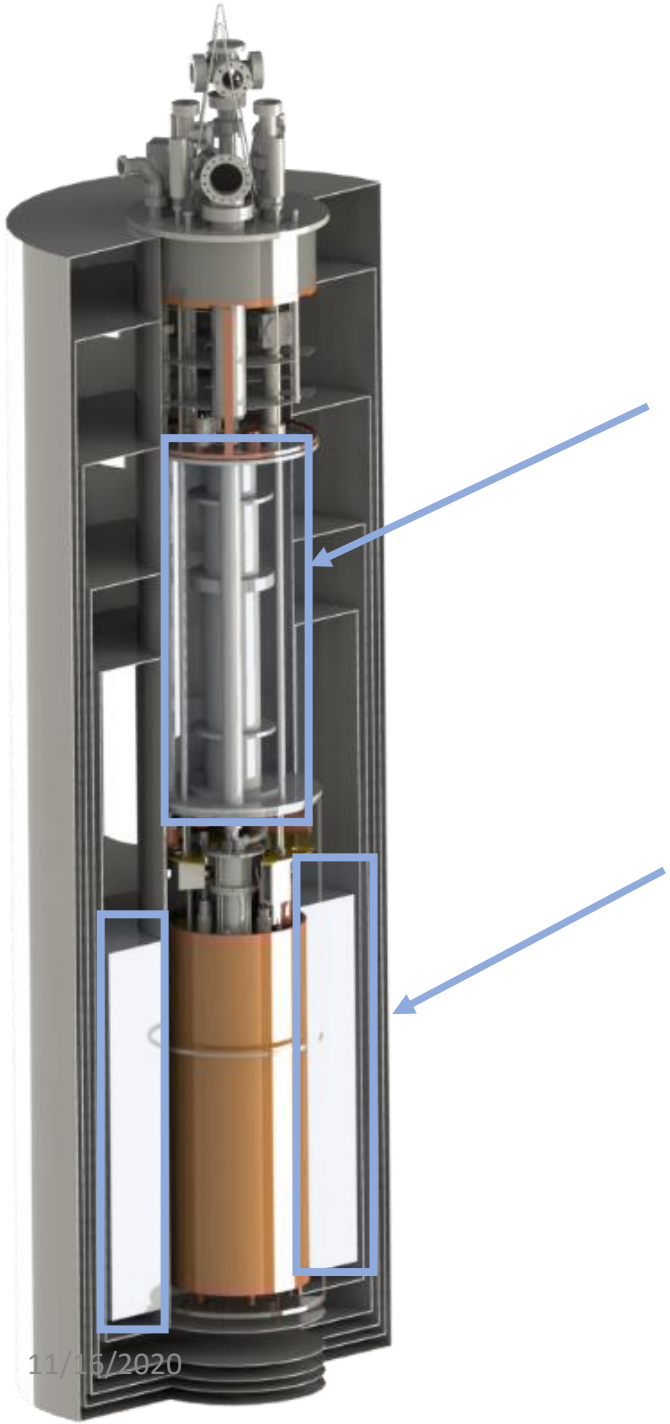
Summary

- ADMX dilution refrigerator helped to reach DFSZ sensitivity
- 2020 Run1C : operating for 9 months
- Major issue : impedance (G3) building up
  - Near term plans : warmups & leak check
  - Future plans : system upgrades

THE END

Thank you

Backup Slides



Cryo System

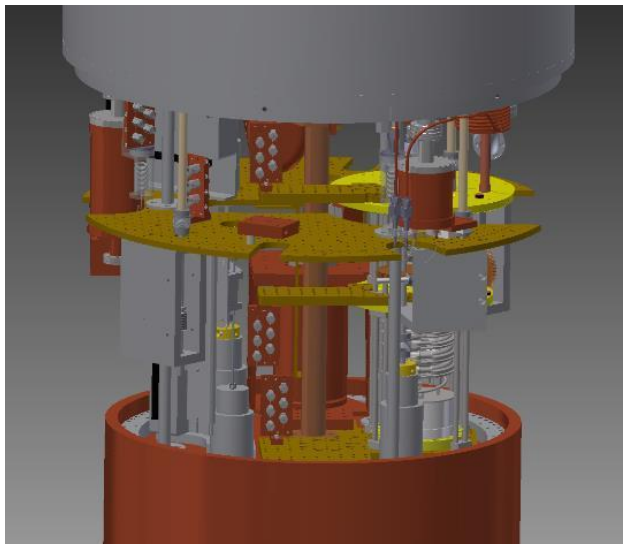
- Bucking coil (4 K)
  - 2 Tesla
  - LHe cooled
  - In LHe reservoir (insert)
- Main magnet (4 K)
  - 8 Tesla
  - LHe cooled
  - LN2 shielded
  - In cryostat (stationary)

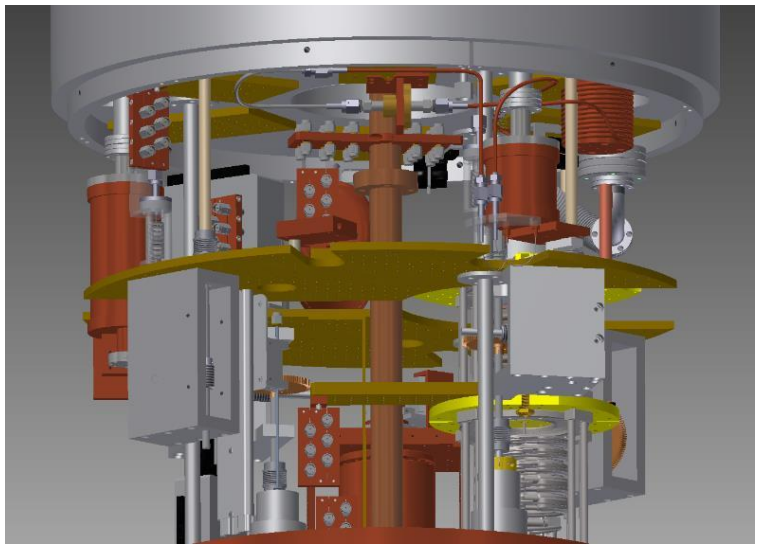
Cryo System

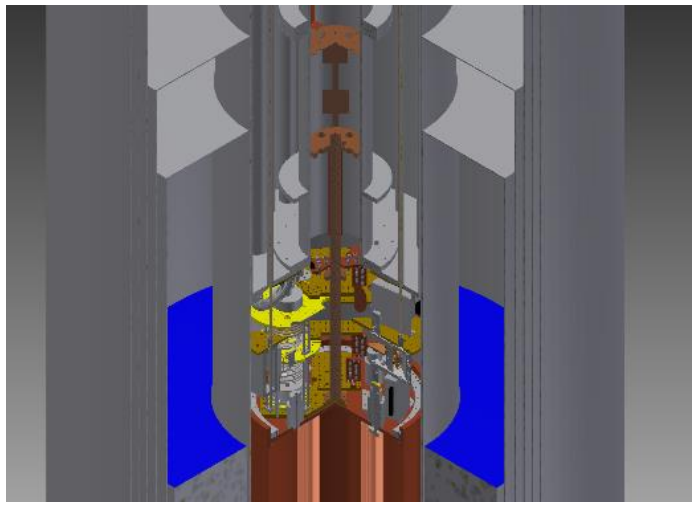
- Insert cooling
  - (40 K) Cryocooler
  - (10 – 4 K) LHe Reservoir
  - (1 K) 1K pots
    - Small 1K pot : precooling mixture
    - Big 1K pot : cooling others (i.e. electrical wire)
  - (700 mK) Still
  - (100 mK) Mixing chamber (MC)

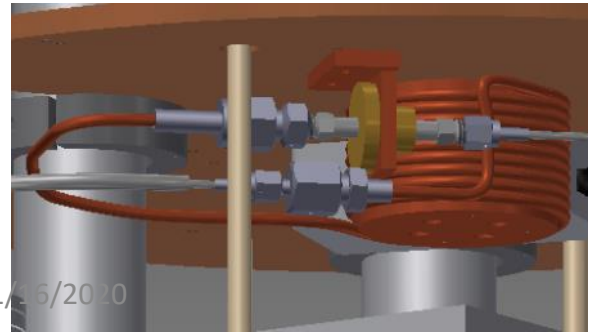
ADMX Dilution Fridge (DF)

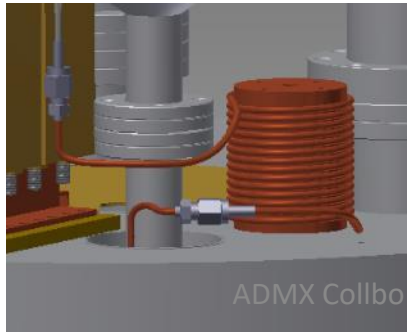
- Details with drawings/Pics

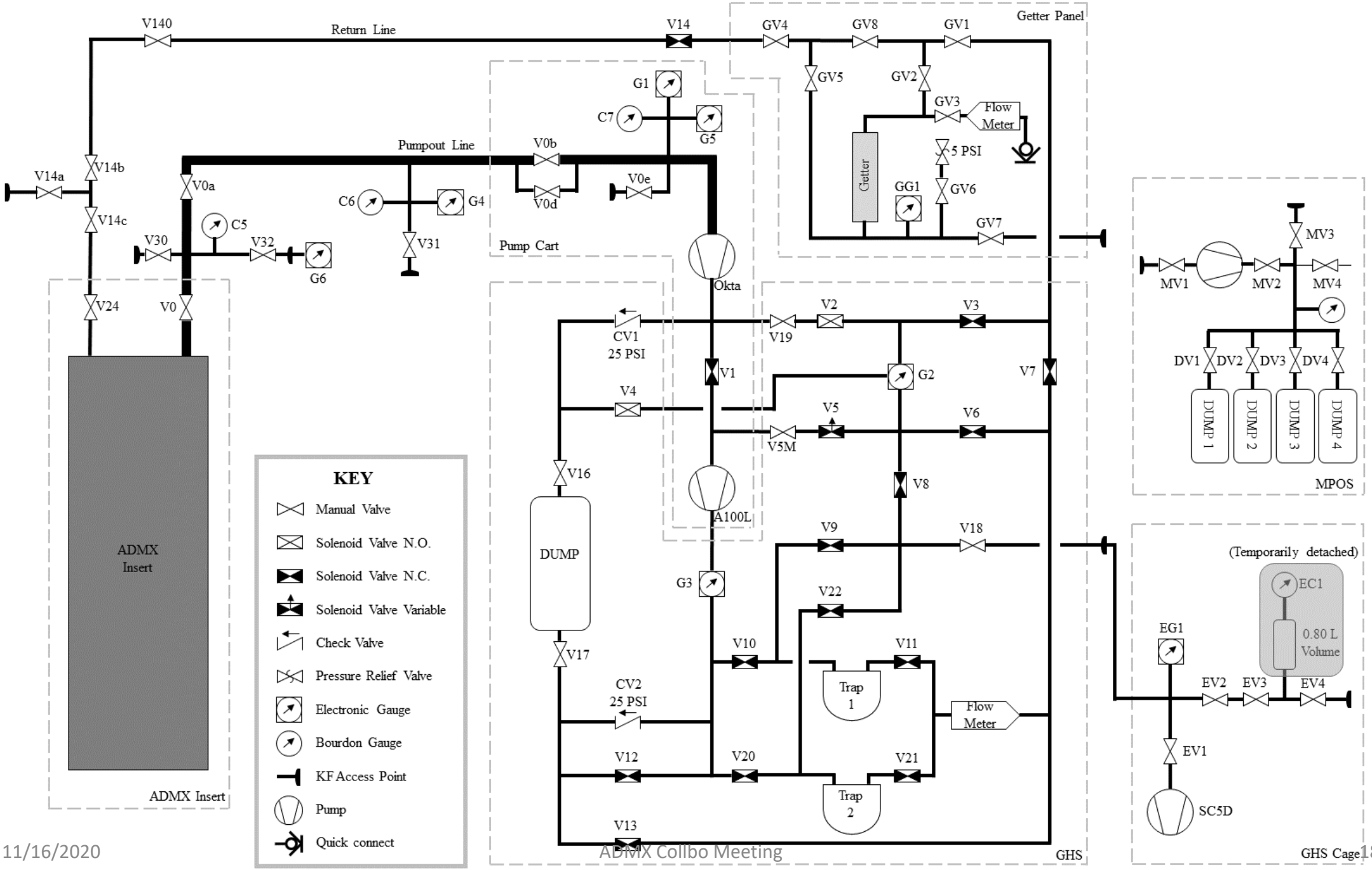











V140
Return Line
V14
Getter Panel
GV4
GV8
GV1
GV5
GV2
GV3
Flow Meter
5 PSI
GV6
GV7
Getter
GG1
G1
C7
G5
Pumpout Line
V0b
V14a
V14b
V0a
V14c
C6
G4
V0d
V0e
C5
V30
V32
G6
V31
Pump Cart
V24
V0
Okta
CV1
25 PSI
V19
V2
V3
V1
G2
V7
V4
V5
V6
V5M
V16
V8
A100L
DUMP
V9
V18
G3
V22
V17
V10
V11
Trap 1
CV2
25 PSI
Flow Meter
V12
V20
V21
Trap 2
V13
ADMX Insert
GHS
MV3
MV1
MV2
MV4
DV1
DV2
DV3
DV4
DUMP 1
DUMP 2
DUMP 3
DUMP 4
MPOS
(Temporarily detached)
EC1
0.80 L Volume
EG1
EV2
EV3
EV4
EV1
SC5D
GHS Cage
KEY
Manual Valve
Solenoid Valve N.O.
Solenoid Valve N.C.
Solenoid Valve Variable
Check Valve
Pressure Relief Valve
Electronic Gauge
Bourdon Gauge
KF Access Point
Pump
Quick connect

Run1C (2020) Timeline

Date	DF Procedure	Heating	T_MC (base)	T_MC (peak)
02/20	Insert into the bore			
03/26		BC quench	105 mK	160 mK
04/30		Sidecar piezo runaway		6 K
06/09	H2 getter bypass test			
07/08	DF line leak check & tightening			4.2 K
07/27	Still heater lowered		120 mK	
08/18		JPA heating study		3 K
09/09	H2 getter swap			
11/02	Still heater off		175 mK	

Run1C (2020) Timeline

Elog	Date	Procedure	Note
2763	2/20/2020	Insert into the bore	
2829	3/16/2020	Normal operation began	Still heater 16.4 mW, T_MC~105 mK
2854	3/26/2020	BC quench	T_mc = 105 mK => 160 mK
2979	4/30/2020	Sidecar piezo runaway	T_mc = 105 mK => 6 K
2988	5/4/2020	Recovered from runaway	Still heater 16.9 mW, T_MC~104 mK
3065	6/9/2020	H2 getter bypass test	No improvement
3106	7/3/2020	Mixture collecting	
3109	7/8/2020	DF line leak check & tightening	
3112	7/14/2020	Mixture flow started	
3141	7/27/2020	Still heater lowered	16.9 mW => 11.0 mW
3201	8/18/2020	GHS Jacob power cycling	
3203	8/18/2020	JPA heating study	
3247	9/9/2020	H2 getter swap	
3381	11/2/2020	Still heater off	11.0 mW => off

G3 Limits

- When G3 reaches the set limits, fail-safe measures will occur
  (from page 54 in Janis manual_2015-02-09)

b) G3

- The program has set the following Hi value and a HiHi value for G3:
  - Hi = 950 mbar
  - HiHi = 1000 mbar
- When G3 reaches the Hi value, the G3 background turns yellow; V5 and V2 close (if it is open); V12 opens; the event is recorded to the log. G3 returns to green when the pressure measured by G3 drops below Hi; V12 closes; the event is recorded to the log.
- When G3 reaches HiHi value, the G3 background turns red, all valves return to the un-energized state (V2 and V4 opened, all other valves closed); all pumps stopped. G3 returns to yellow when the pressure measured by G3 drops below HiHi, and green when it drops below Hi; the pumps will not start;

CV1 and CV2 Check Valves

- Check valves CV1 and CV2 as pressure relief measure
  (from page 54 in Janis manual_2015-02-09)

e) Valves

- All solenoid valves will open up in one direction when the pressure difference reached 1.5 bar in that direction. These valves are installed with the correct pressure protection directions.
- CV1 and CV2 are Inline Check Valves, and they will open up and relief the mixture to the Dump and reduce the pressure difference when the pressure difference reaches 25 psi along the arrow direction as shown in Figure 15.

MC Power Plots

From in Janis manual_2015-02-09), page 118, 119

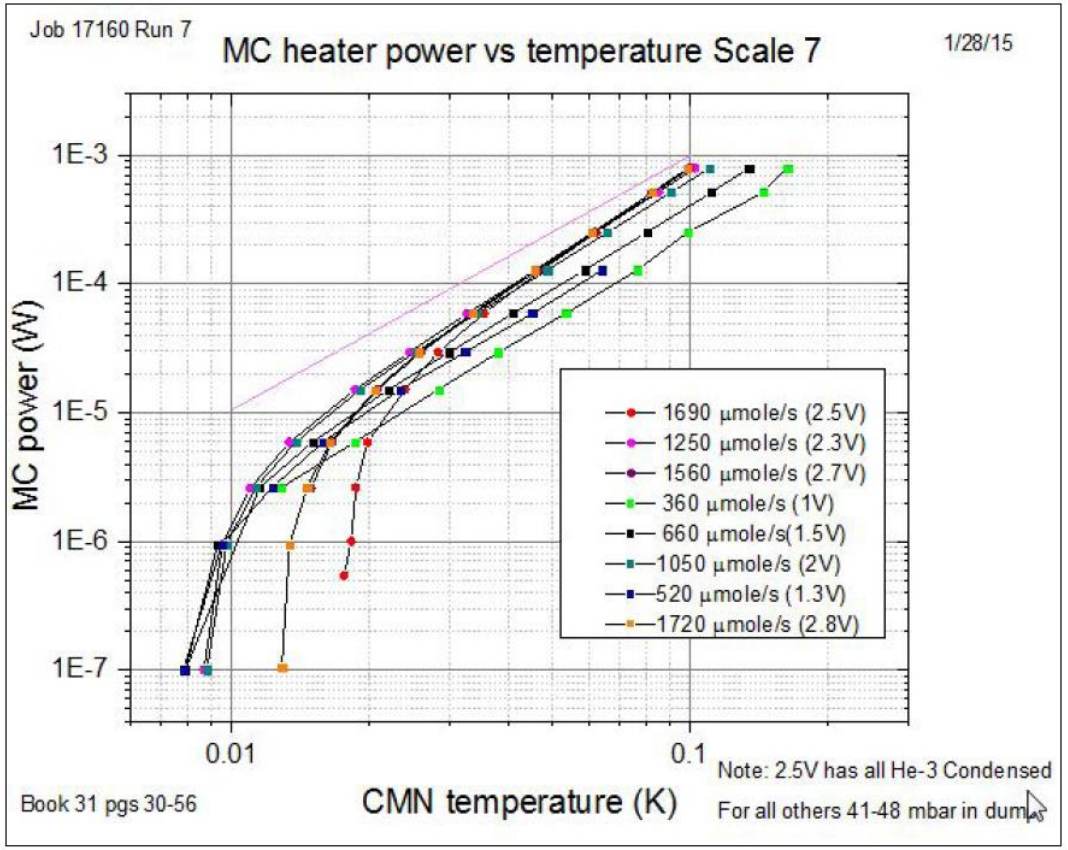


Figure 32 A Performance - cooling power measurement

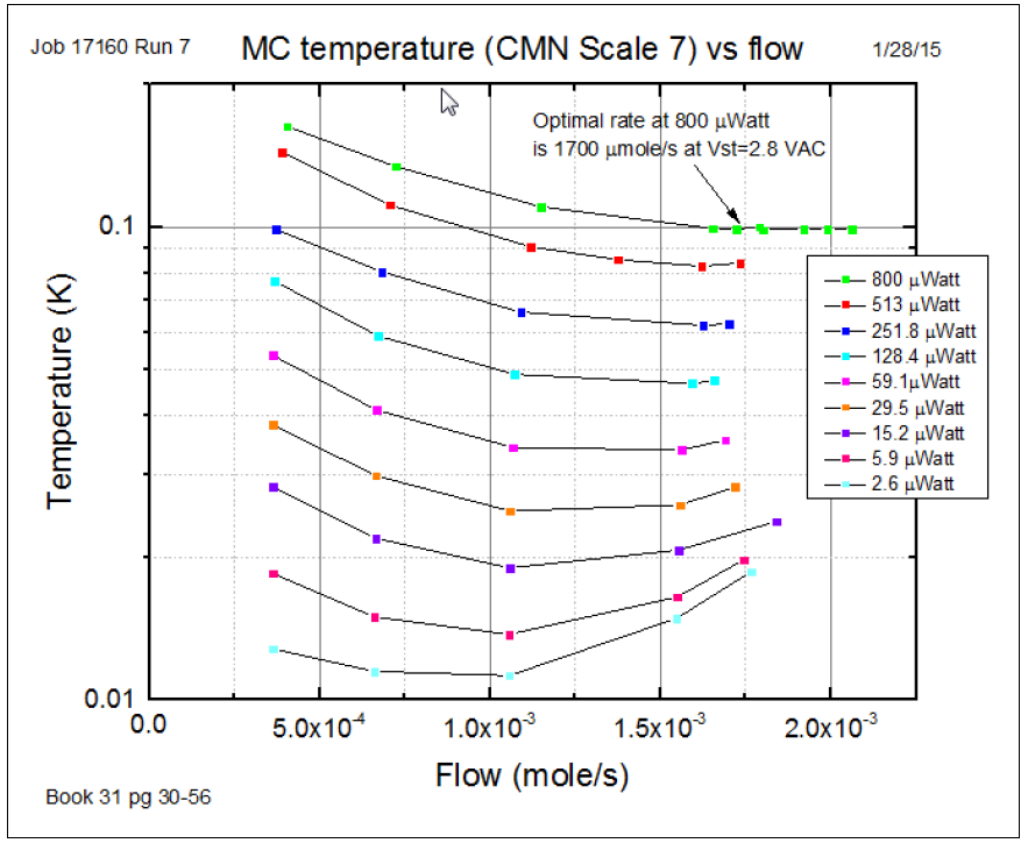


Figure 32 B Performances – MC temperature vs circulation rate

Janis GHS Control Software (HMI)