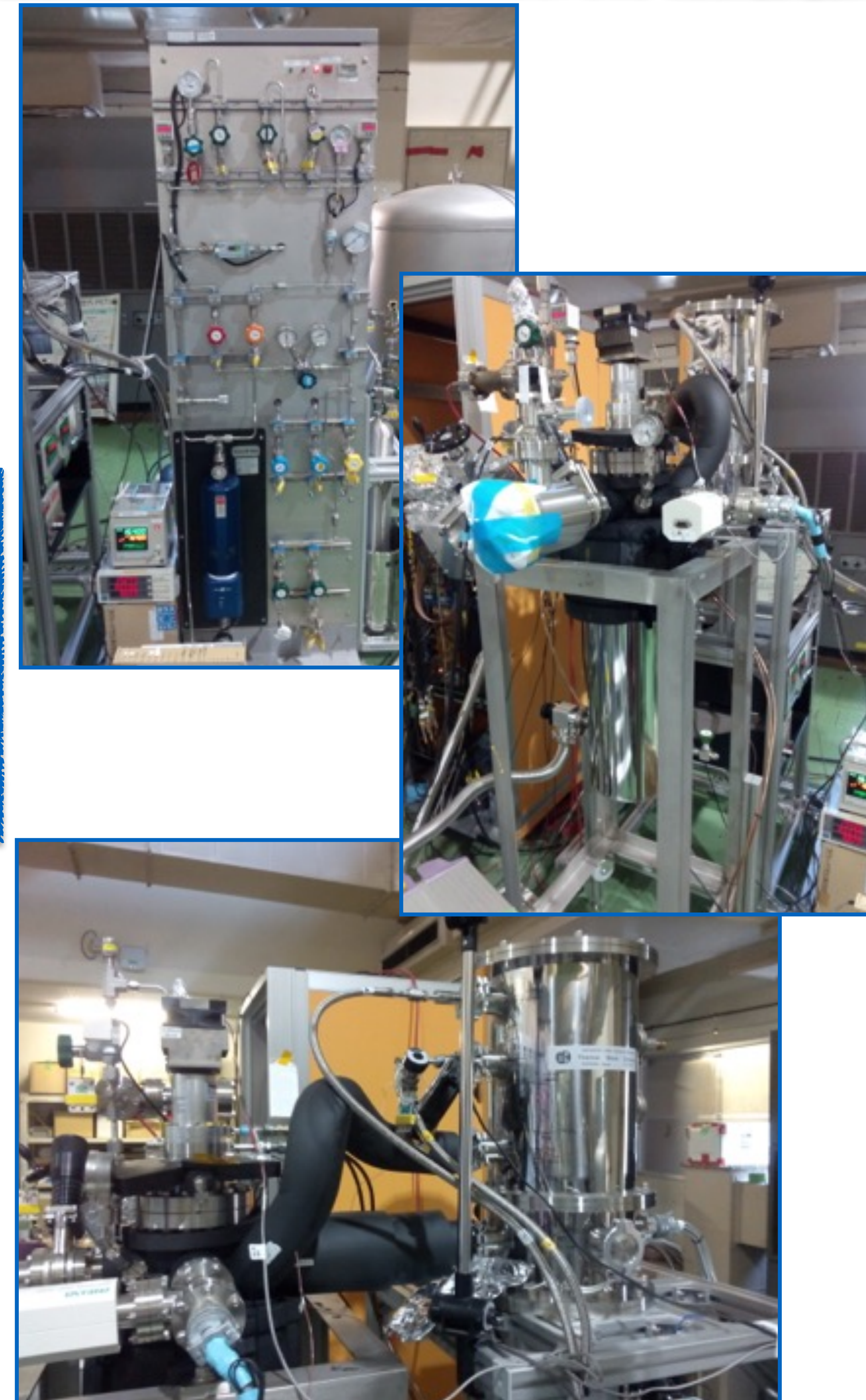
Cryogenic Study of the LXe TPC at KEK



Sara Diglio and Lucia Gallego

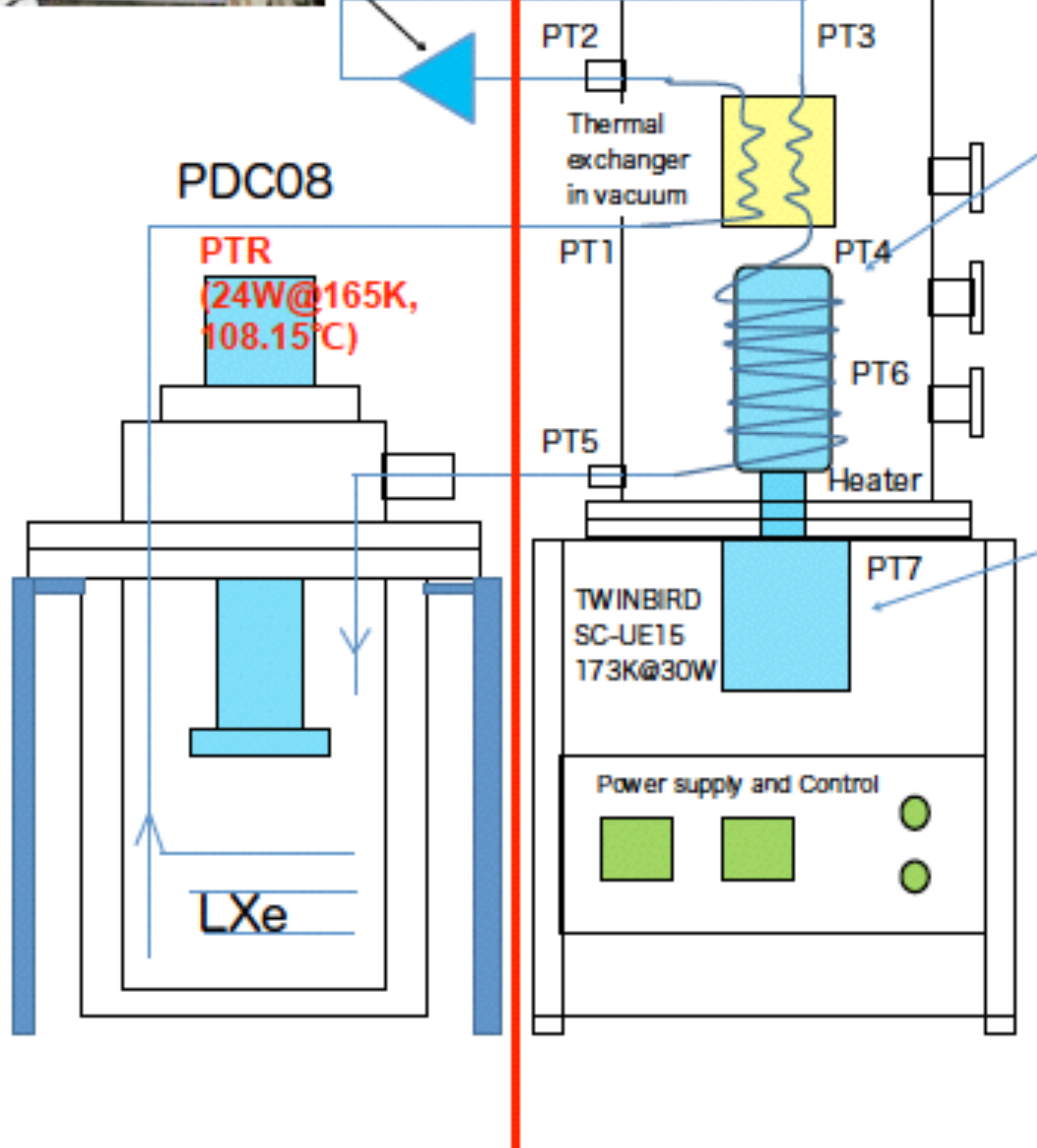
KEK December 1st 2015

KEK Experimental Set-up

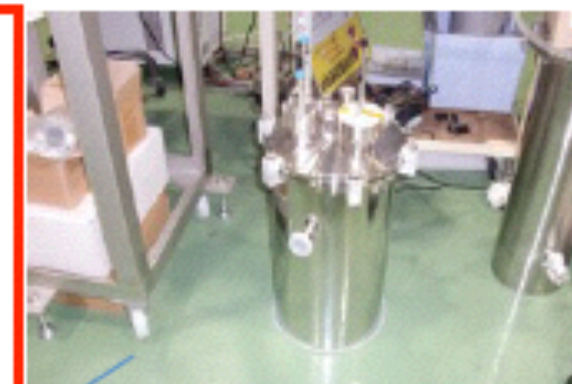
Control system of cryogenics

pump of the gas circulation

Xe Pre-cooling system



Heat exchanger with vacuum insulation

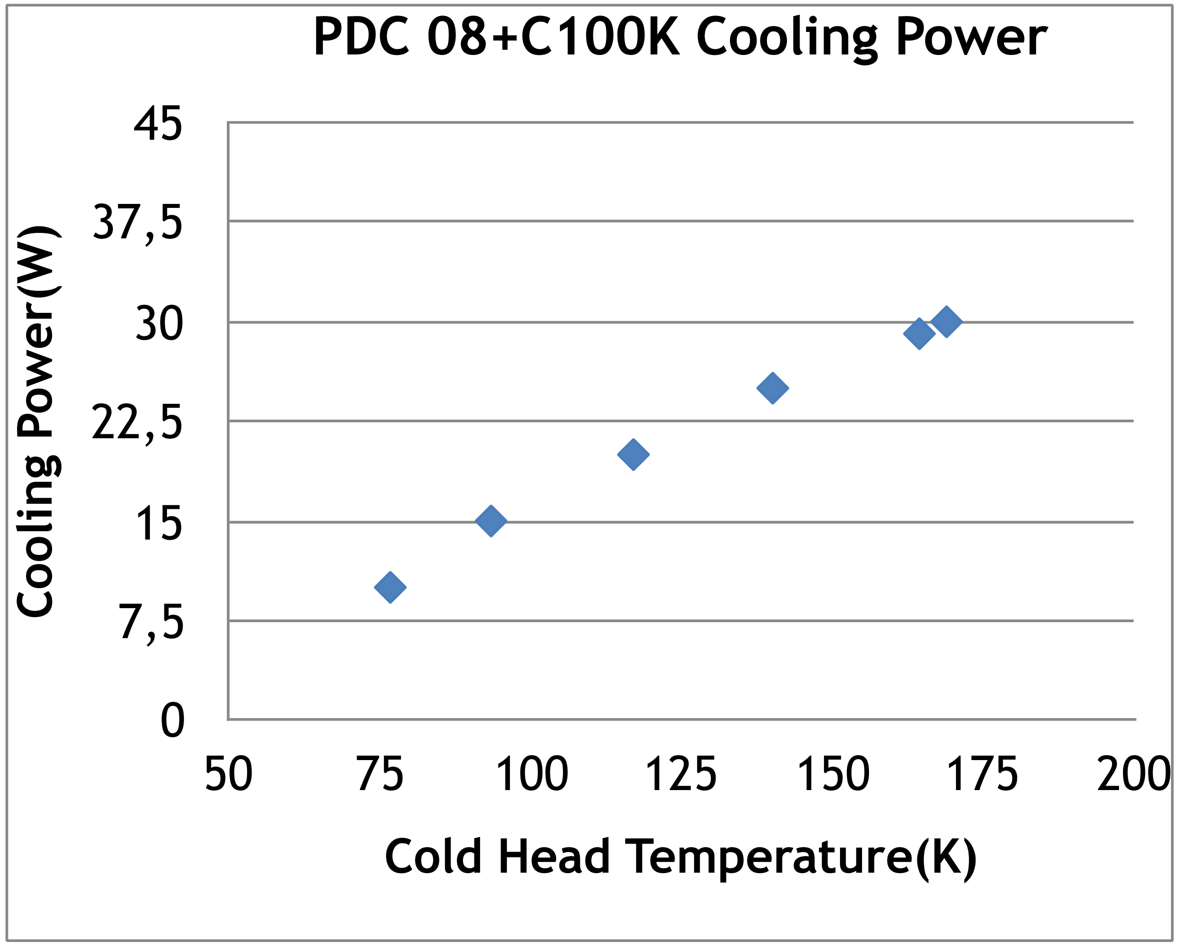


Additional cooler

TWINBIRD SC-UE15
173K@30W

LXe Cryostat

Cooling Power Iwatani PTR PDC08 (8W at 77K)



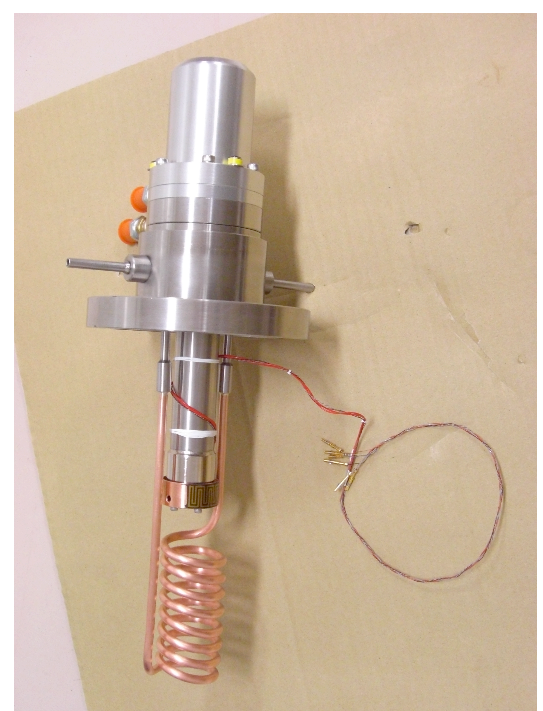
PDC08+C100K Cooling Power

Cold Head Temperature(K)	Cooling Power(W)
76,8	10
93,5	15
117,1	20
140,19	25
164,5	29,1
169	30

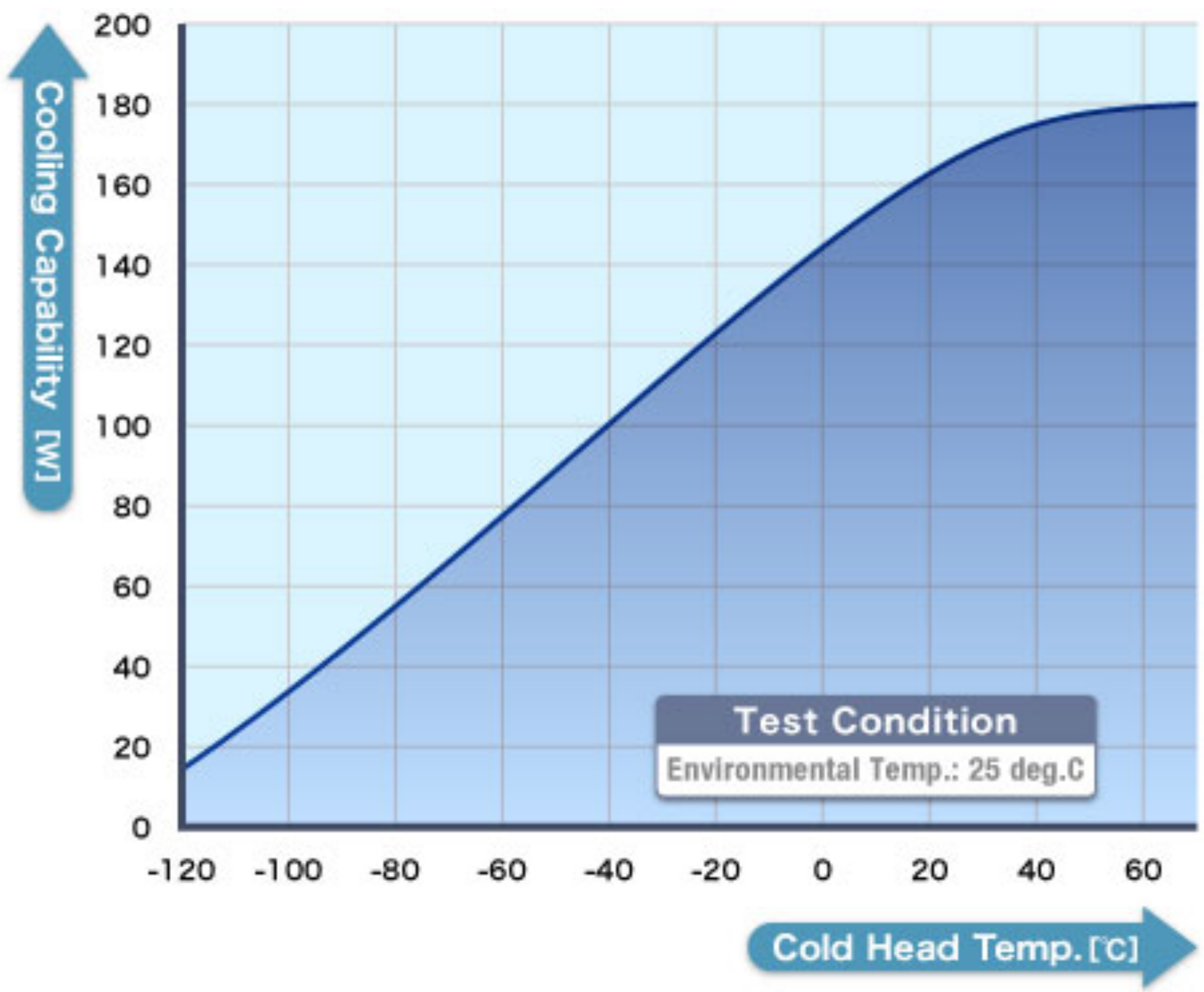
→ **Approx. 29W at 164 K**

Volts….200
Hertz…50
Phase…1
Compressor Suzuki Shokan co..Ltd. C100K
Cryocooler Iwatani PDC-08

Static Pressure:1.60MpaG
Measured by KEK on 2014/07/11



Cooling Power TWINBIRD Stiring Cooler



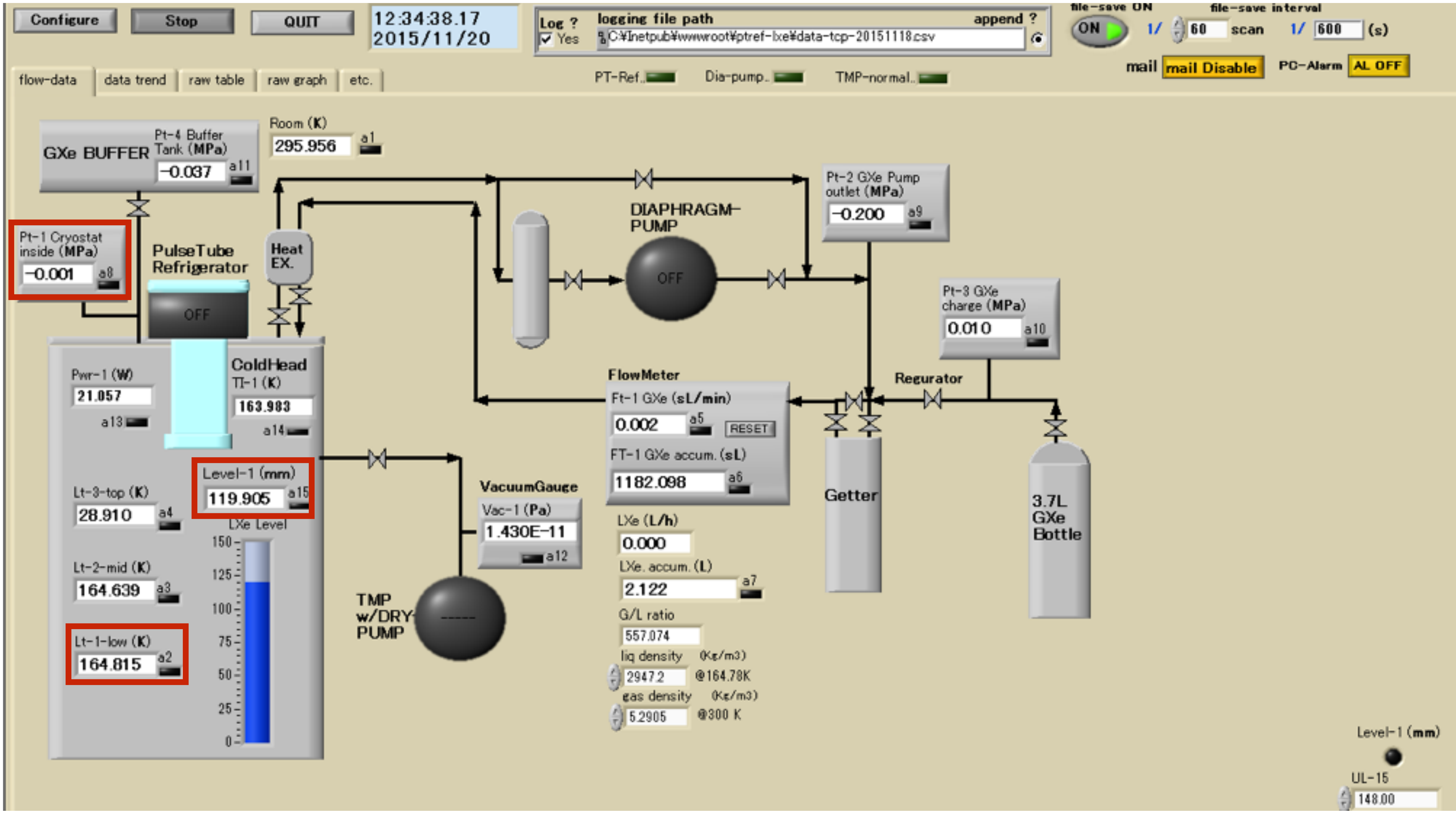
(Measured by TWINBIRD)

Cooling temperature range: -120 °C to +70 °C

• Cooling Capacity	Approx. 120W (at the cold side temperature of -23.3℃) Approx. 50W (at the cold side temperature of -80℃)

→ **Approx. 12W at -125 °C**

Slow Control



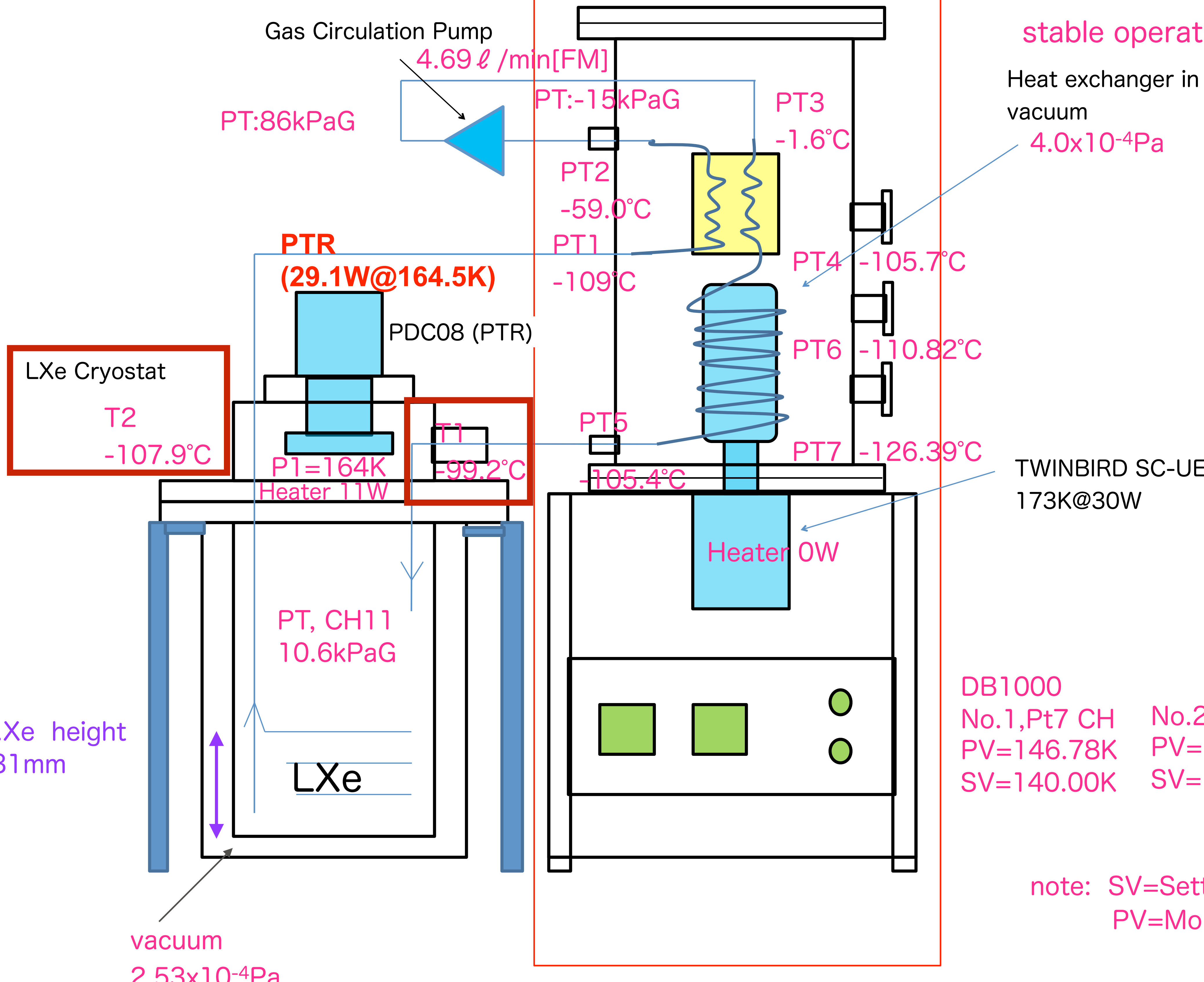
Operation for 10 days

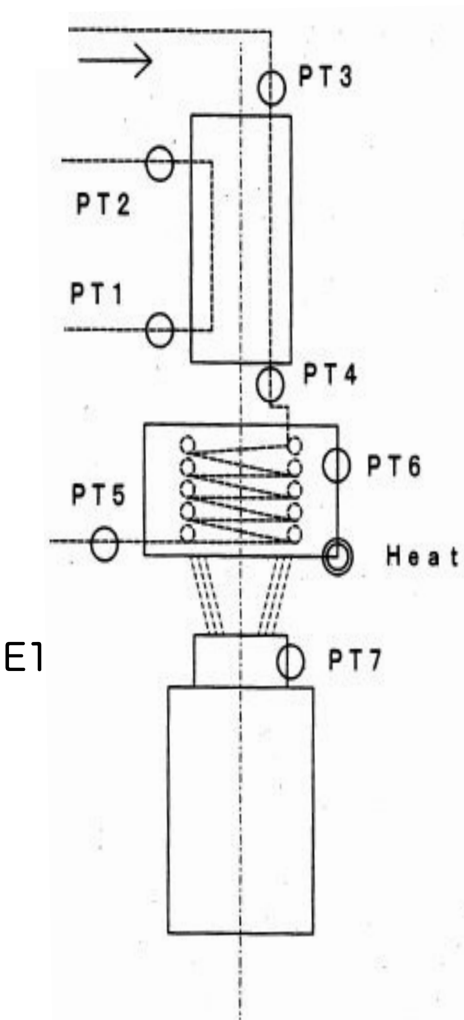
2015 3/27 - 4/7

Maximum：4.69ℓ/min

PDC08: SV=164K

stable operation, 3/27 - 4/7





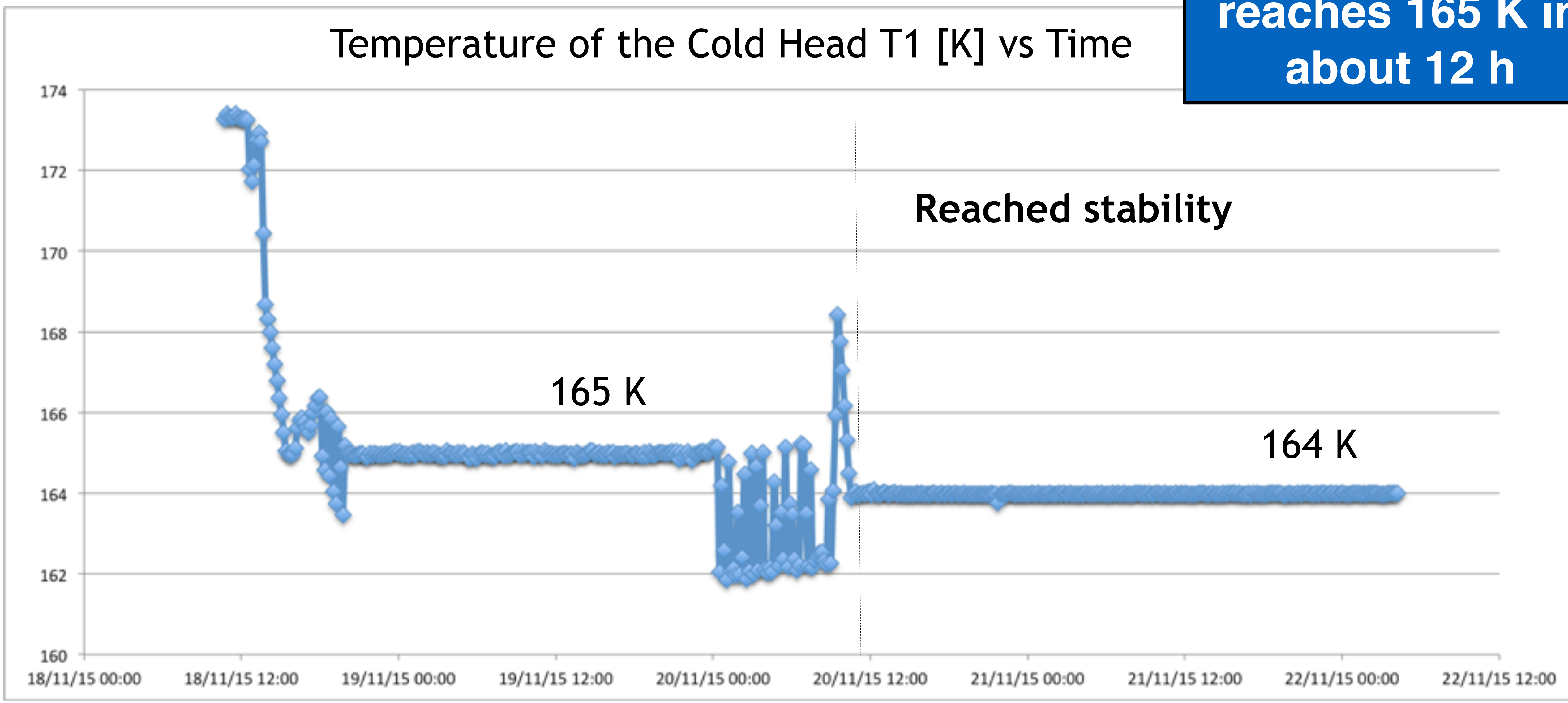
DB1000
No.1,Pt7 CH
PV=146.78K
SV=140.00K

No.2 Pt6 コイル
PV=162.34K
SV=162.00K

note: SV=Setting Value
PV=Monitor Value

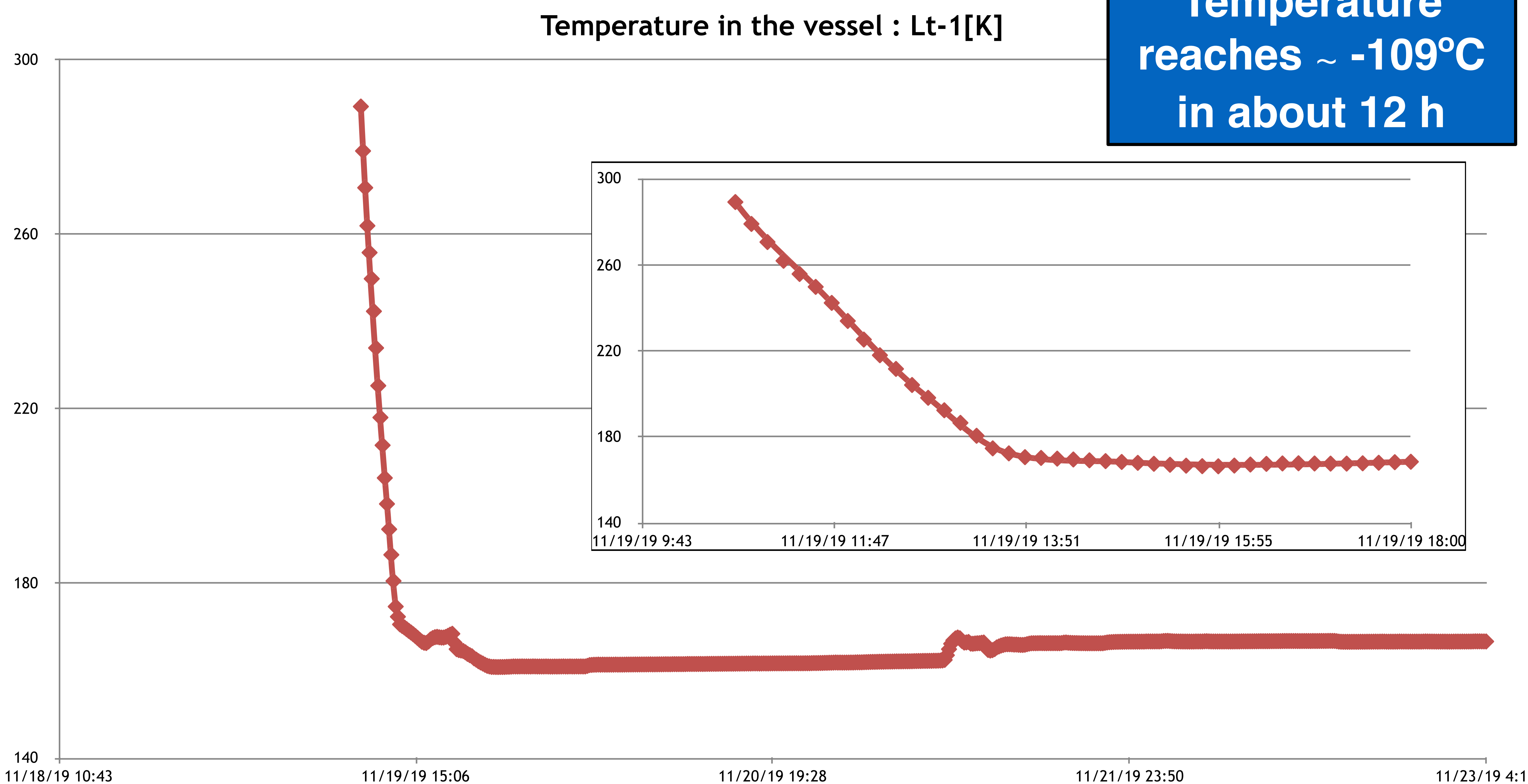
Temperature profile during pre-cooling and liquefaction

Cold head Temperature reaches 165 K in about 12 h

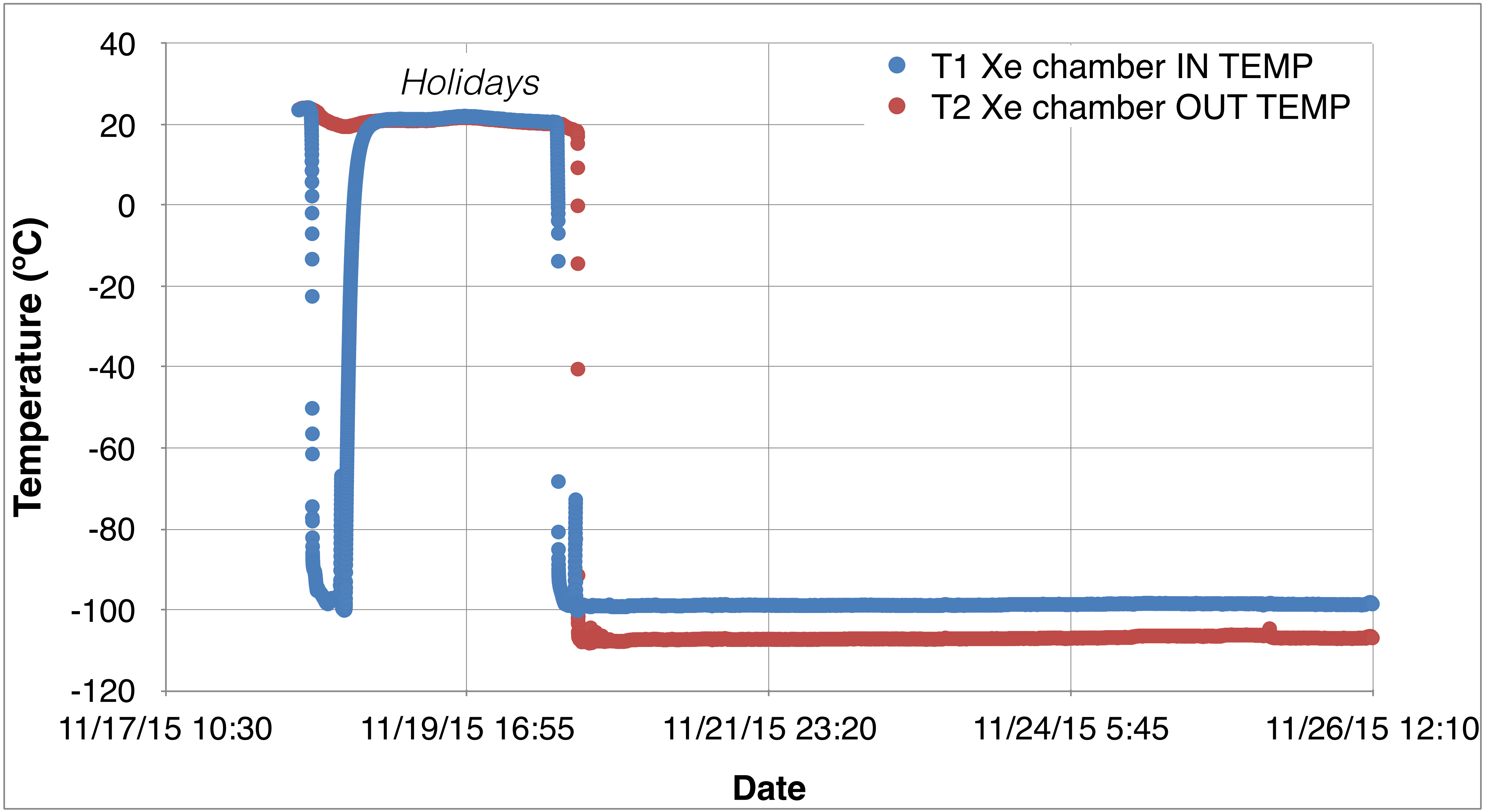


Temperature profile during pre-cooling and liquefaction

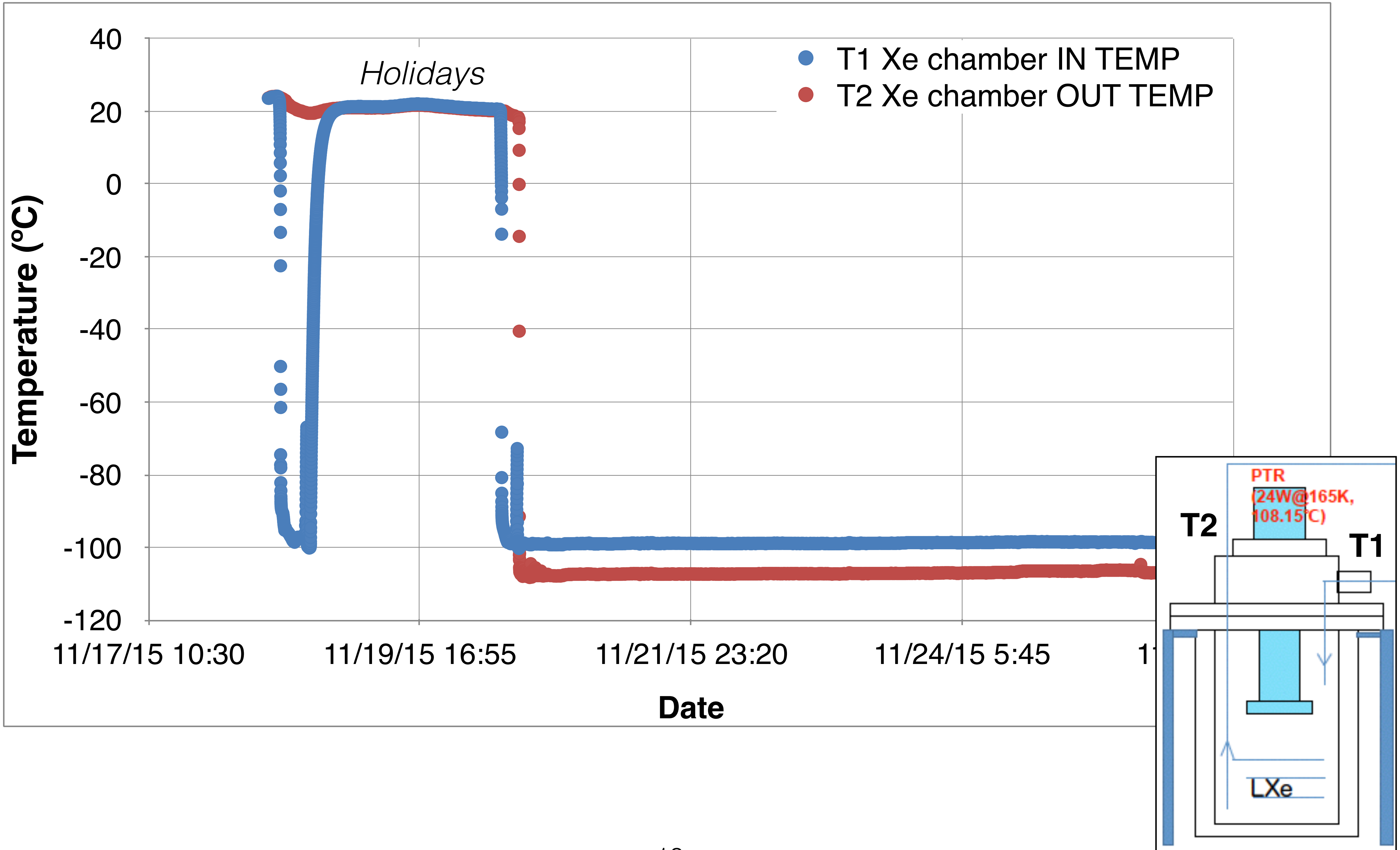
Internal cryostat Temperature reaches ~ -109ºC in about 12 h



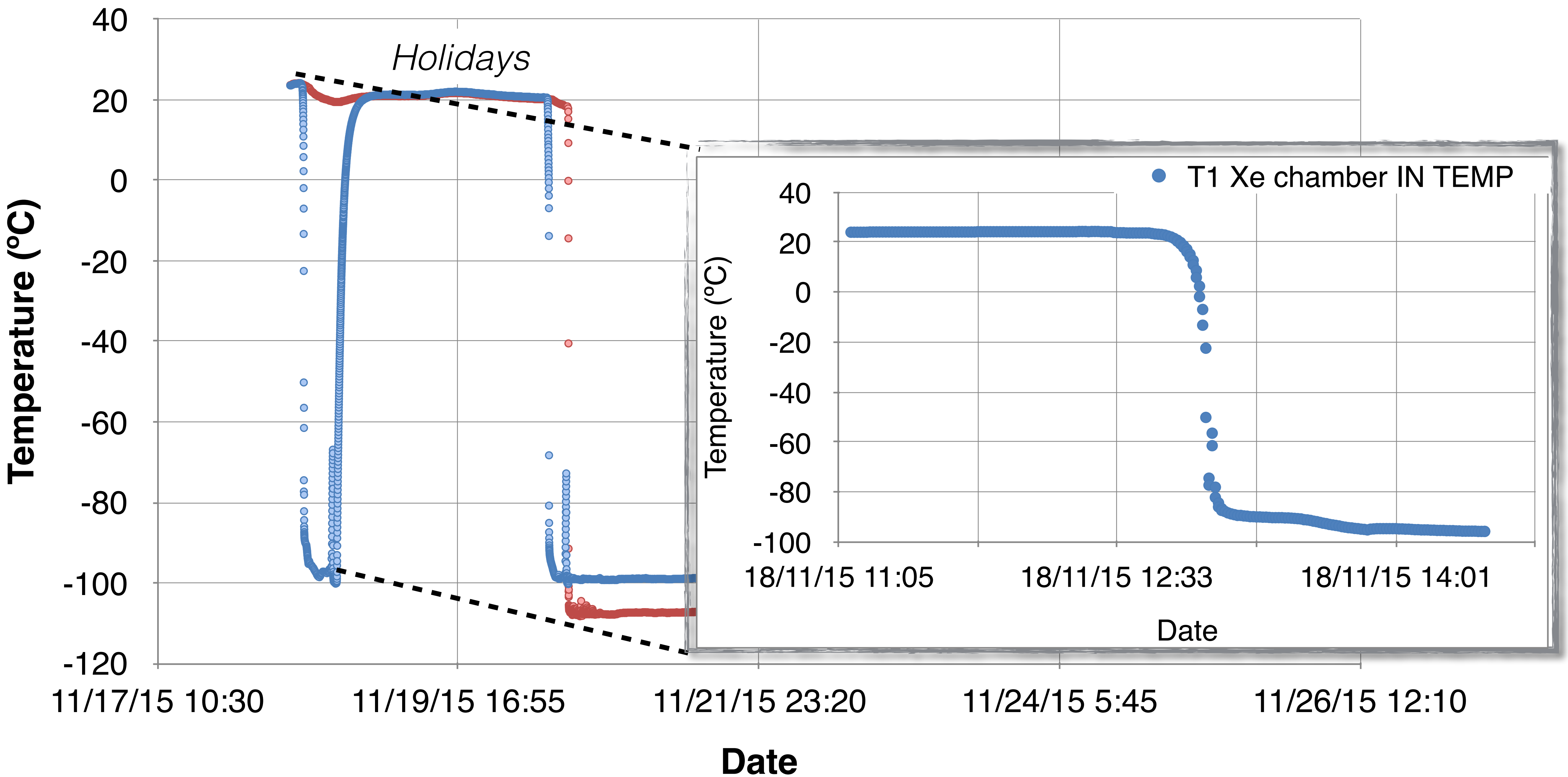
Temperature profile during all data-taking



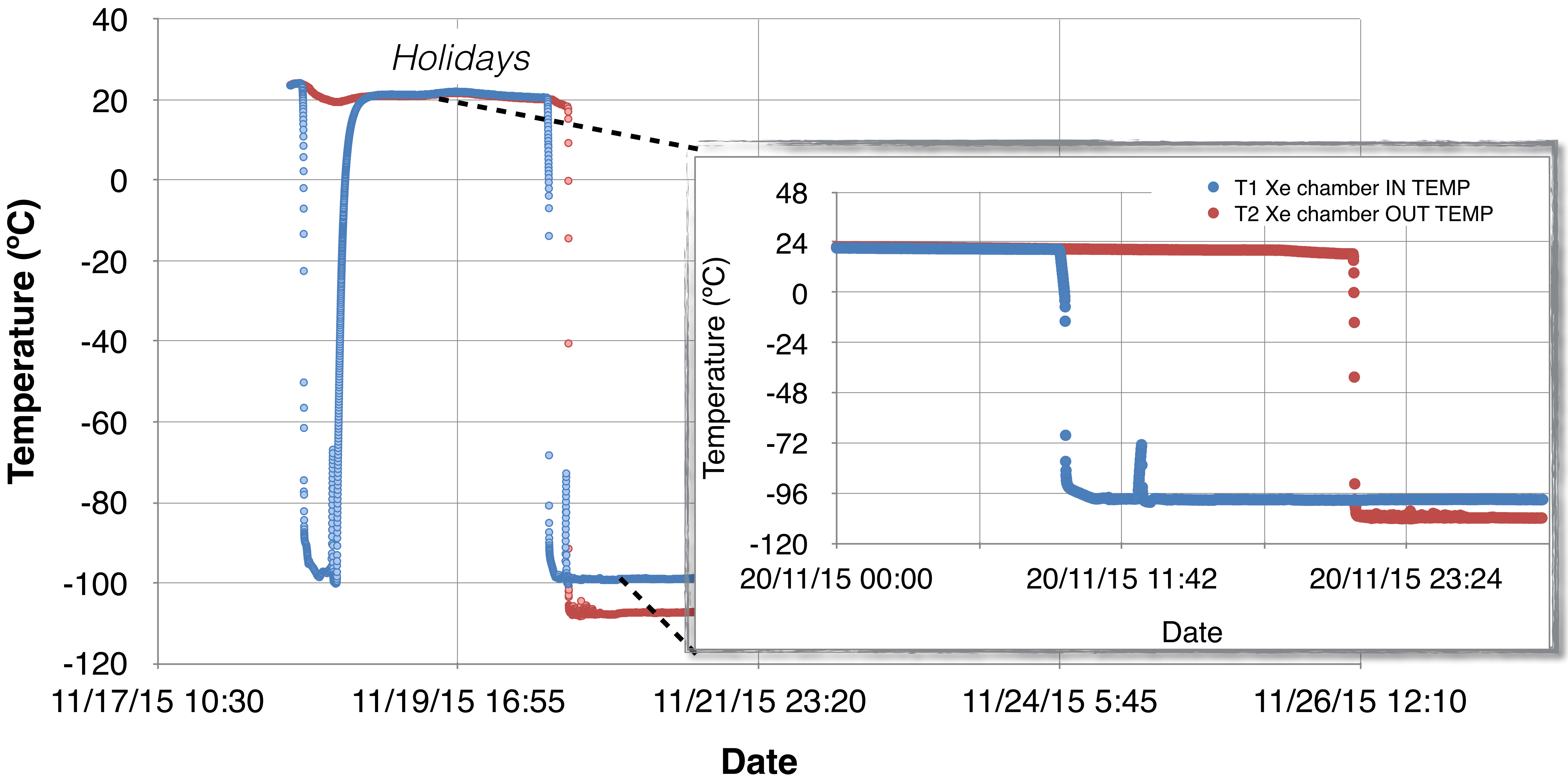
Temperature profile during all data-taking



Temperature profile during pre-cooling and liquefaction

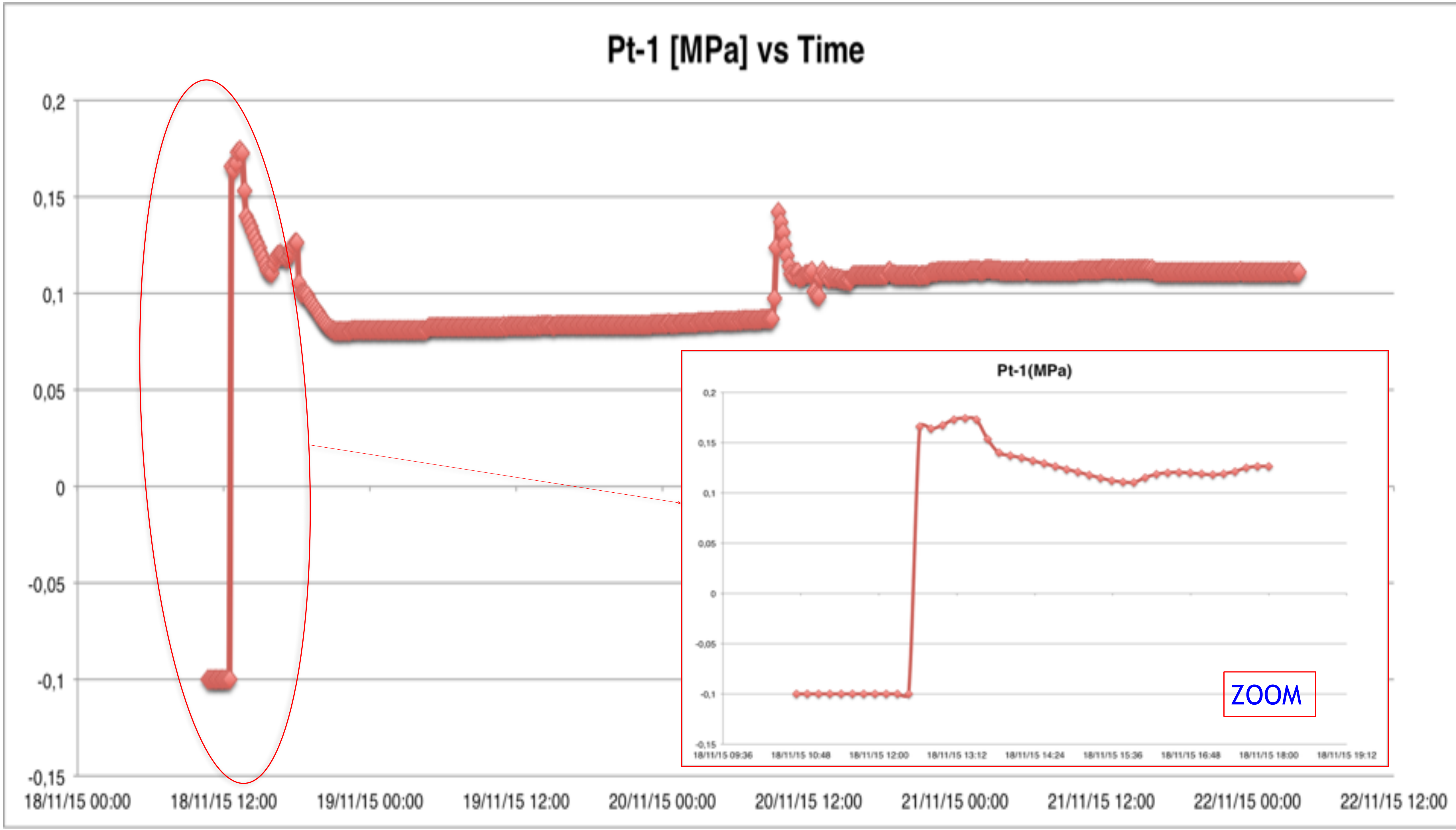


Temperature profile during pre-cooling and liquefaction

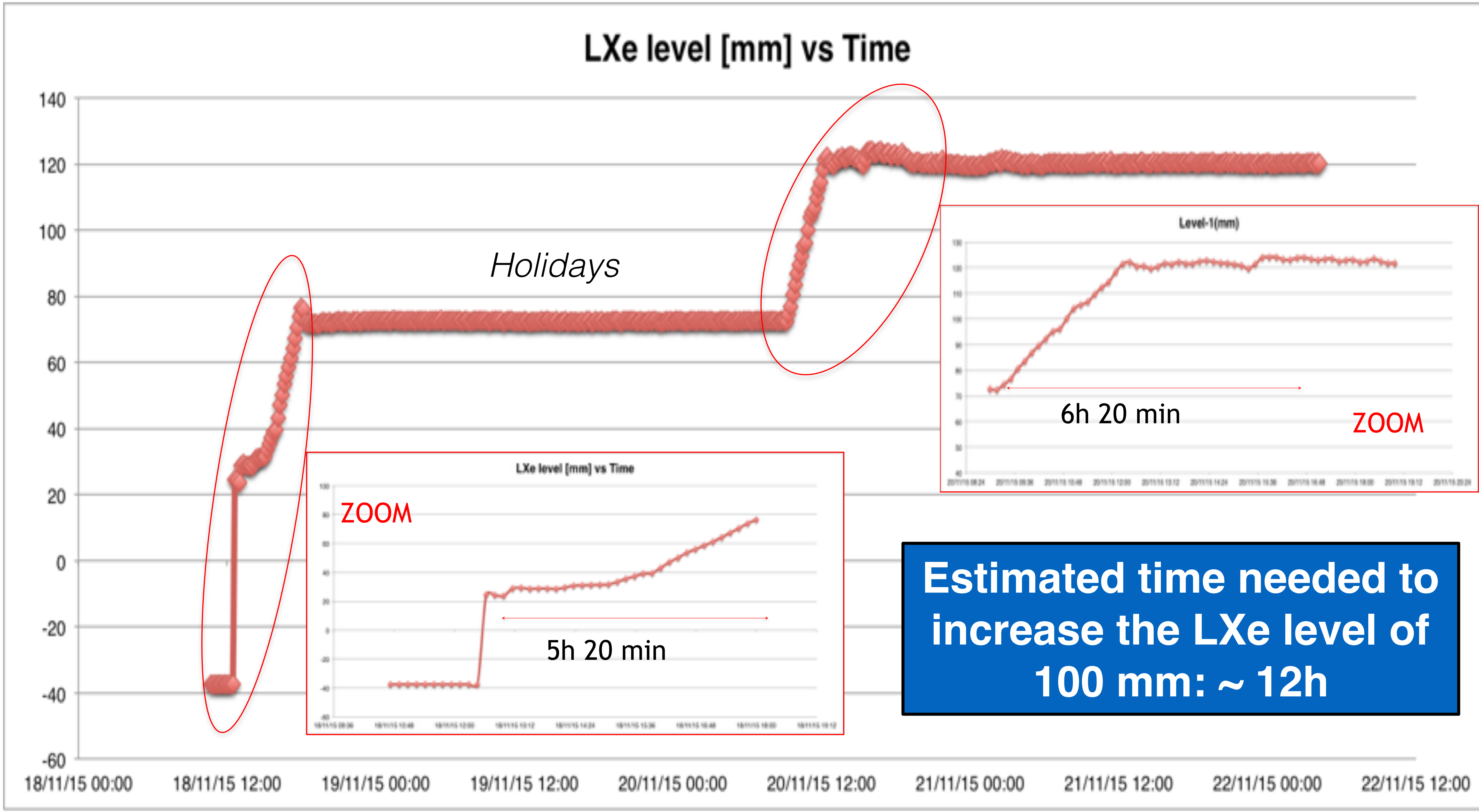


Less than 24 h to cool down the system.

Pressure profile inside cryostat during pre-cooling and liquefaction

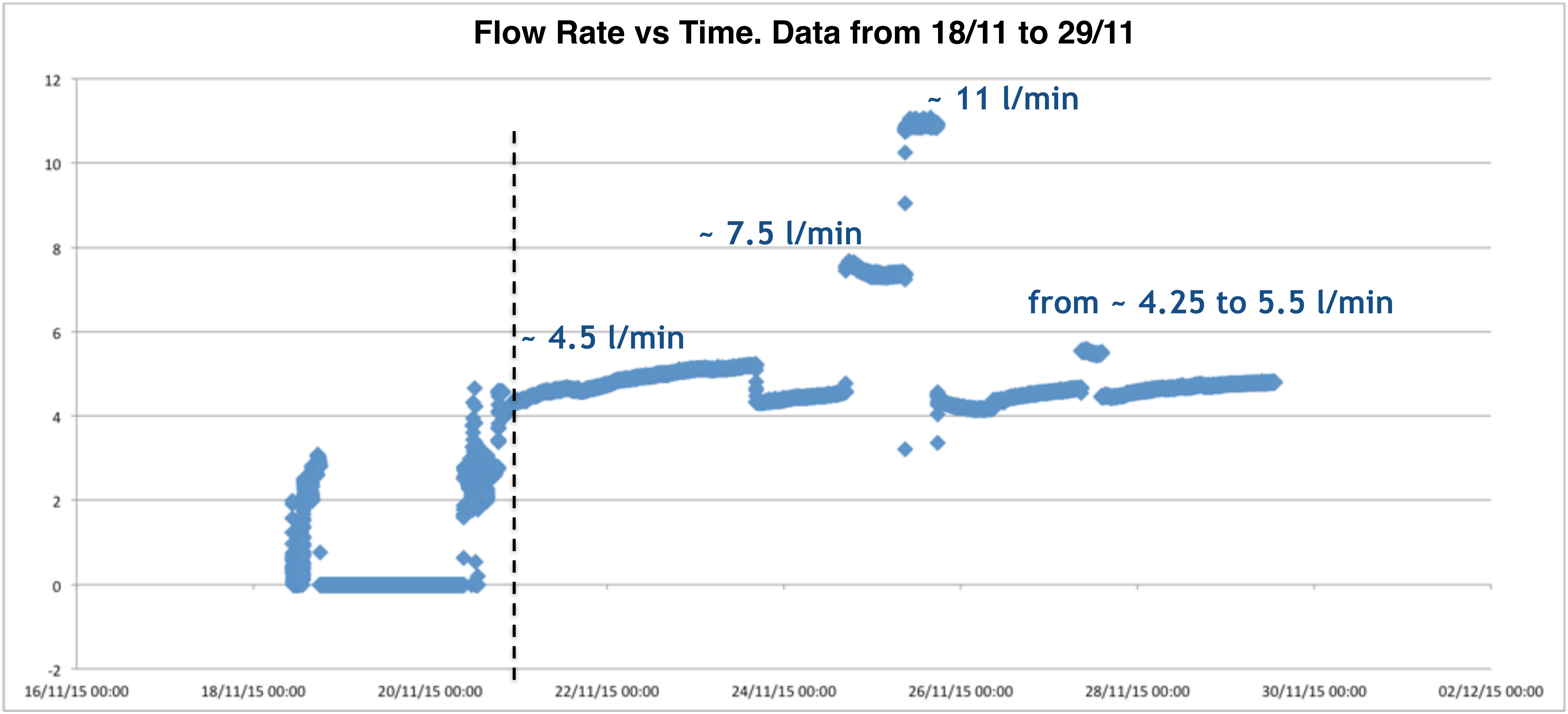


LXe level profile during Liquefaction

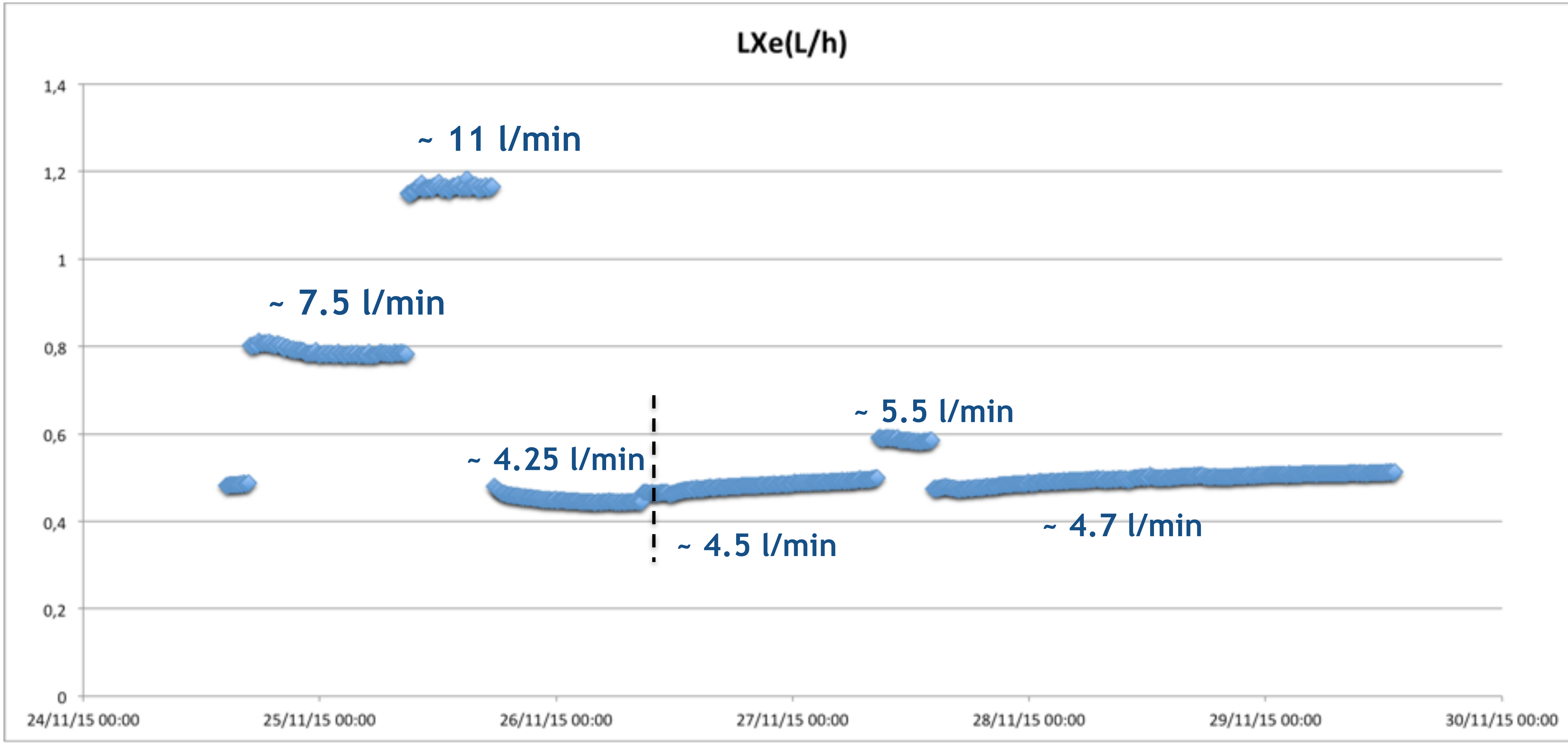


Estimated time needed to increase the LXe level of 100 mm: ~ 12h

Circulation

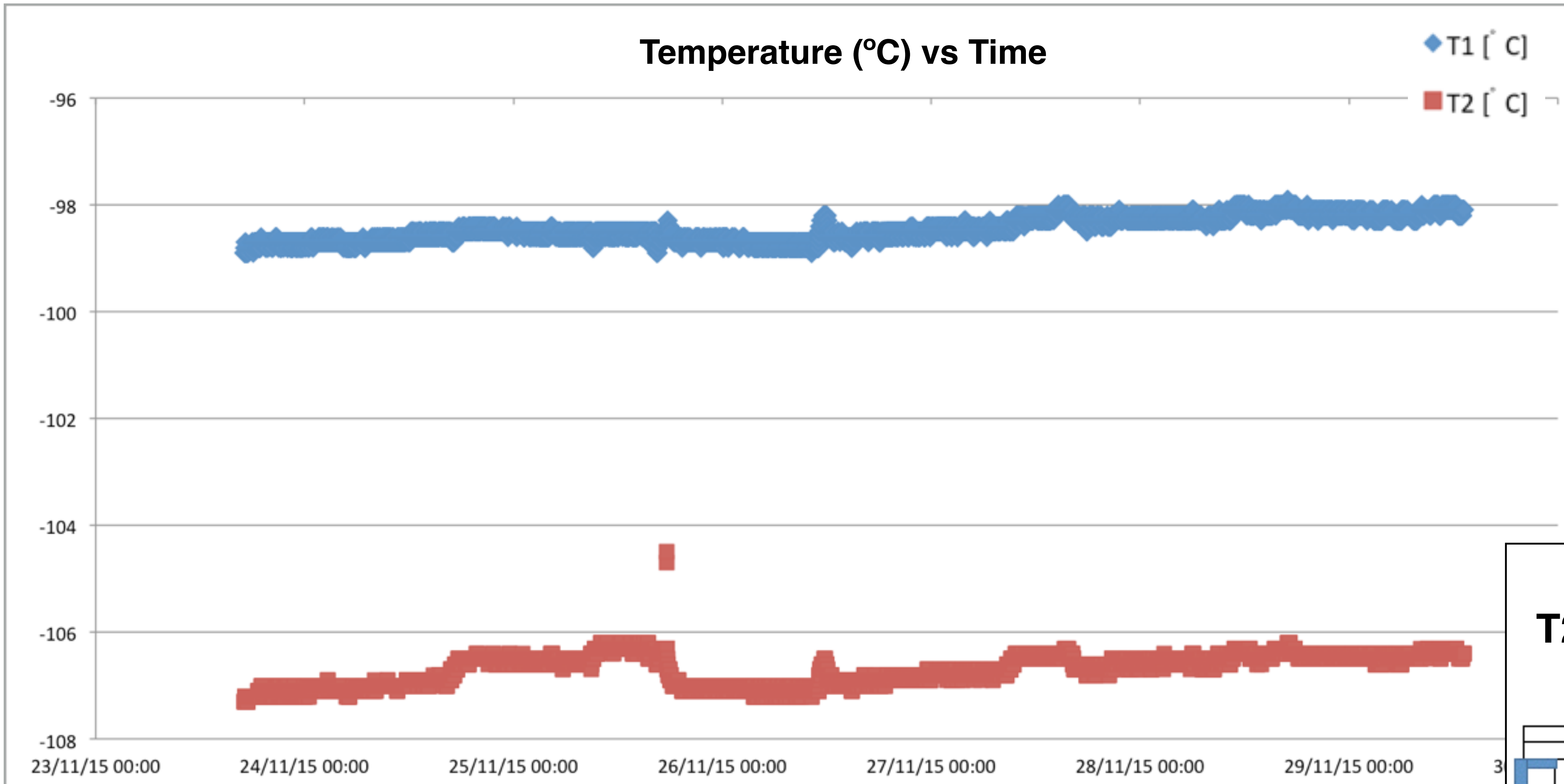


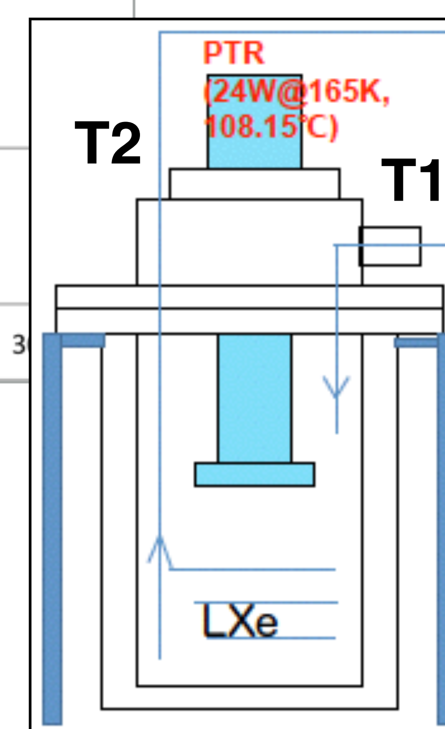
Flow Rate vs Time



Temperature profile during circulation

Temperature stability during relative long period

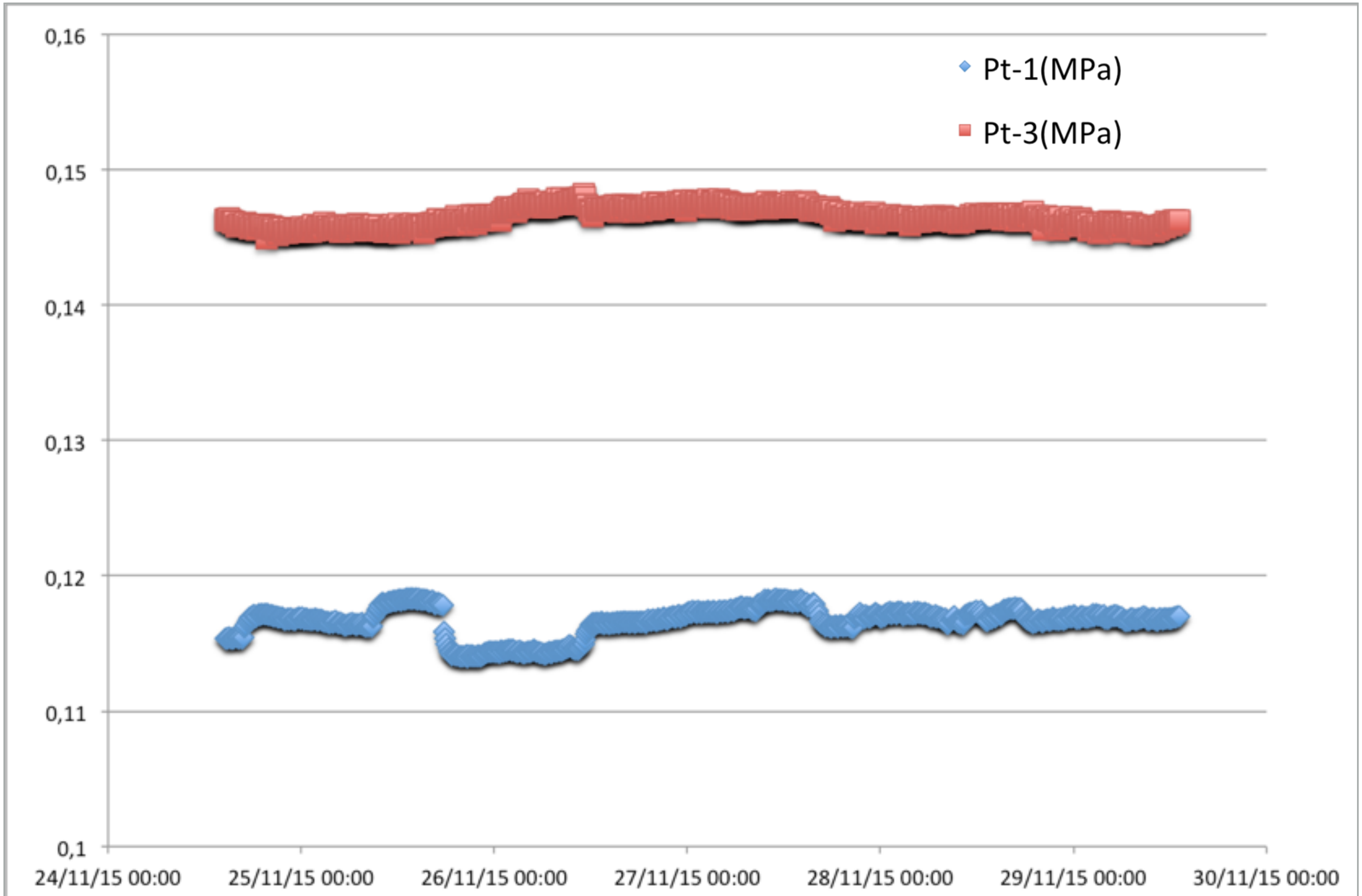




Pressure profile during circulation

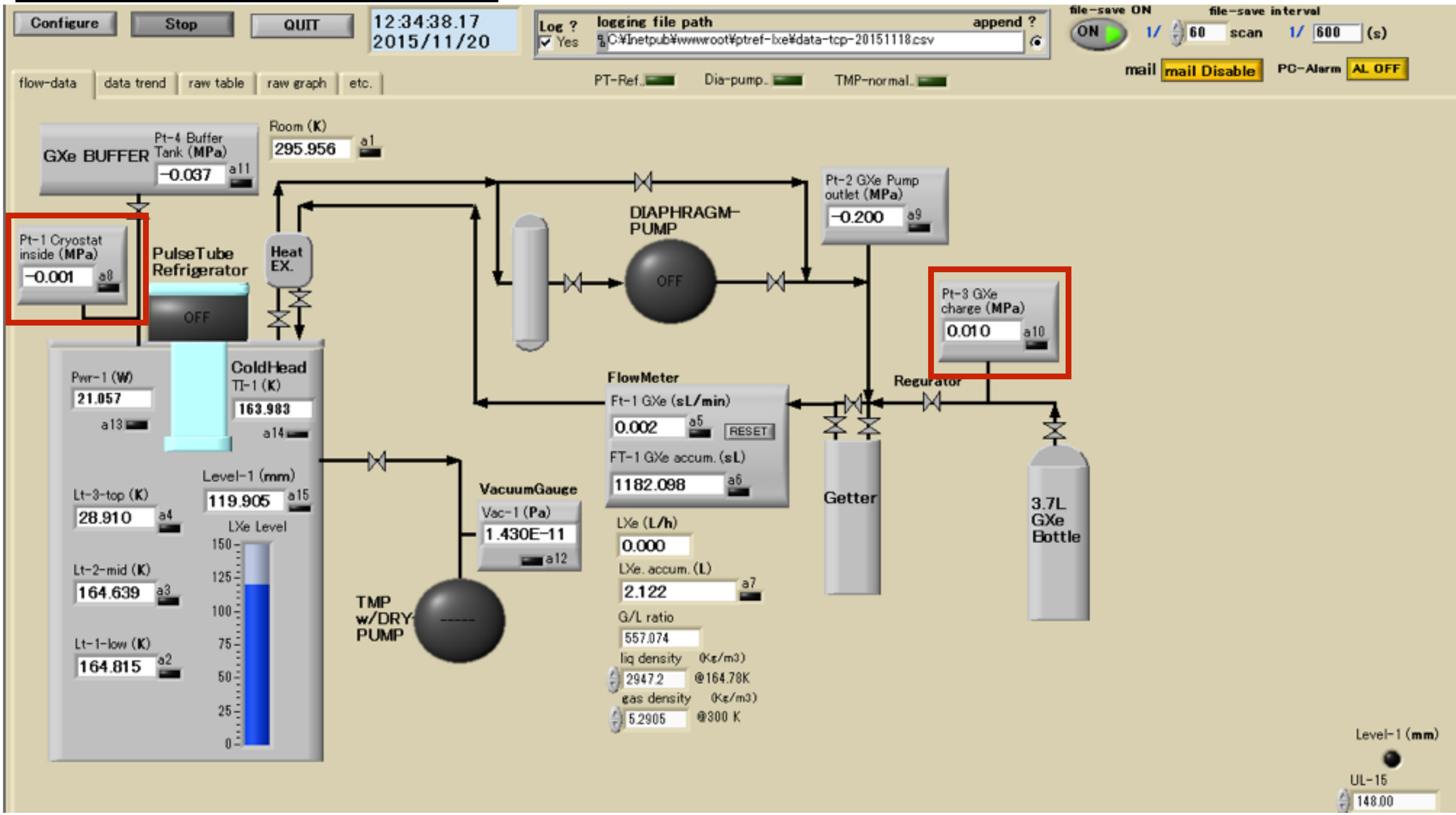
Pt-1: pressure inside cryostat
Pt-3: pressure at exchanger inlet

Pressure stability during relative long period

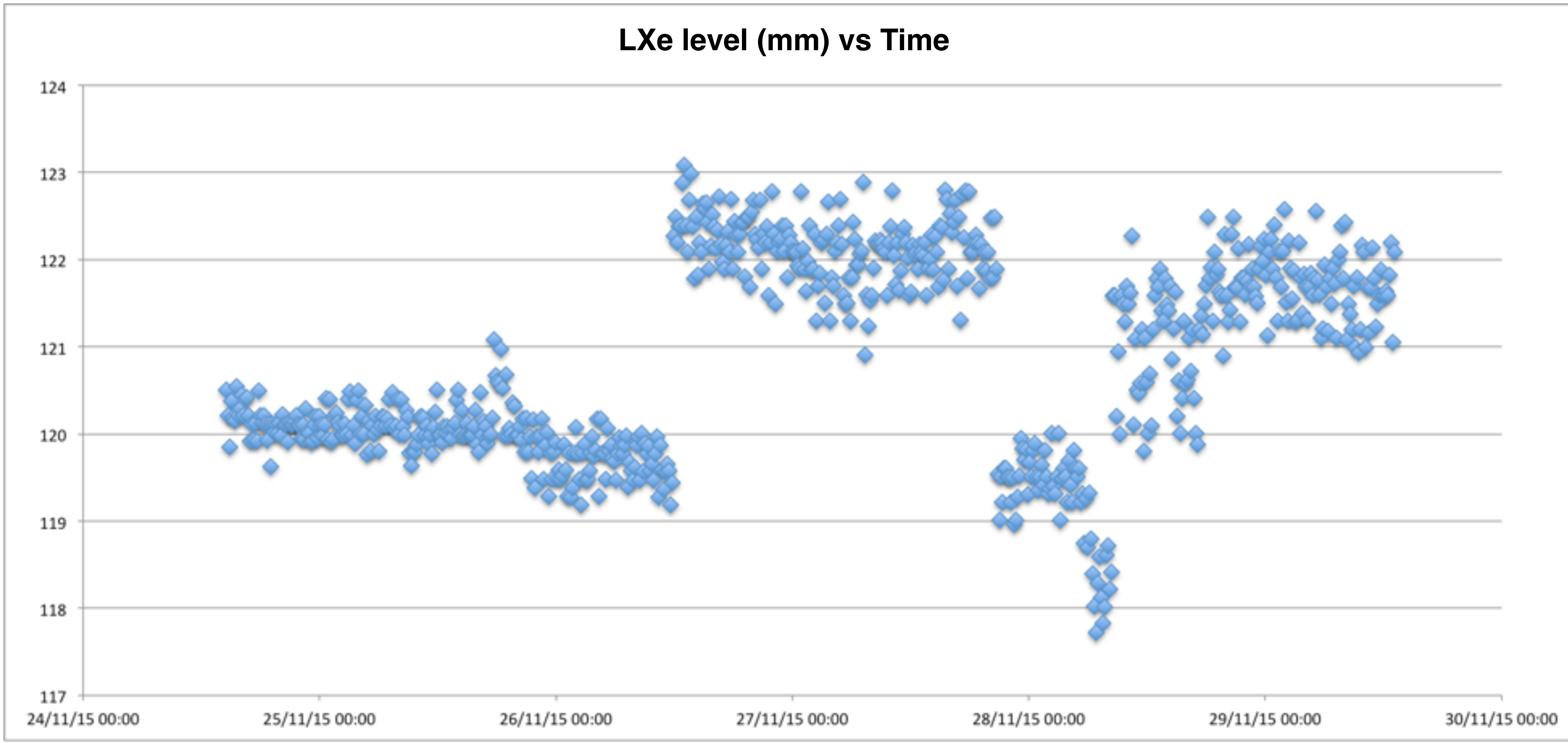


Pressure profile during circulation

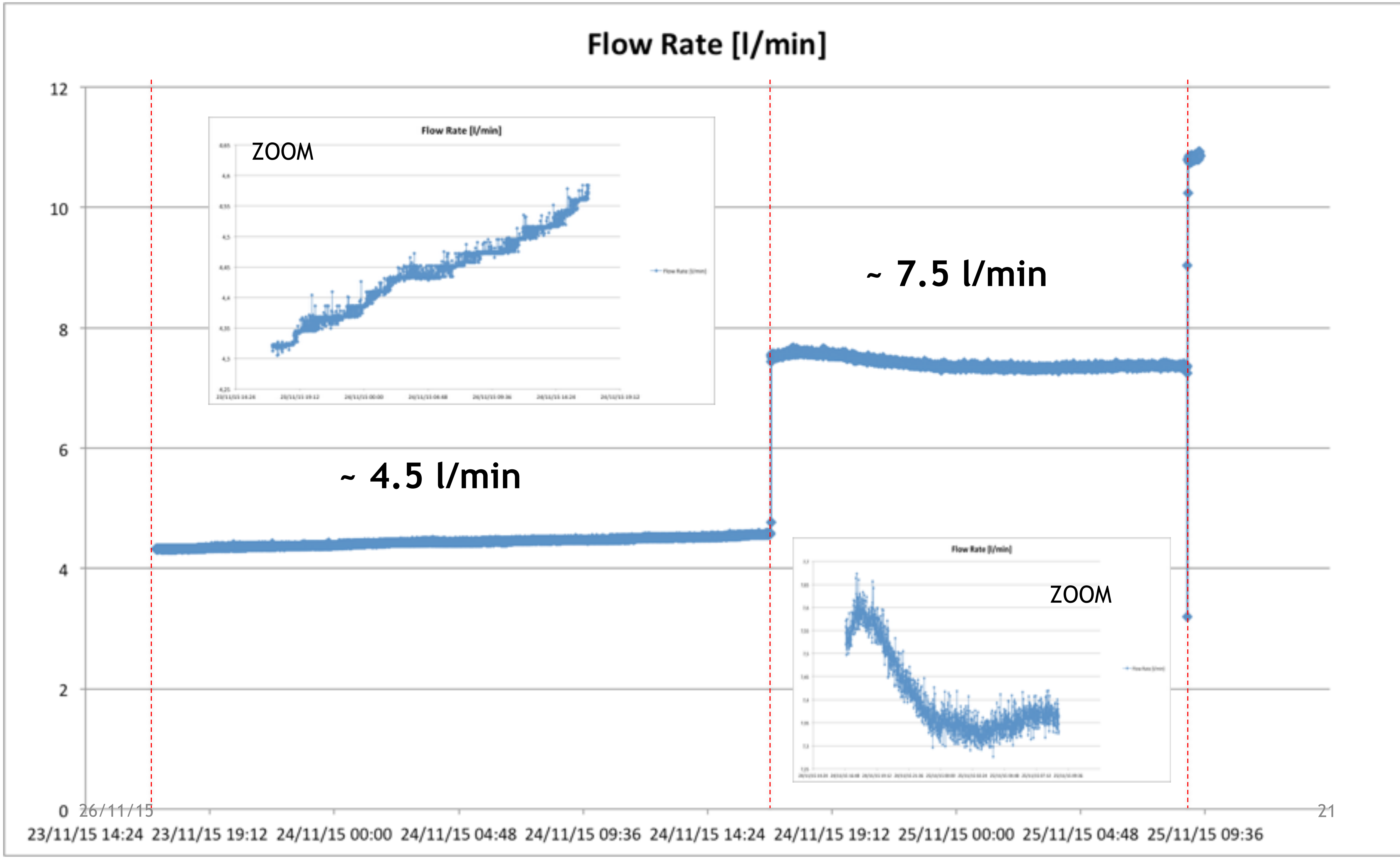
Pt-1: pressure inside cryostat
Pt-3: pressure at exchanger inlet



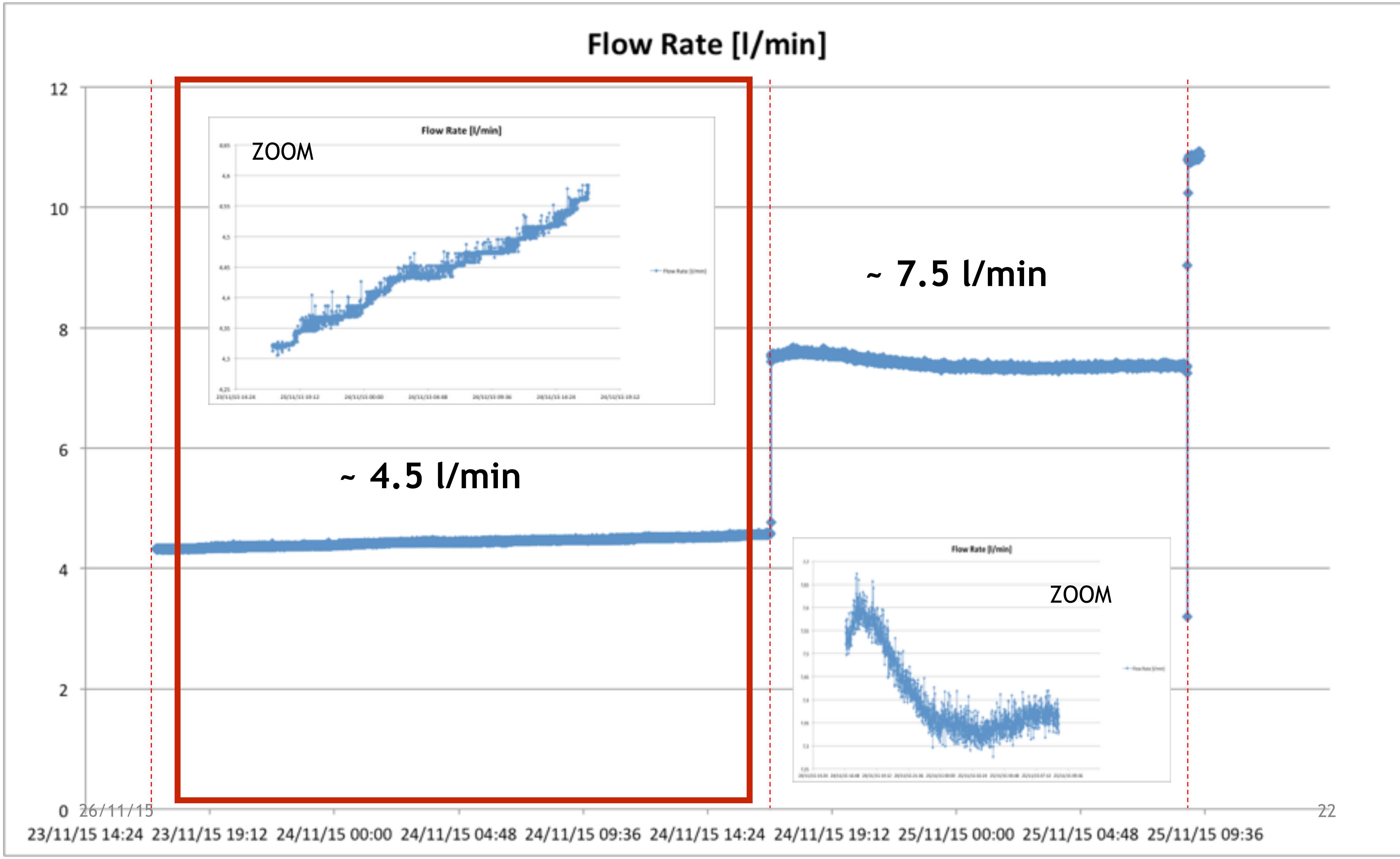
LXe level profile during circulation



Flow rate vs Time

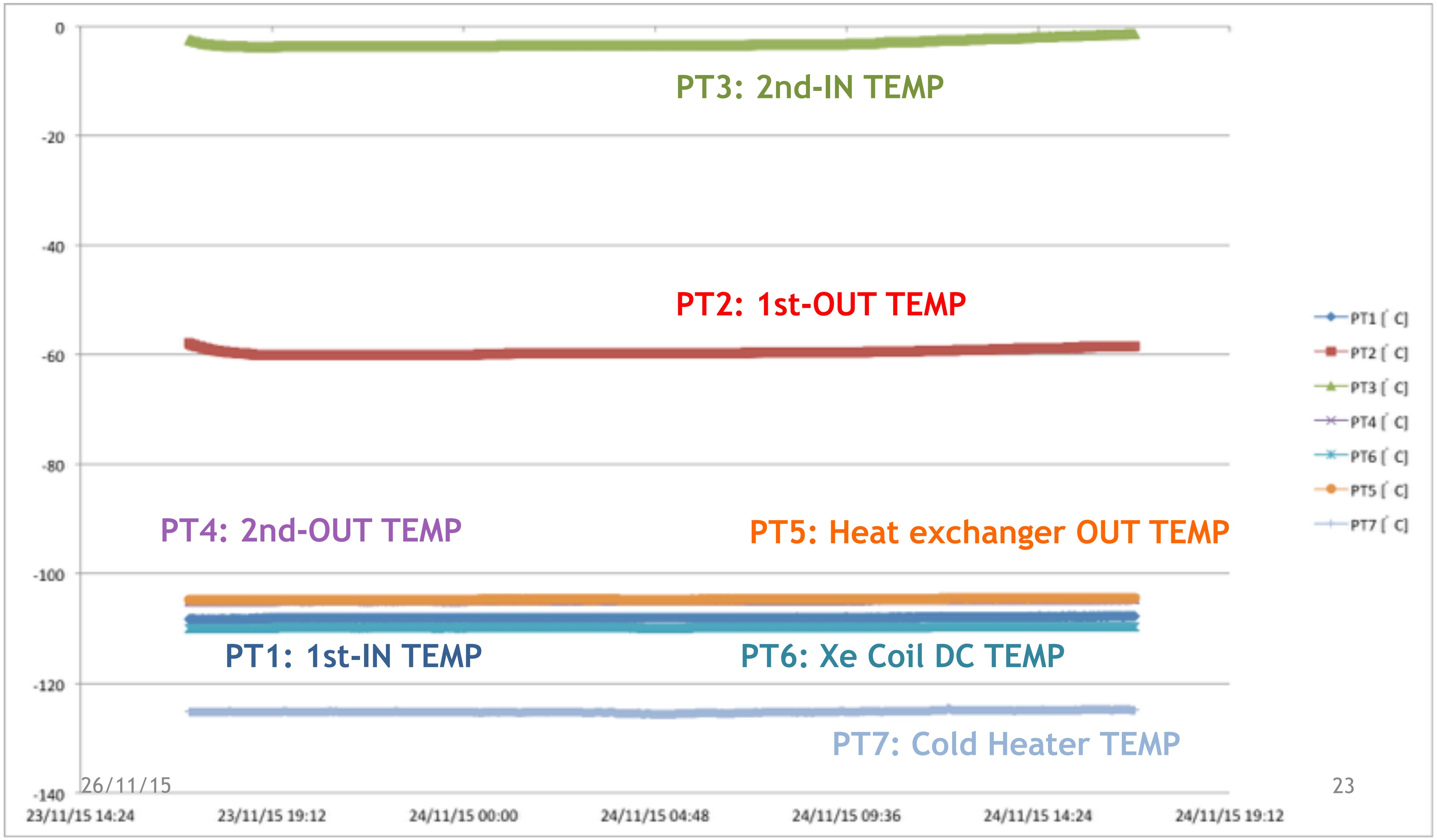


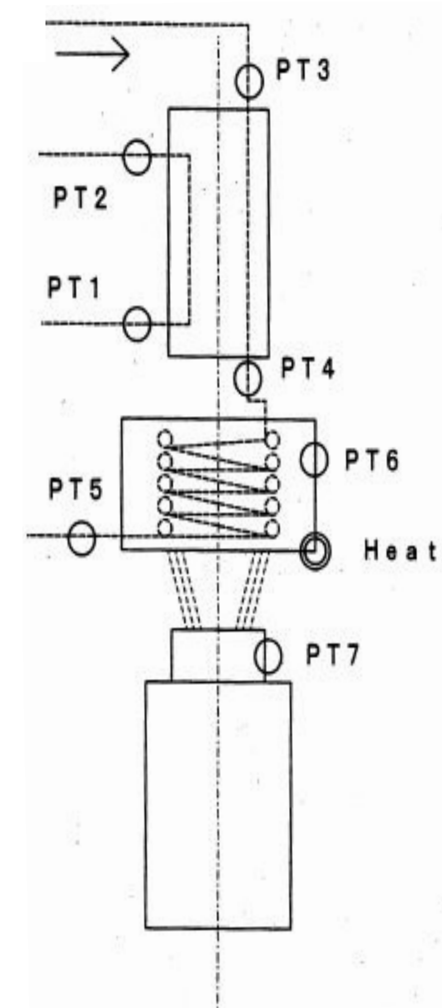
Flow rate vs Time



Temperature vs Time

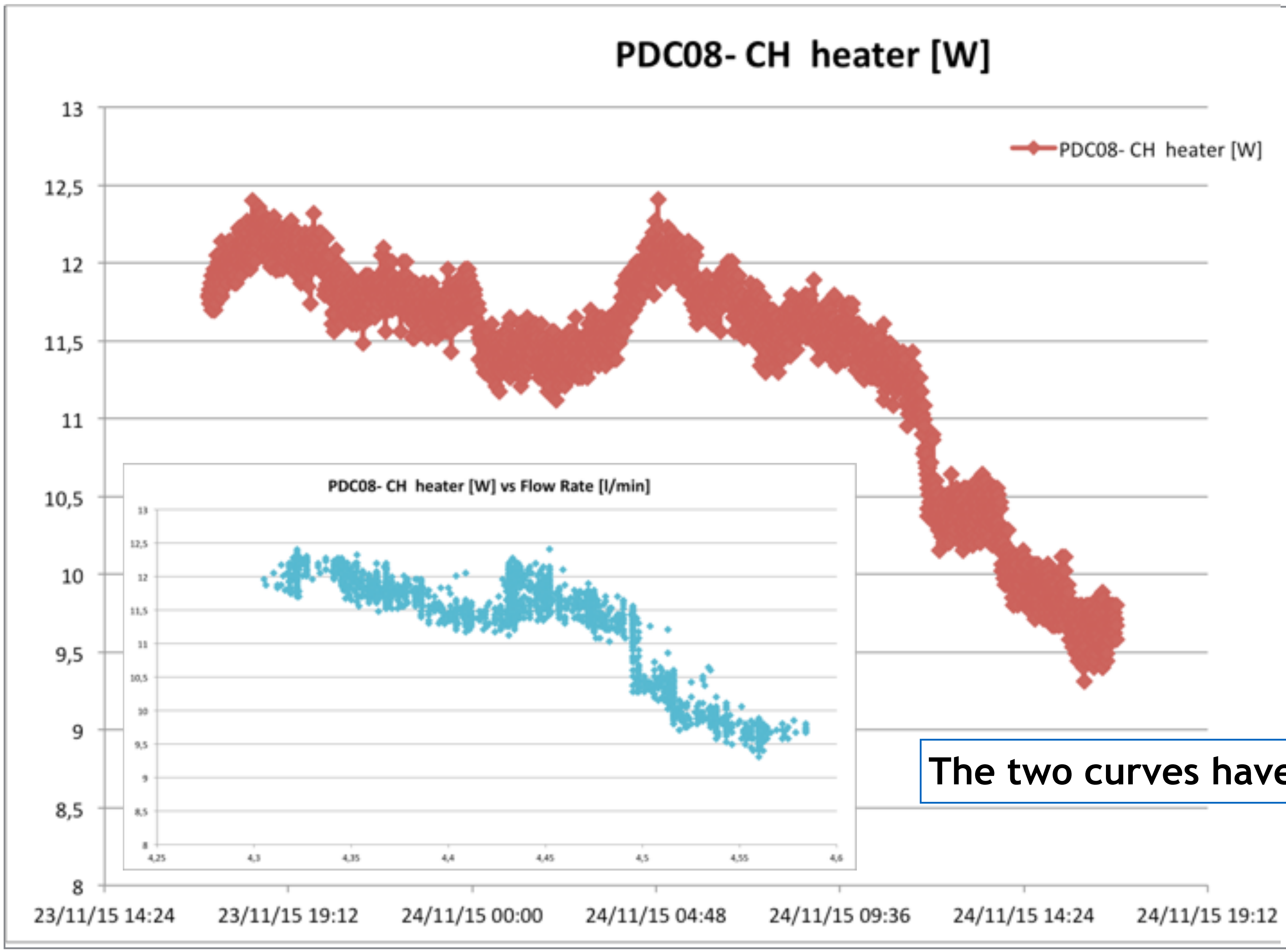
Flow rate of 4.5 l/min





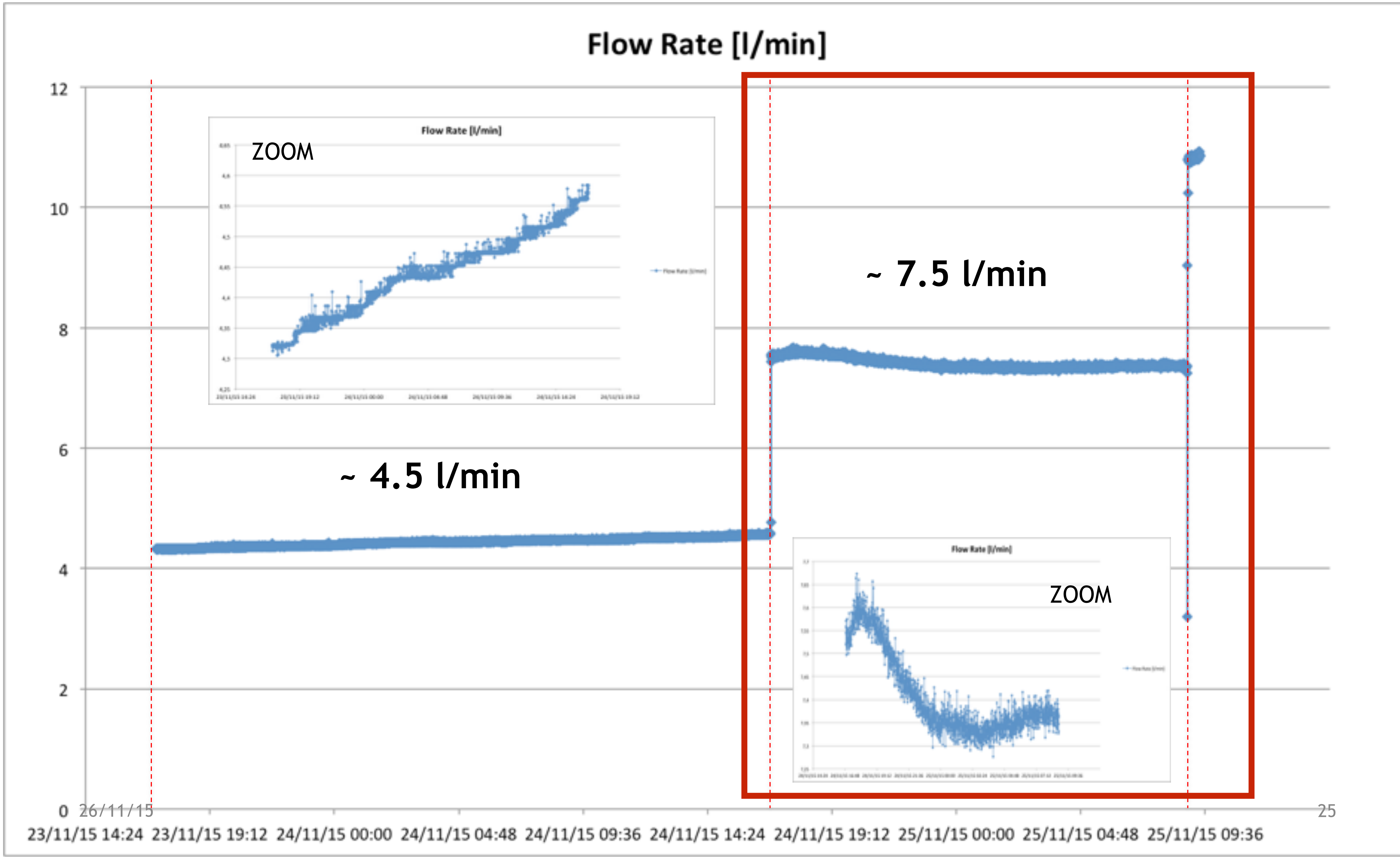
Heater vs Time and Heater vs Flow rate

Flow rate of 4.5 l/min



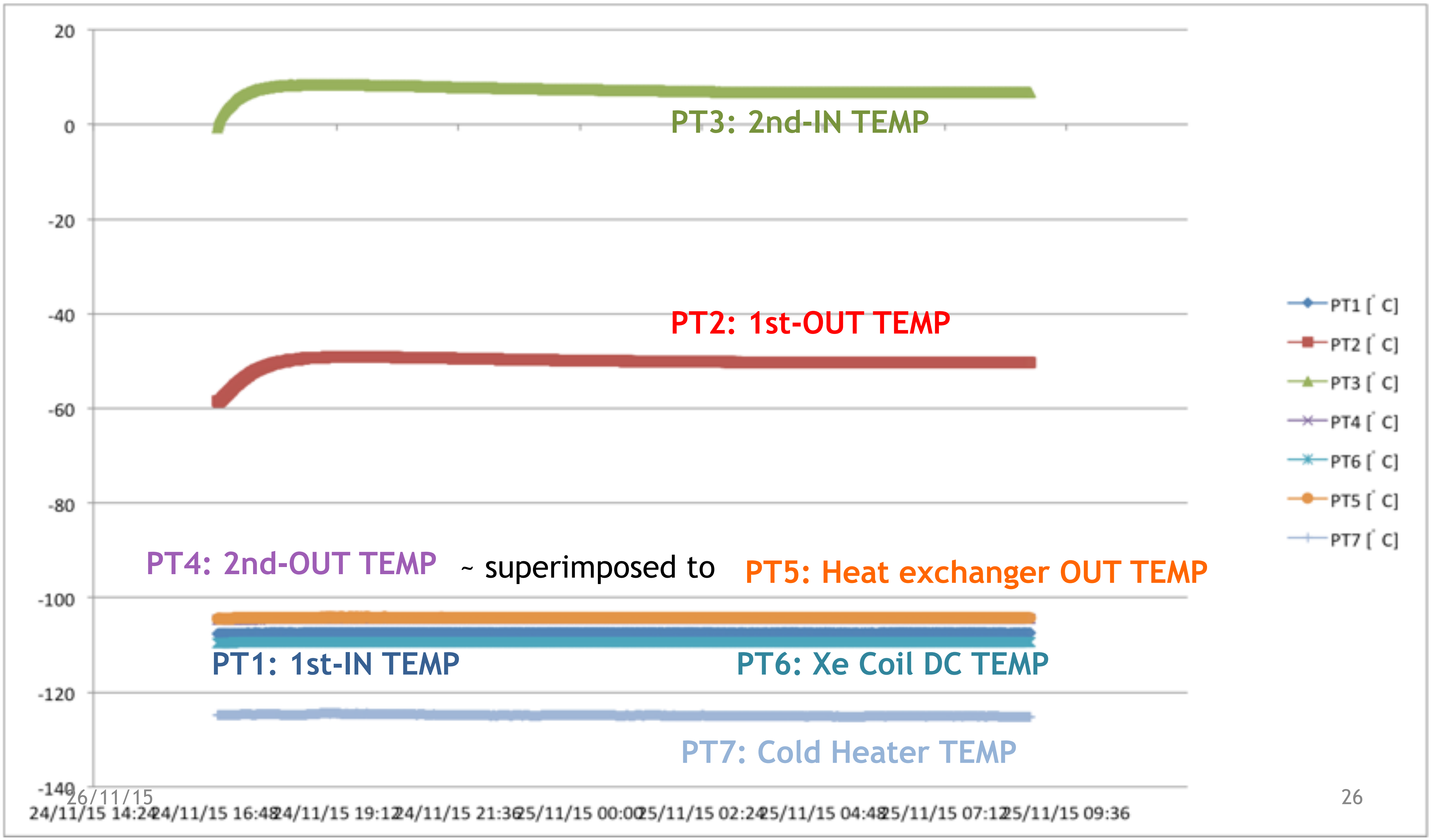
The two curves have a similar trend

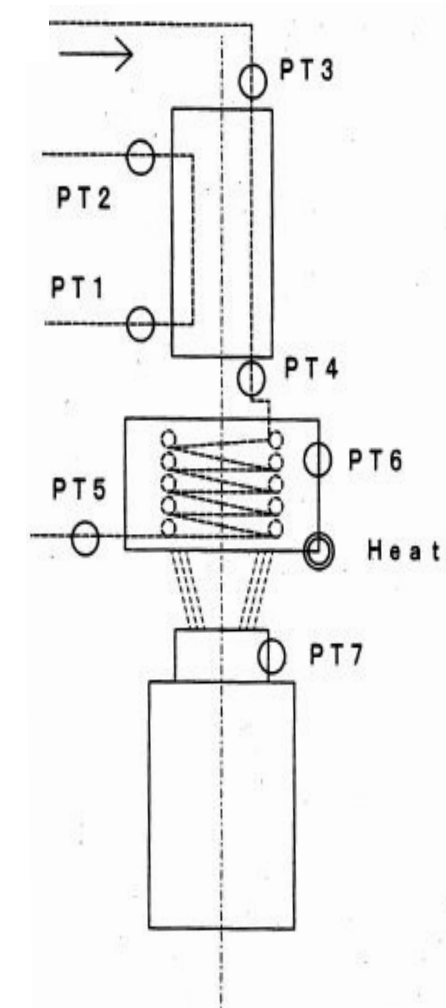
Flow rate vs Time



Temperature vs Time

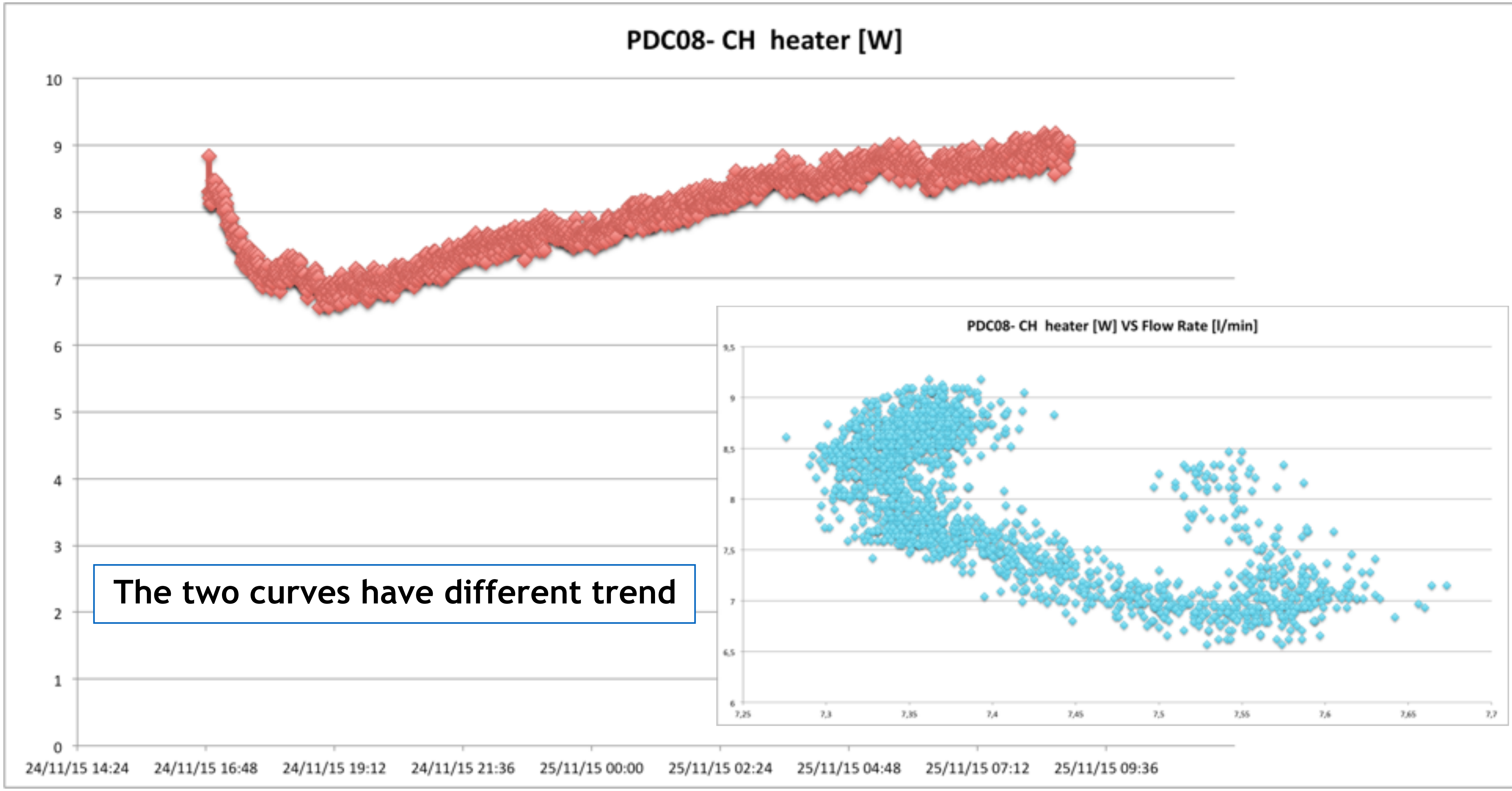
Flow rate of 7.5 l/min





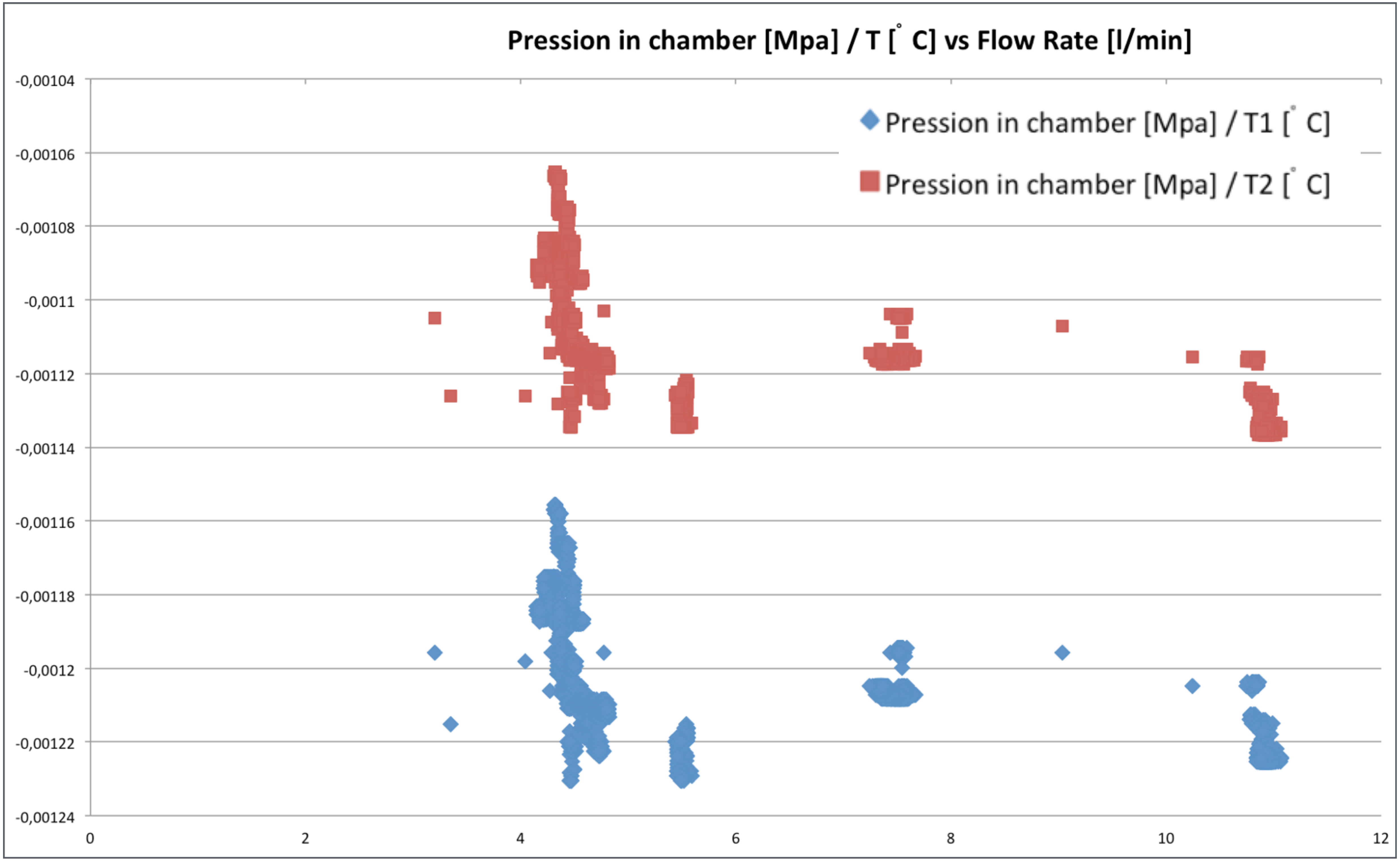
Heater vs Time and Heater vs Flow rate

Flow rate of 7.5 l/min



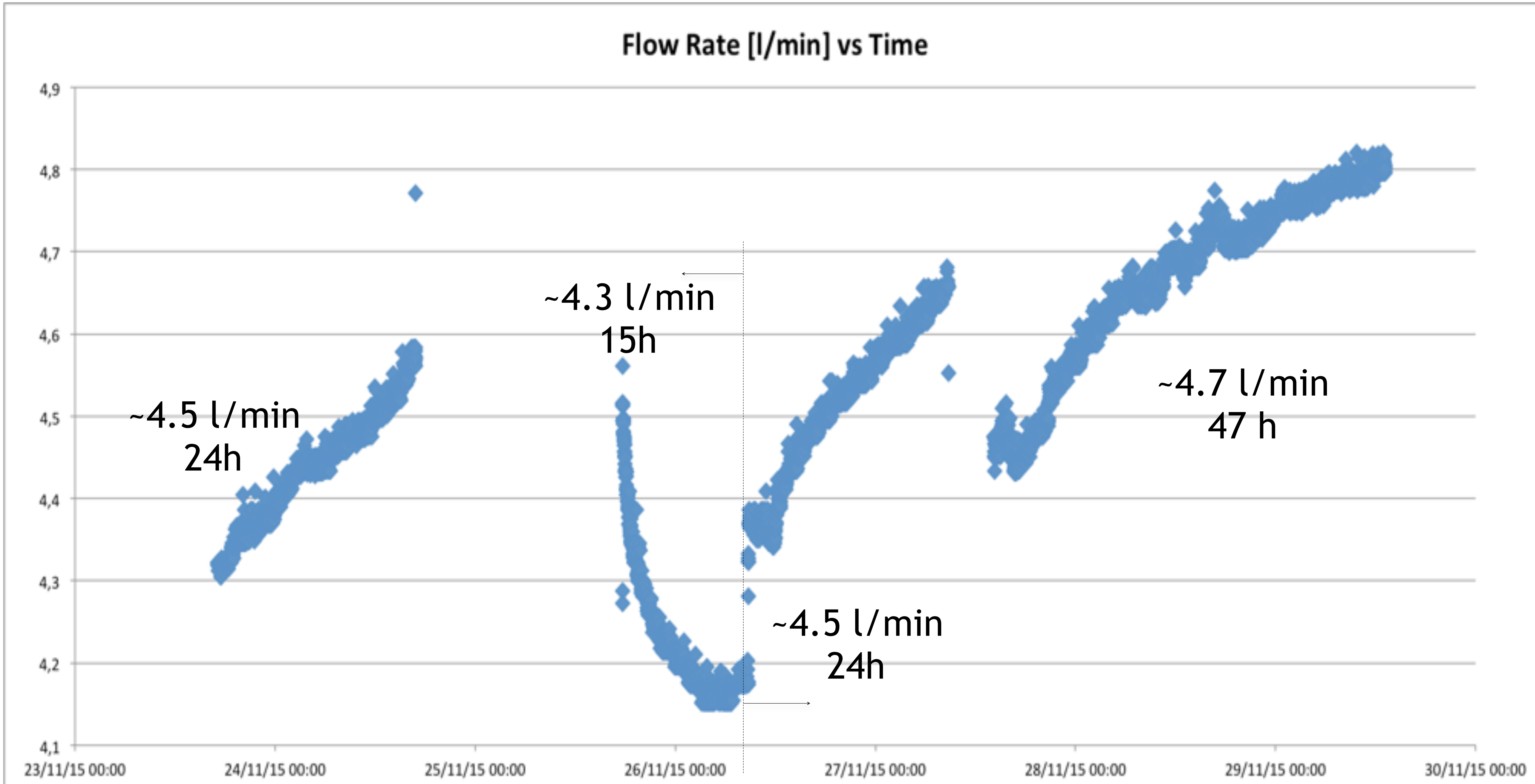
The two curves have different trend

Ratio Pressure/Temperature vs Gas Flow



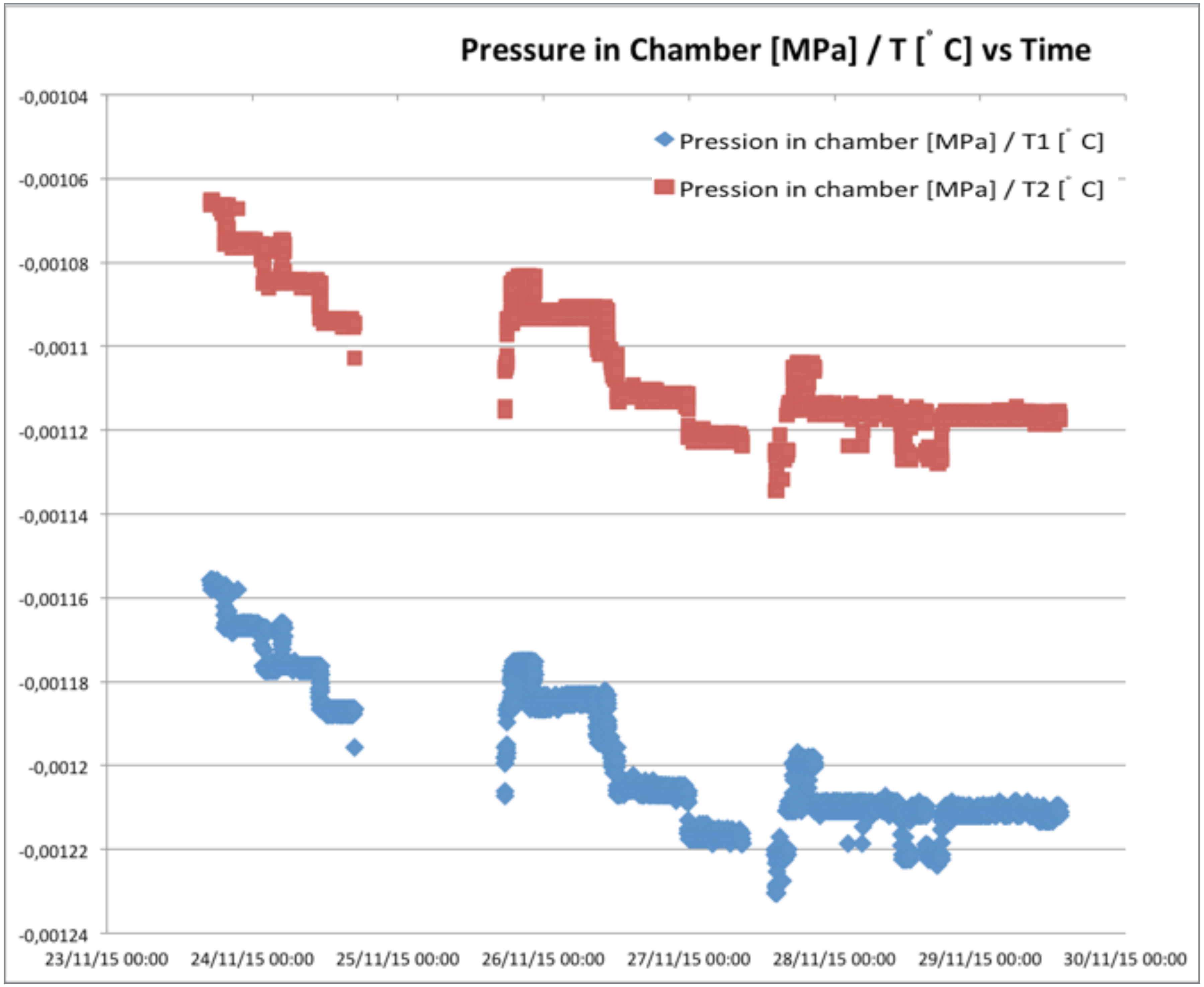
Flow rate vs Time

Flow rate around 4.5 l/min



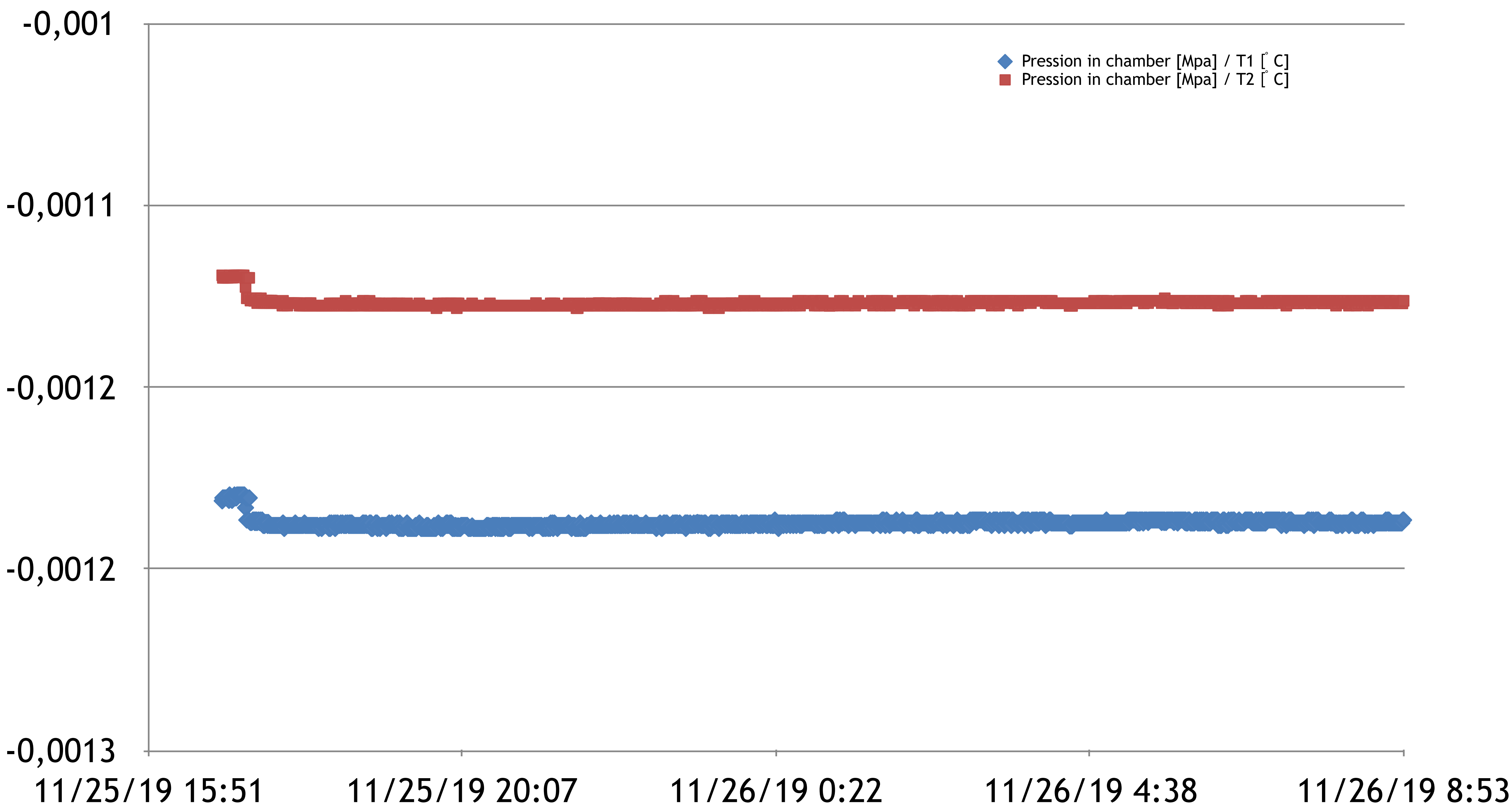
Ratio Pressure/Temperature vs Time

Flow rate around 4.5 l/min



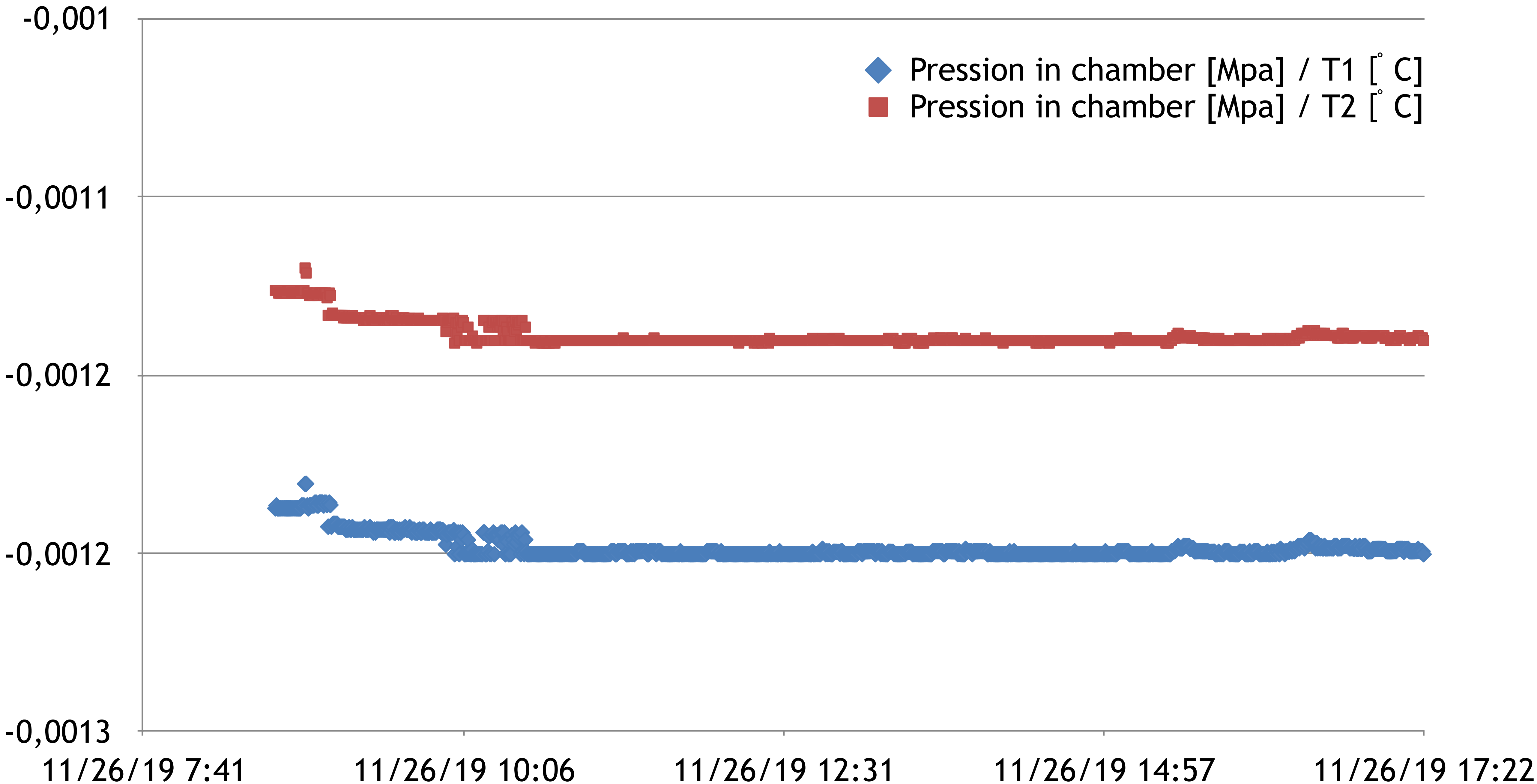
Ratio Pressure/Temperature vs Time

Flow rate around 7.5 l/min



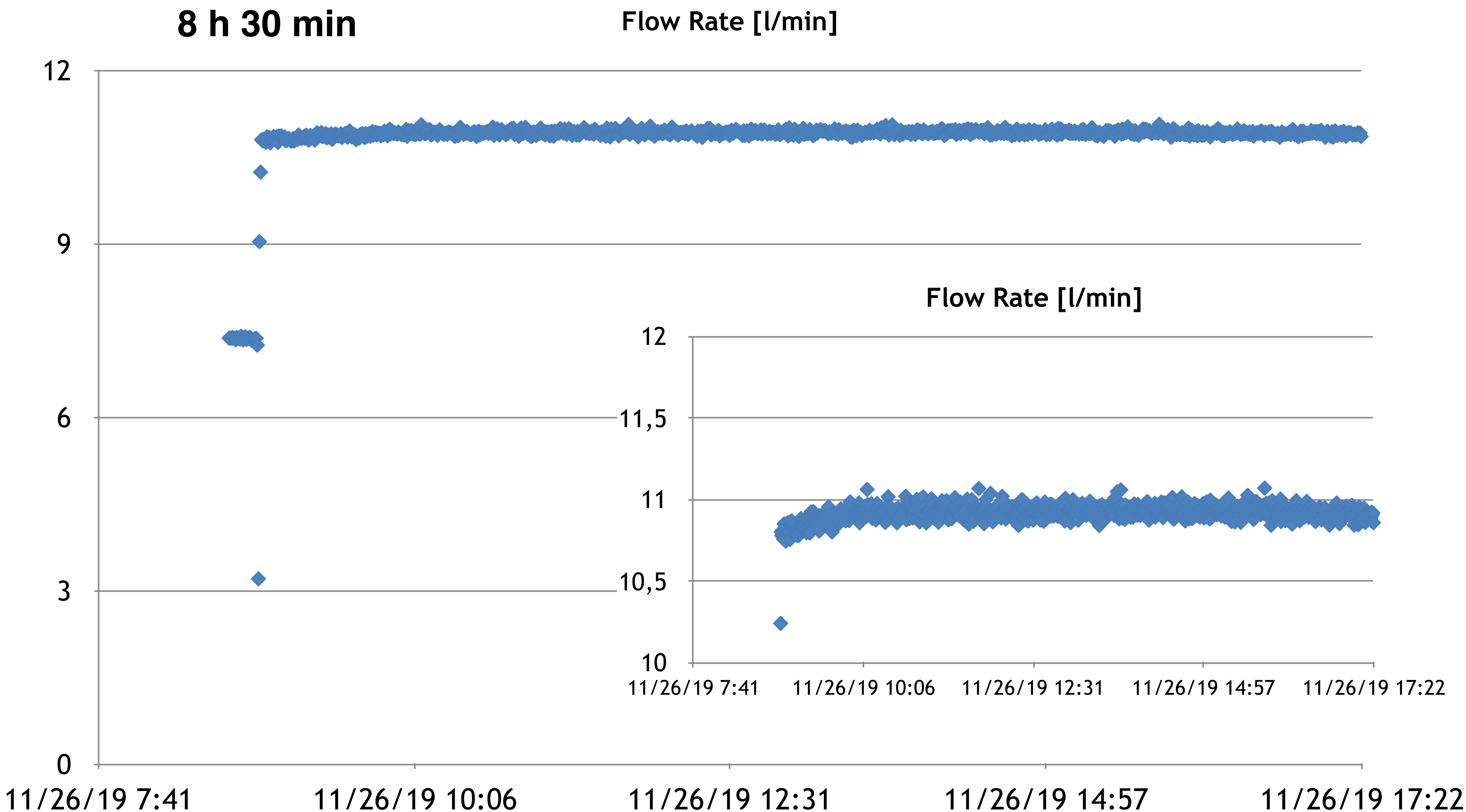
Ratio Pressure/Temperature vs Time

Flow rate around 11.0 l/min

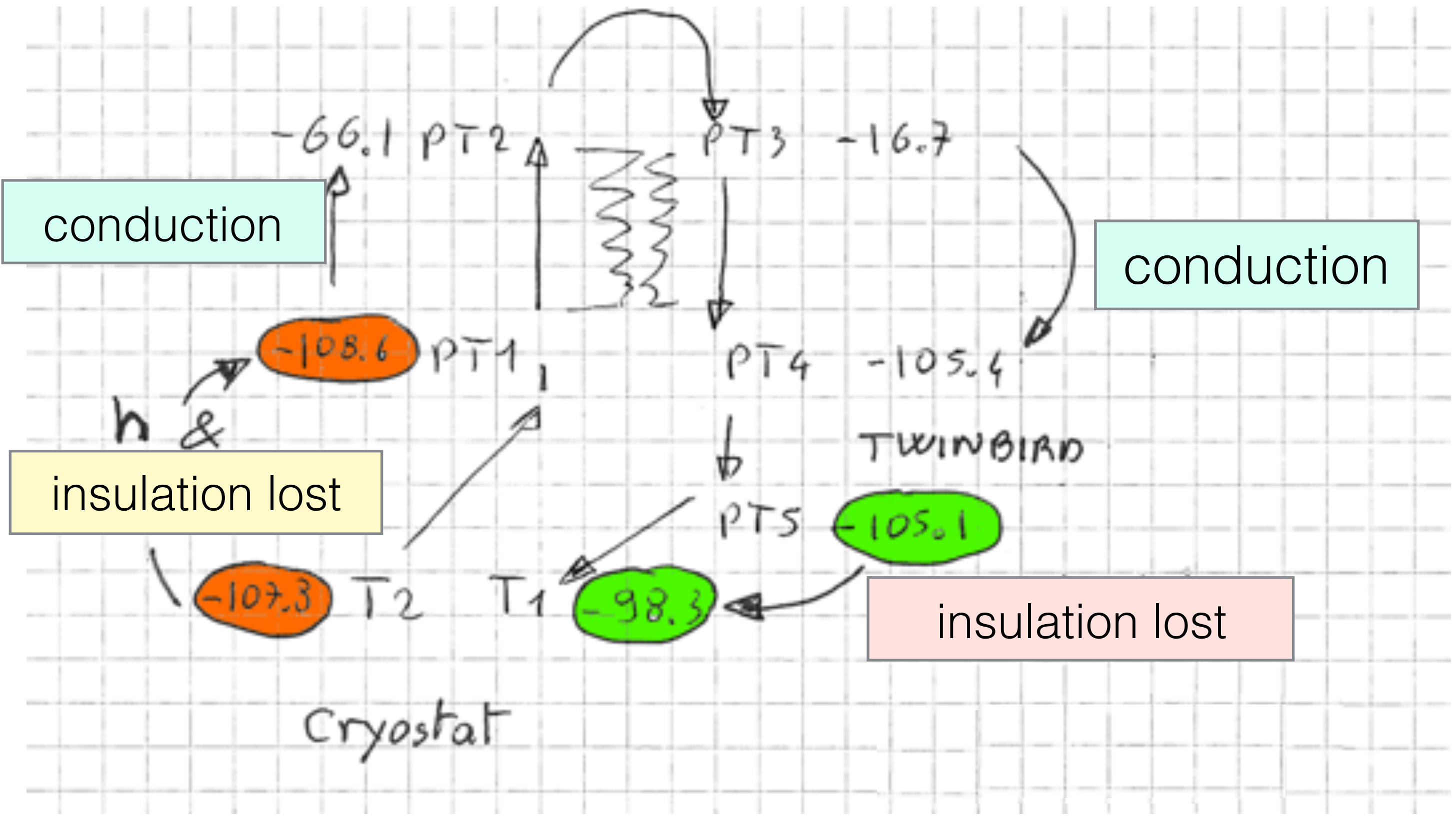


Flow rate vs Time

Flow rate around 11.0 l/min
8 h 30 min



Cryogenics Study



By courtesy of Eric Morteau

	TWINBIRD		
Gas flow (l/min)	4.5	7.5	11.0
PT7 (°C)	-124.8	-125.1	-124.9
PT6 (°C)	-109.6	-109.5	-109.2
PT4 (°C)	-104.7	-104.5	-104.3
PT5 (°C)	-104.4	-104.3	-104.0
Cooling Power (W)	~ 12	~ 12	~ 12
Heater (W)	0	0	0

*Average values during stability
*PTR Cooling power from data sheet

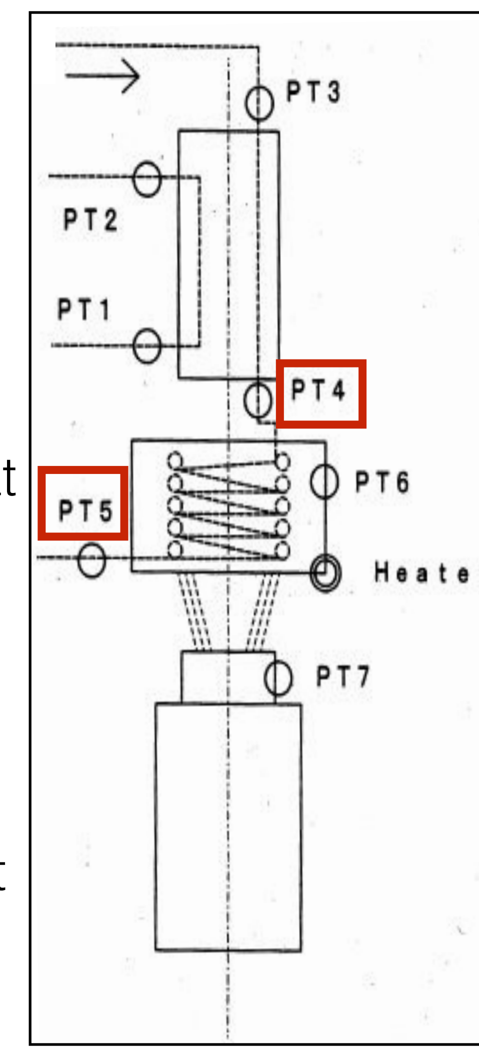
	SUBATECH	KEK		
Gas flow (l/min)	31.3	4.5	7.5	11.0
T inside cryo T2 (°C)	-100.7	-106.9	-106.5	-106.3
PT1 (°C)	-106	-107.9	-107.5	-107.3
PT2 (°C)	18.1	-58.5	-50.3	-44.1
PT3 (°C)	24.5	-1.5	6.7	11.7
PT5 (°C)	-104.4	-104.7	-104.3	-104.0
T1 (°C)	-104.4	-98.6	-98.5	-98.5

*Average values during stability

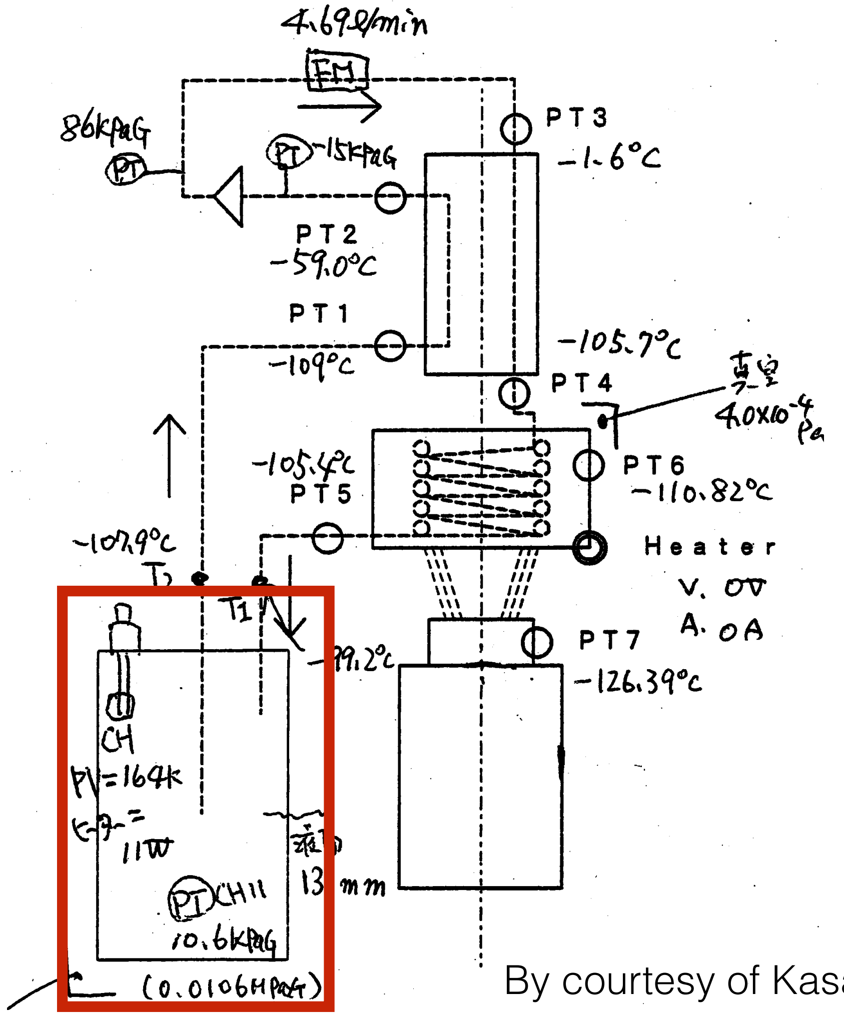
Thermal loss between cryostat and heat exchanger

Thermal conduction inside heat exchanger

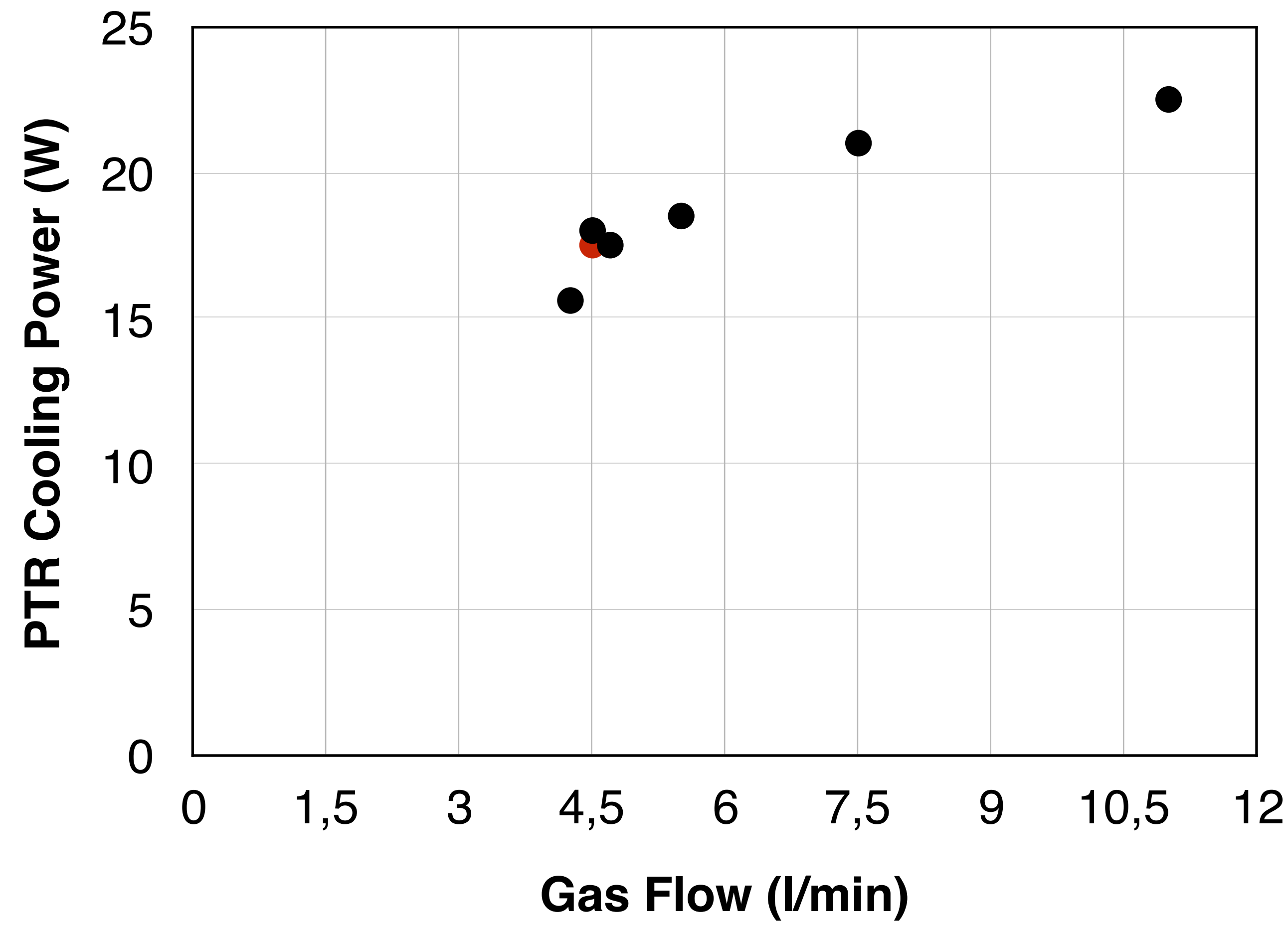
Thermal loss between exchanger outlet and cryostat inlet



KEK Cryogenics Set-up — Data (18 - 26/11/2015)



By courtesy of Kasami-san

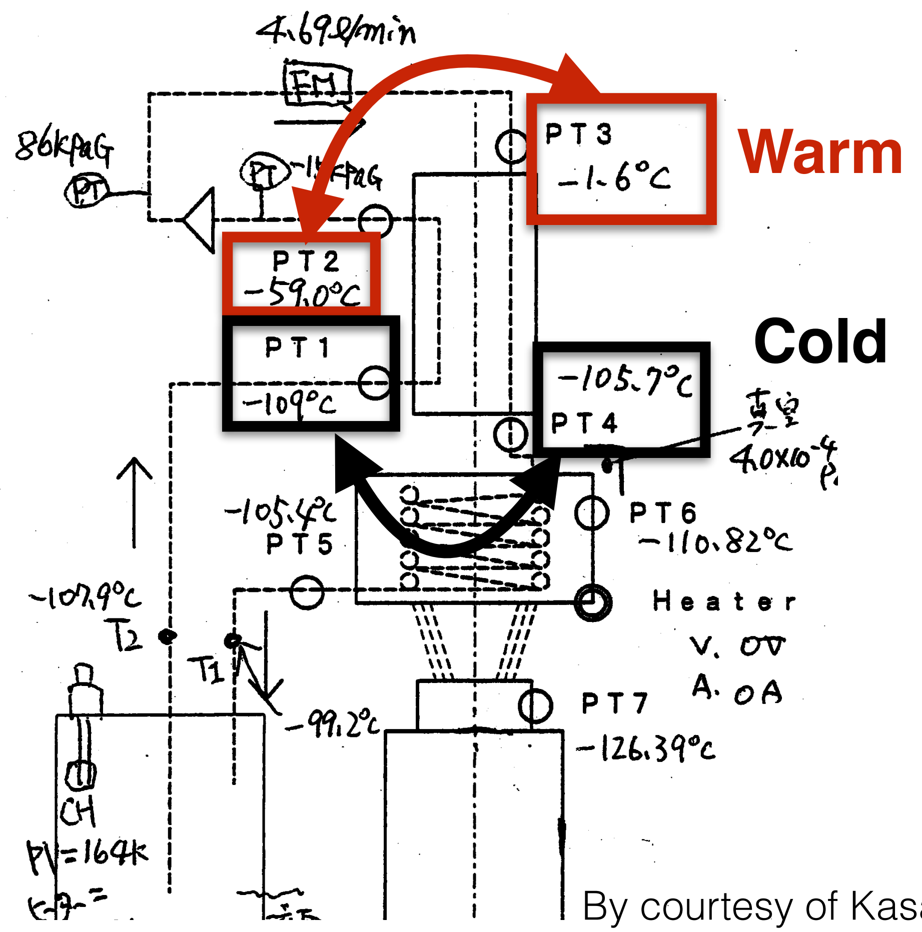


	SUBATECH	KEK		
Gas flow (l/min)	31.3	**4.5**	**7.5**	**11.0**
T inside cryo T2 (°C)	-100.7	-106.9	-106.5	-106.3
PT1 (°C)	-106	-107.9	-107.5	-107.3
PT2 (°C)	18.1	-58.5	-50.3	-44.1
PT3 (°C)	24.5	-1.5	6.7	11.7
PT5 (°C)	-104.4	-104.7	-104.3	-104.0
T1 (°C)	-104.4	-98.6	-98.5	-98.5

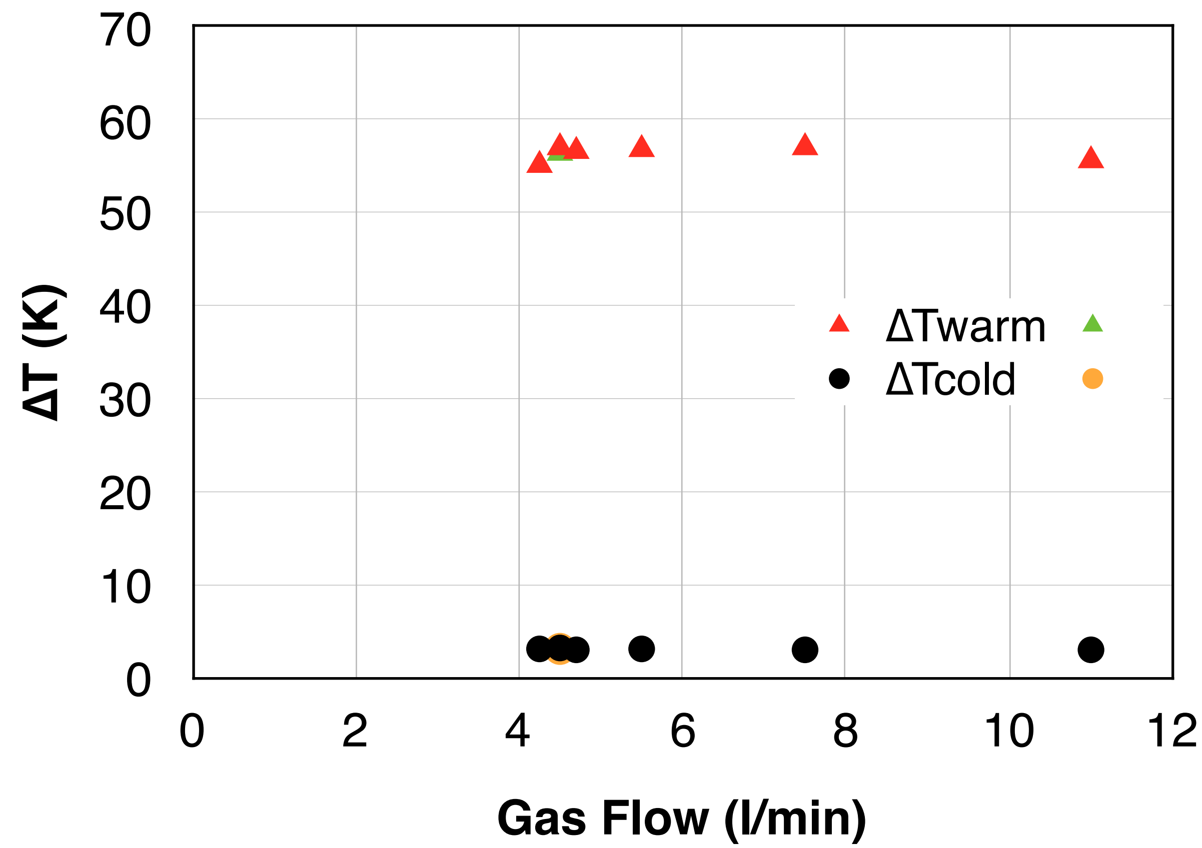
	PTR (164 K@24 W)		
Gas flow (l/min)	**4.5**	**7.5**	**11.0**
Cold Head T (°C)	164	164	164
PTR Power (W)	29	29	29
Heater (W)	11	8	6.5
Cooling Power (W)	**18**	**21**	**22,5**

*Average values during stability
*PTR power from KEK measurements

Heat Exchanger Efficiency



By courtesy of Kasami-san

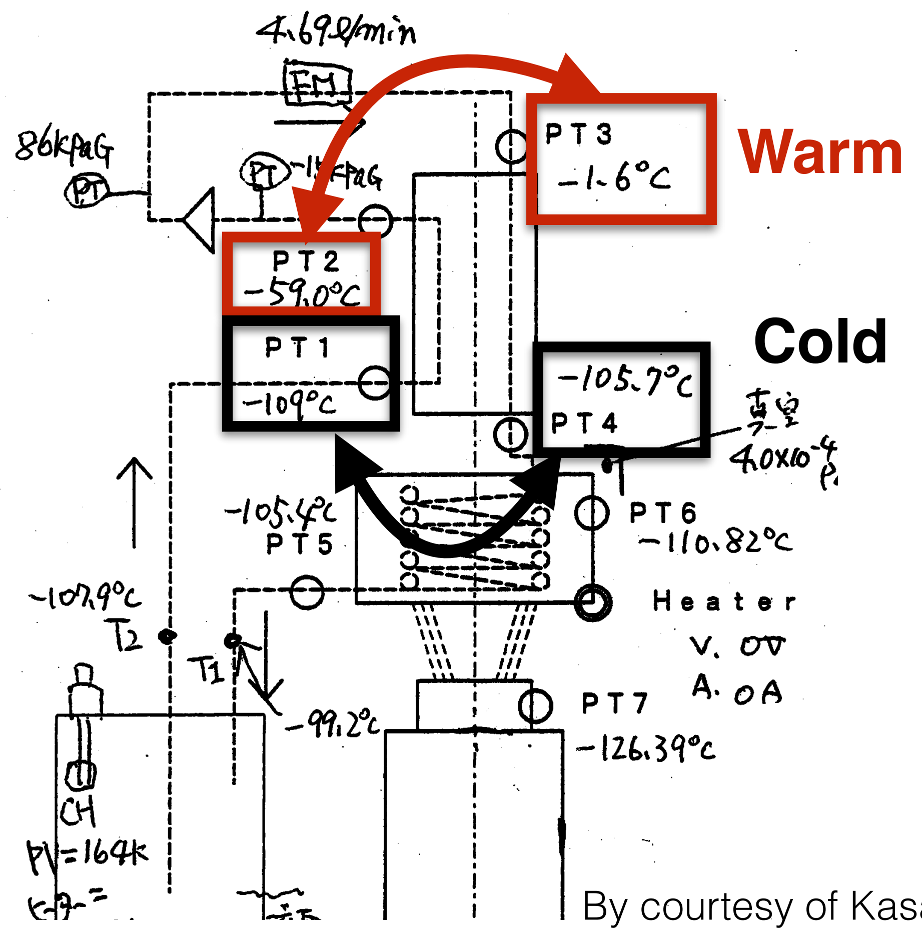


	SUBATECH	KEK			
Gas flow (l/min)	31.3	**4.5**	**7.5**	**11.0**	**4.5**
PT2 (°C)	18.1	-58.5	-50.3	-44.1	-58.5
PT3 (°C)	24.5	-1.5	6.7	11.7	-2.1
Efficiency (%)	99.9	86.1	86.1	86.5	86.3

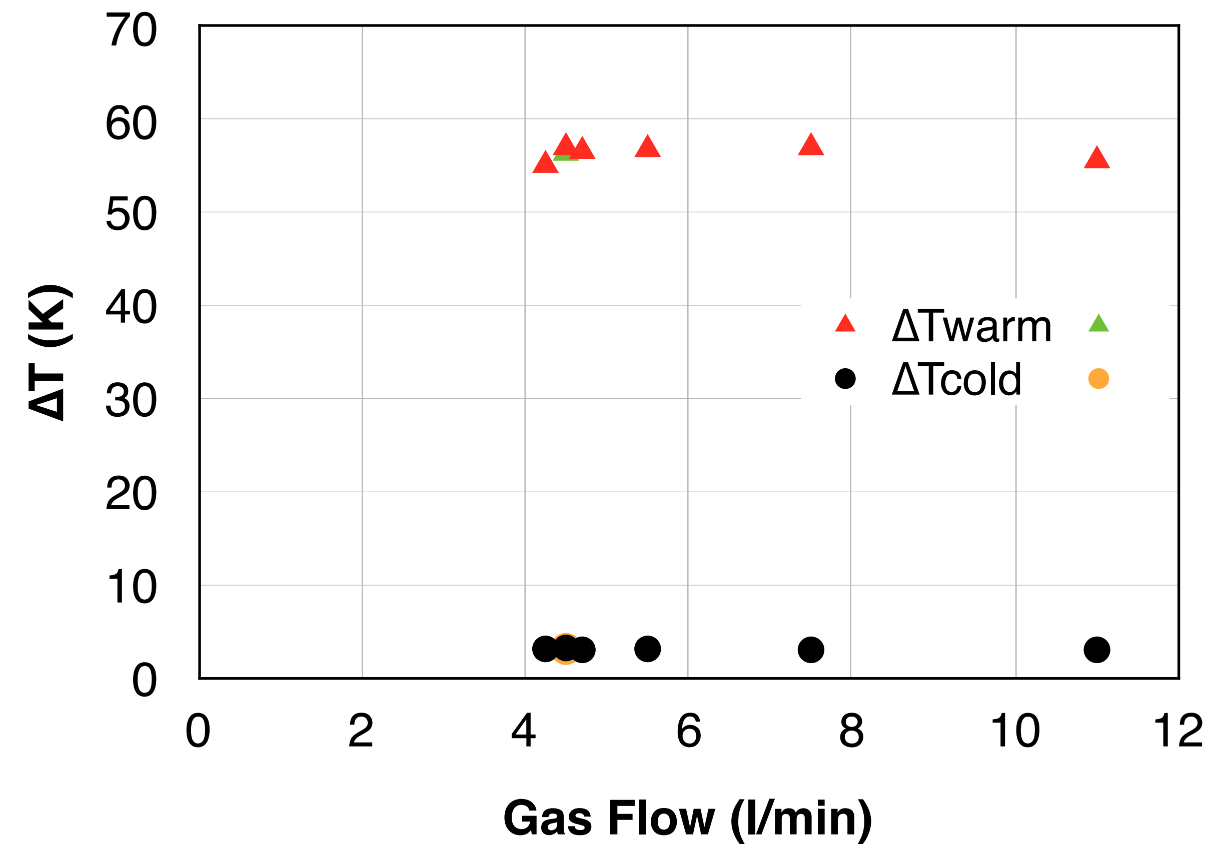
Cp (J/g/K)	0.34
Lp (J/g)	96.26

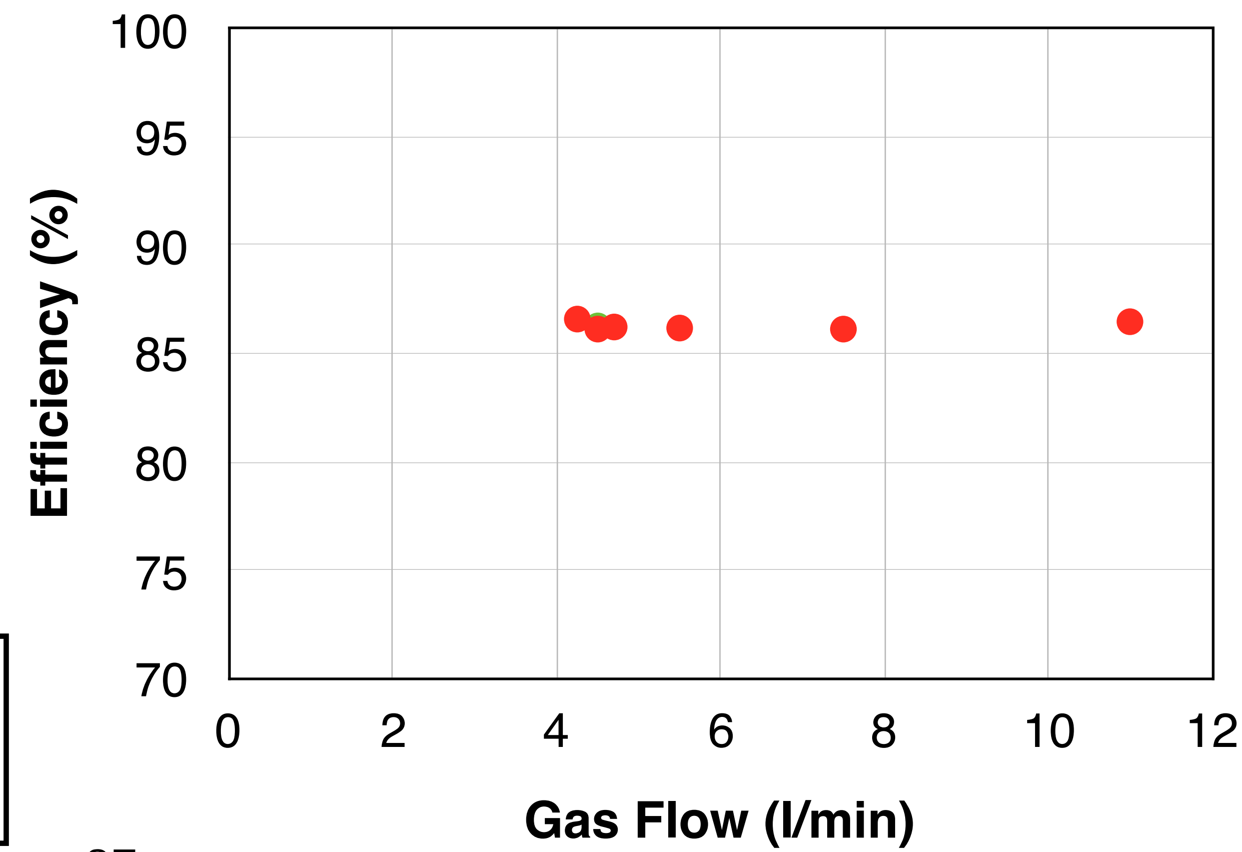
$$\varepsilon = 1 - \frac{C_p \times \Delta T_{warm} \times F(\mathrm{g/s})}{Q\,(\mathrm{W})}$$

Heat Exchanger Efficiency



By courtesy of Kasami-san



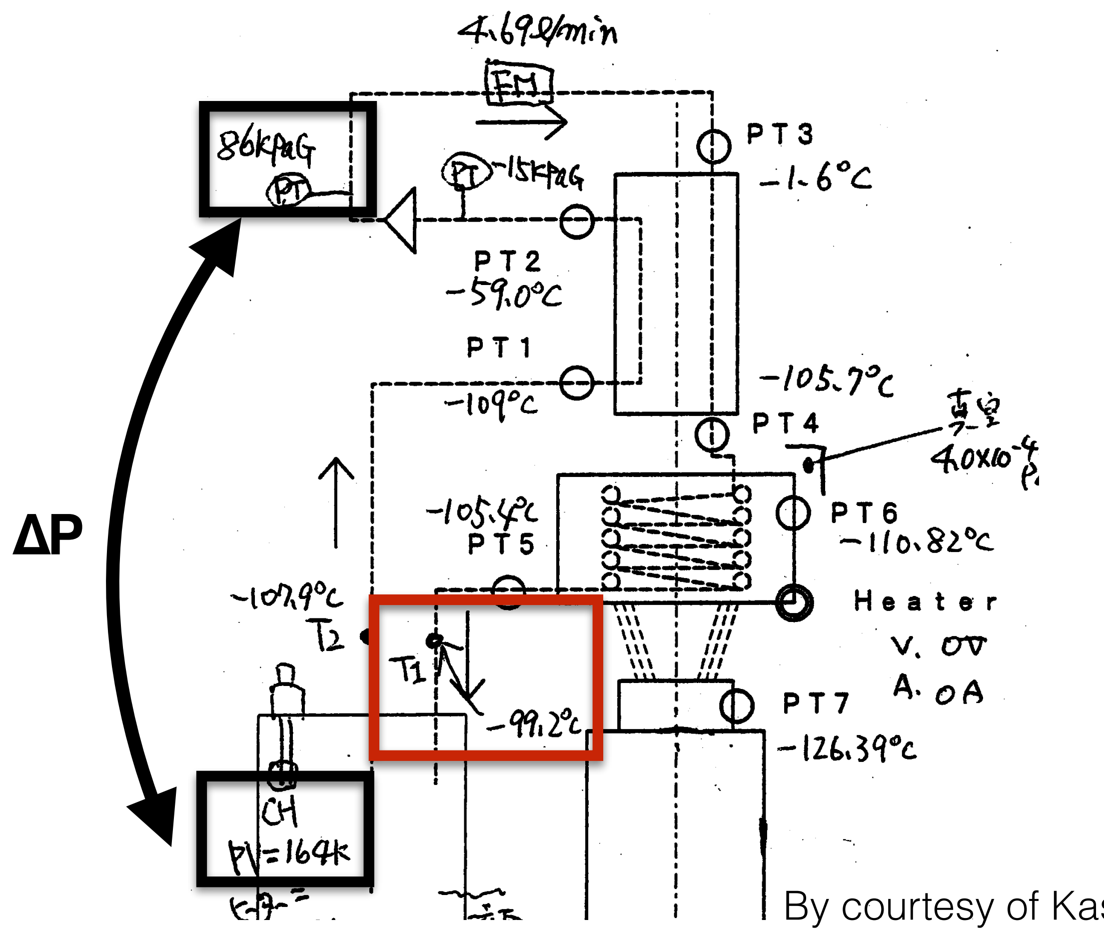


	SUBATECH	KEK			
Gas flow (l/min)	31.3	**4.5**	**7.5**	**11.0**	**4.5**
PT2 (°C)	18.1	-58.5	-50.3	-44.1	-58.5
PT3 (°C)	24.5	-1.5	6.7	11.7	-2.1
Efficiency (%)	99.9	86.1	86.1	86.5	86.3

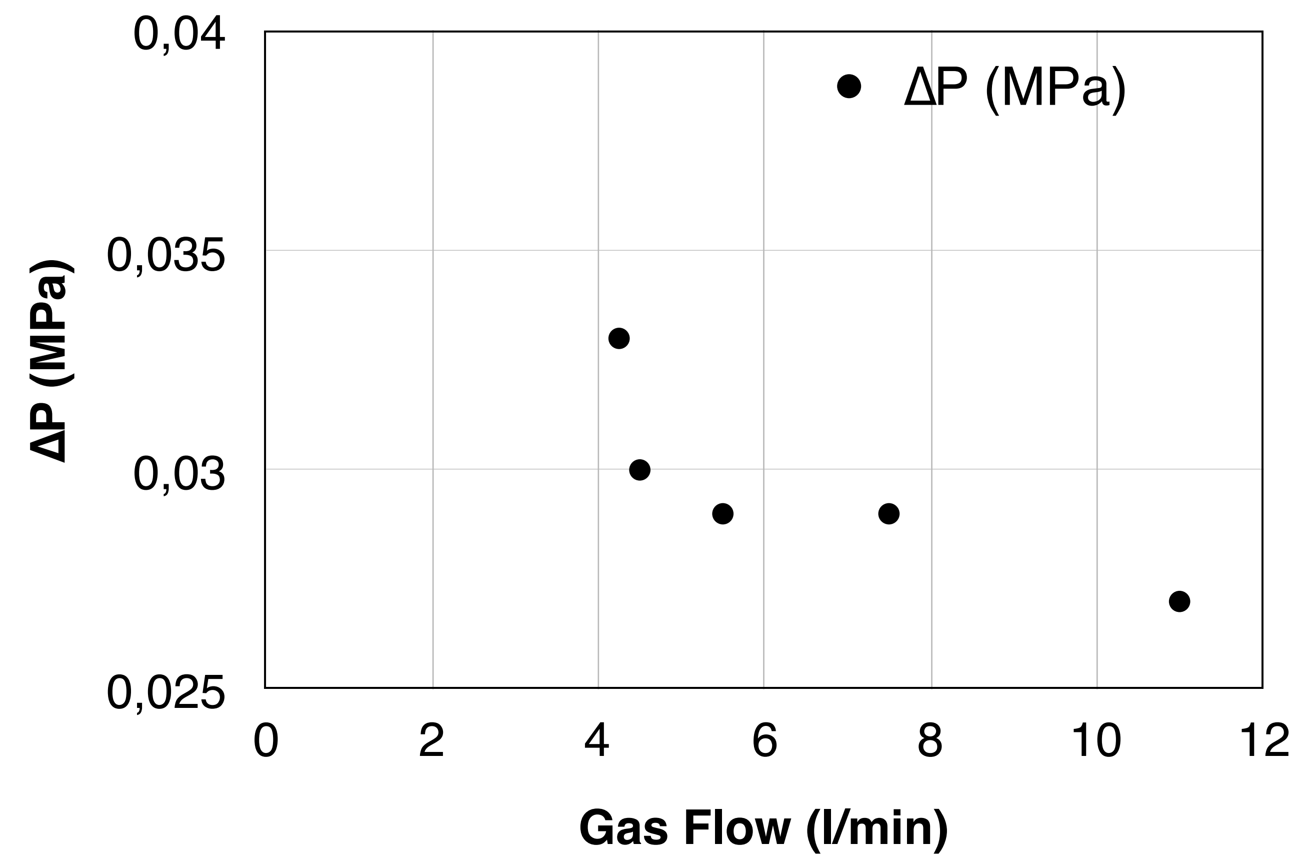
Cp (J/g/K)	0.34
Lp (J/g)	96.26

$$\varepsilon = 1 - \frac{C_p \times \Delta T_{warm} \times F(\mathrm{g/s})}{Q\,(\mathrm{W})}$$

Heat Exchanger Efficiency



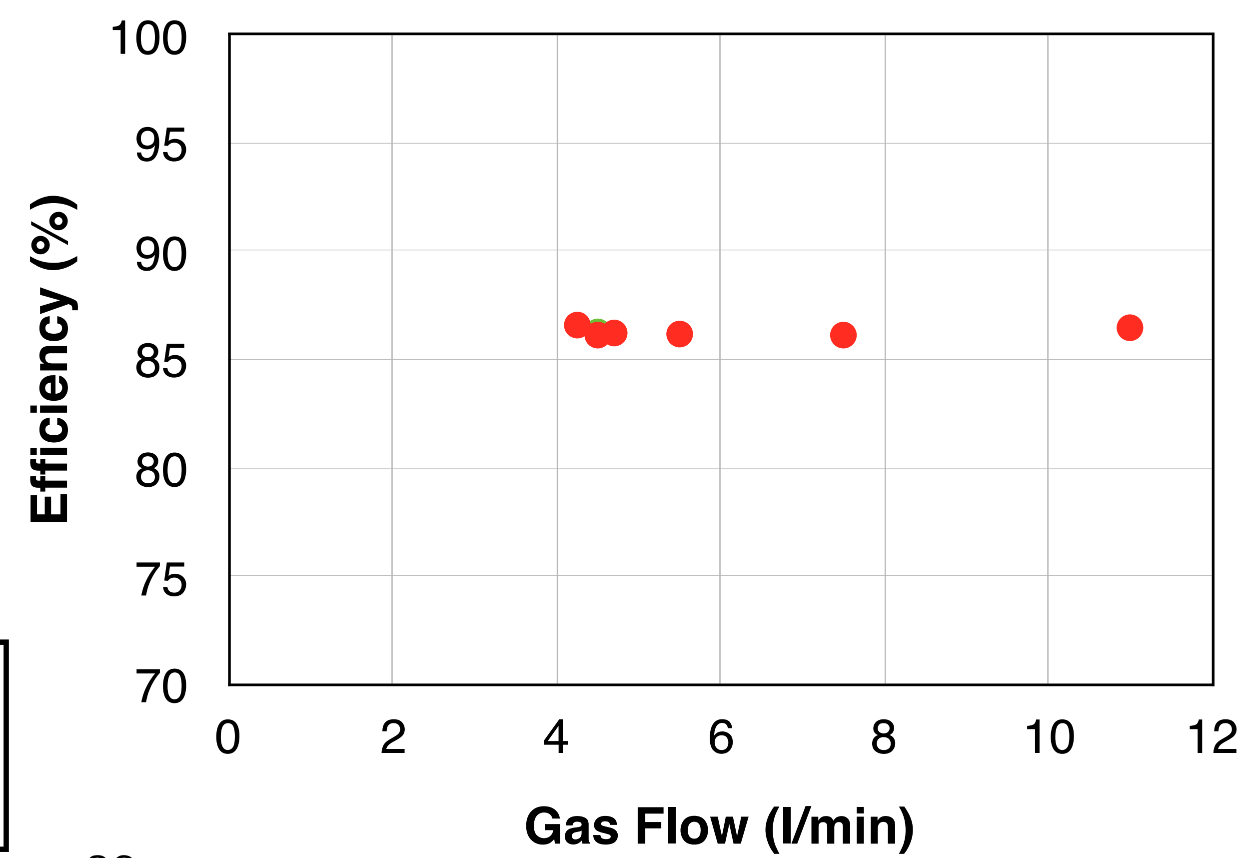
By courtesy of Kasami-san



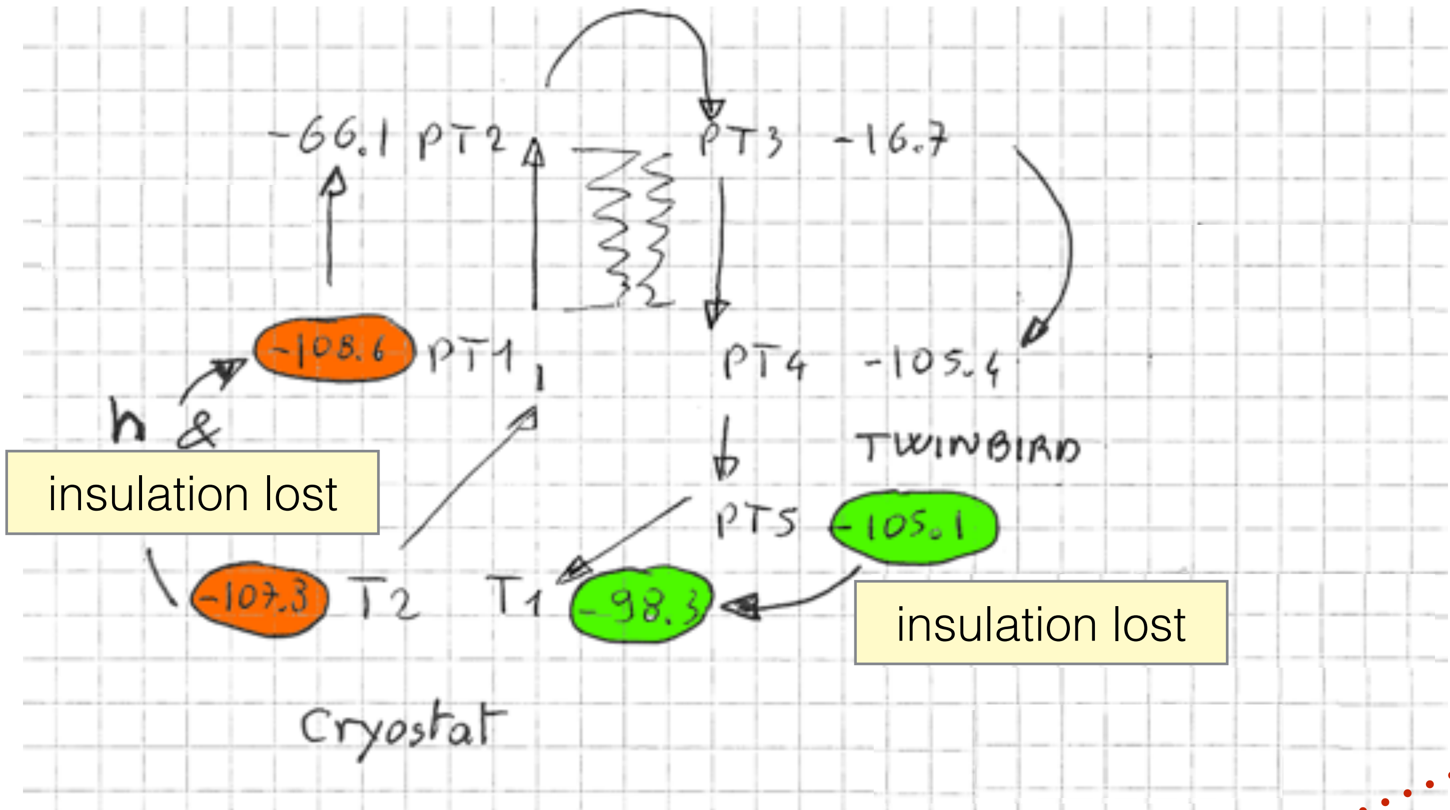
	SUBATECH	KEK			
Gas flow (l/min)	31.3	**4.5**	**7.5**	**11.0**	**4.5**
PT2 (°C)	18.1	-58.5	-50.3	-44.1	-58.5
PT3 (°C)	24.5	-1.5	6.7	11.7	-2.1
Efficiency (%)	99.9	86.1	86.1	86.5	86.3

Cp (J/g/K)	0.34
Lp (J/g)	96.26

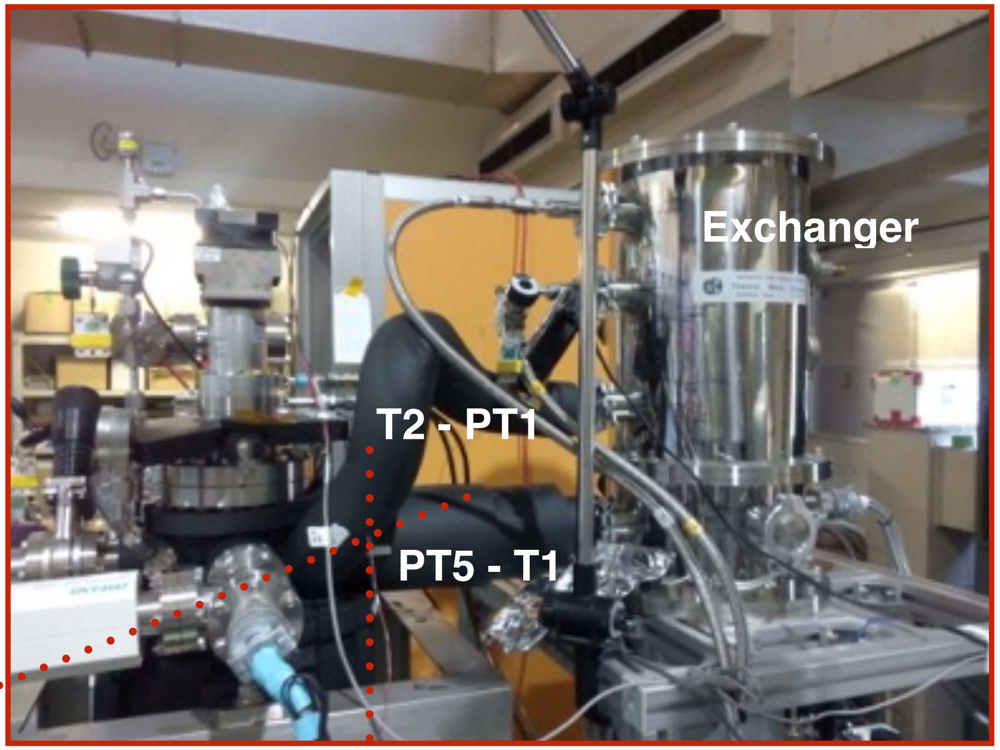
$$\varepsilon = 1 - \frac{C_p \times \Delta T_{warm} \times F(\mathrm{g/s})}{Q\,(\mathrm{W})}$$

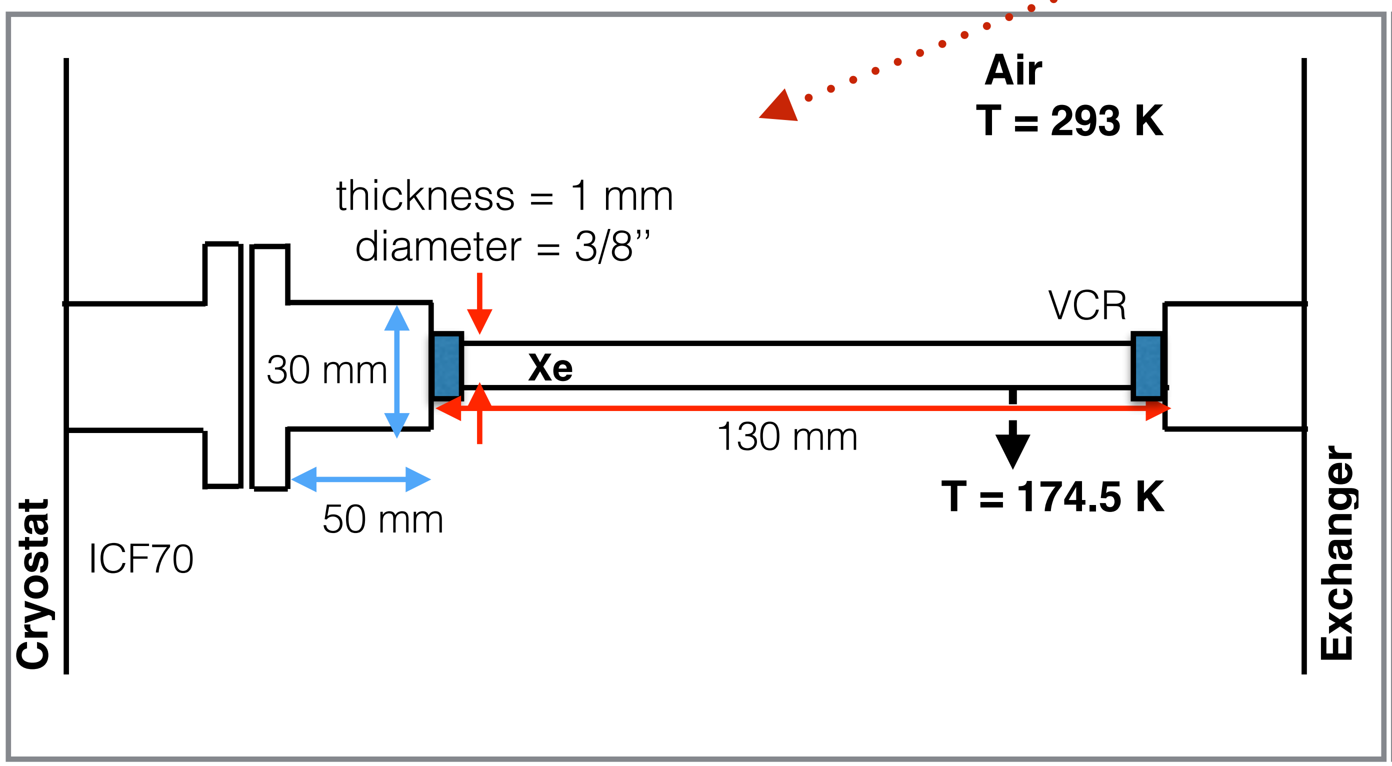


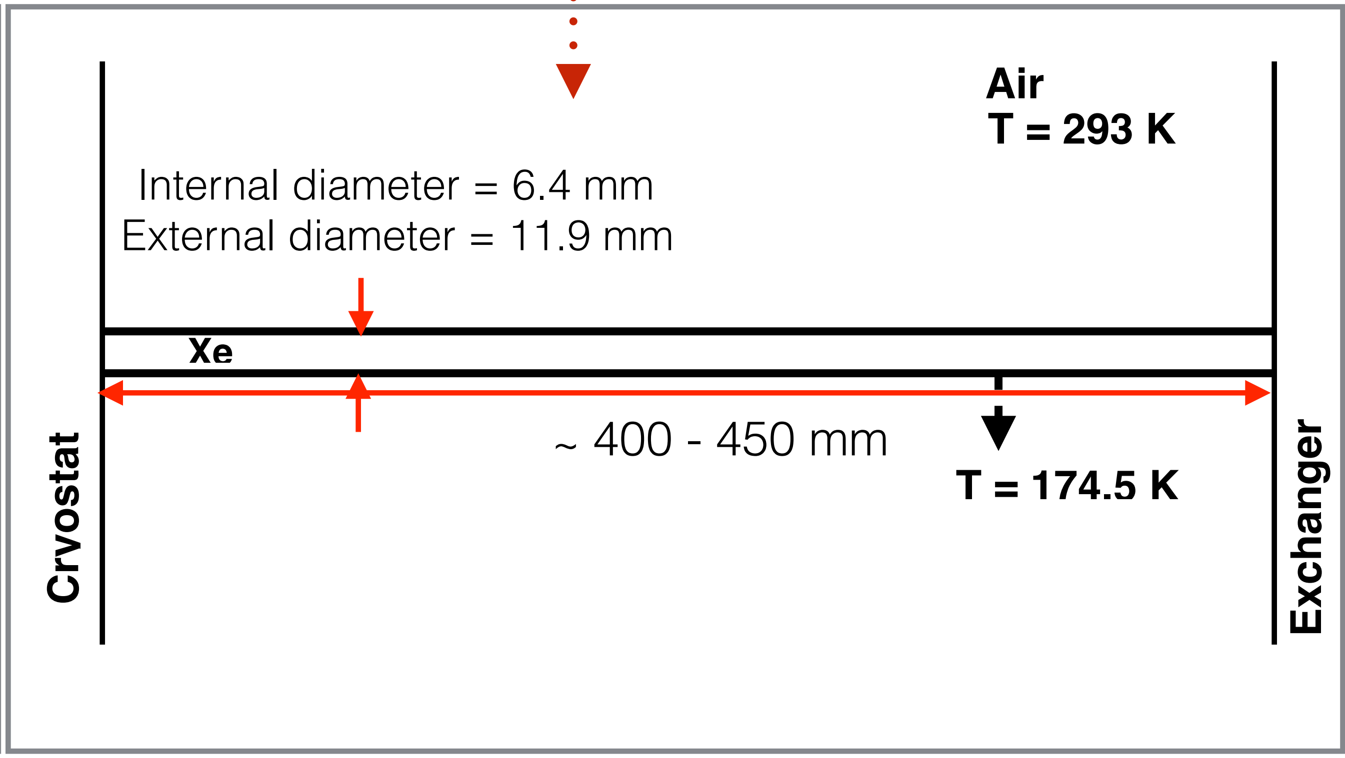
Thermal Losses



By courtesy of Eric Morteau

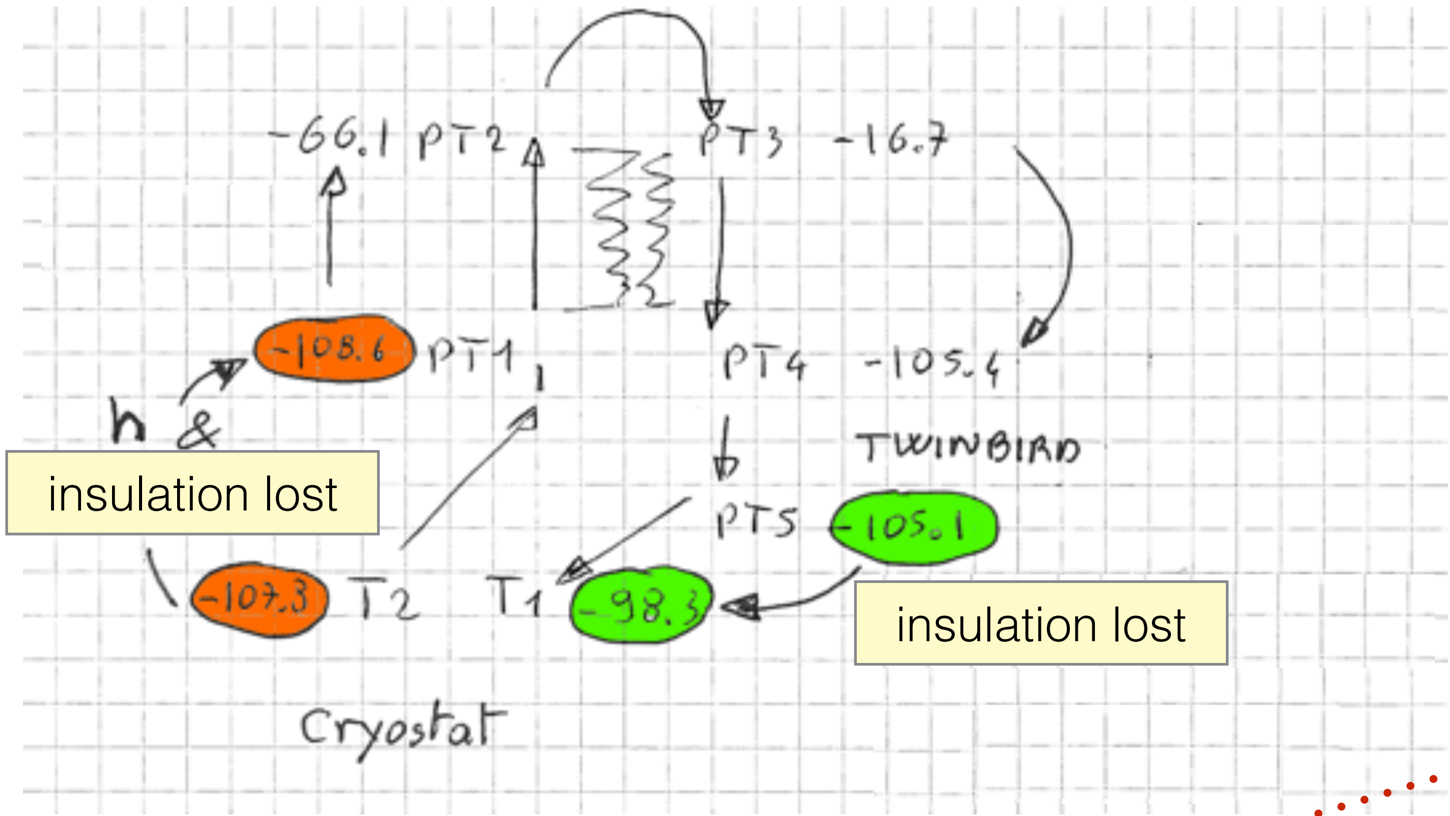




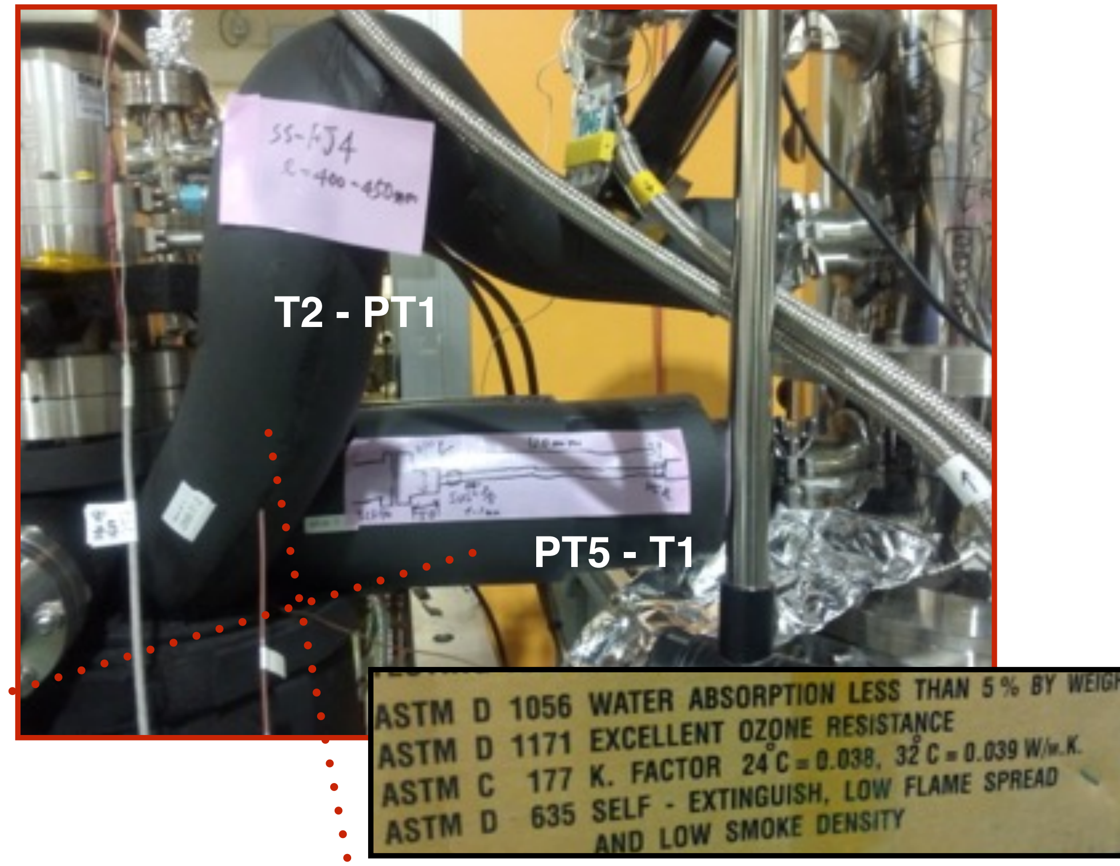


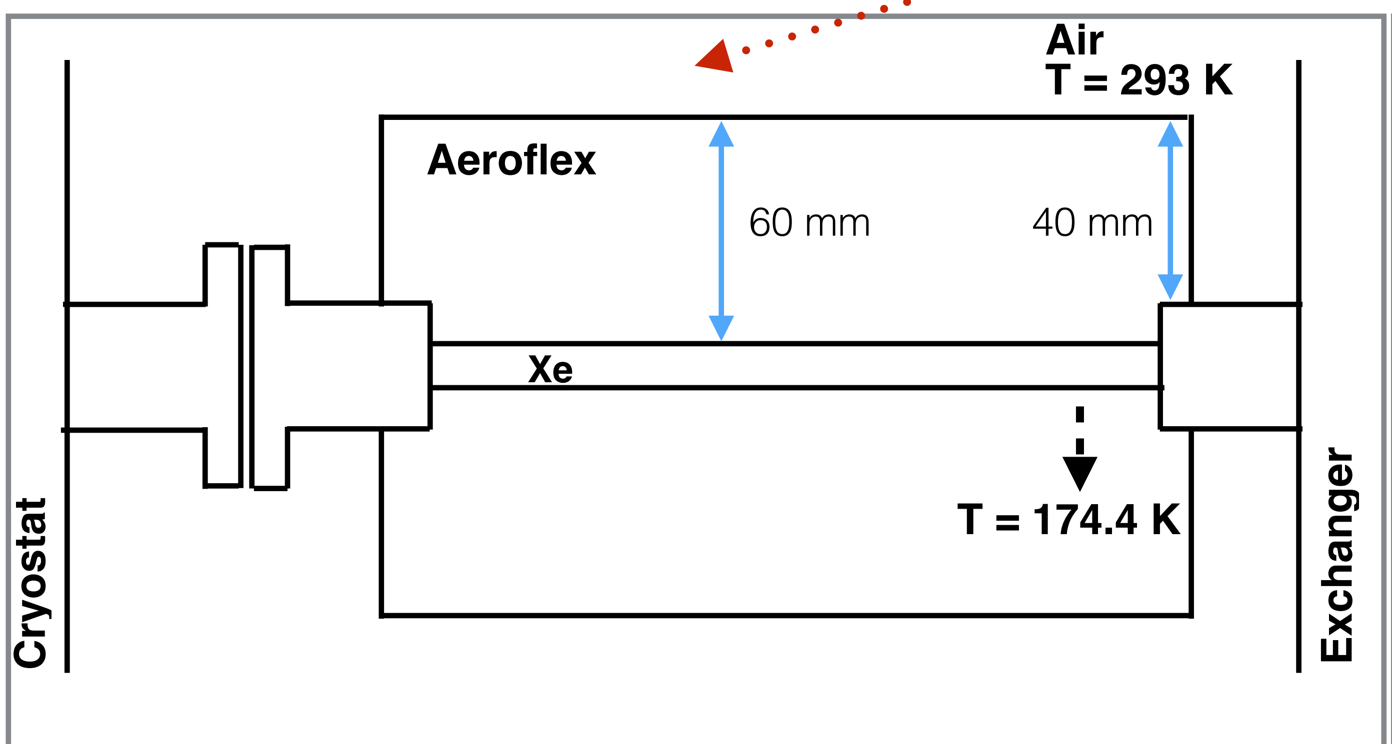
*Temperature values for a gas flow of 4.5 l/min

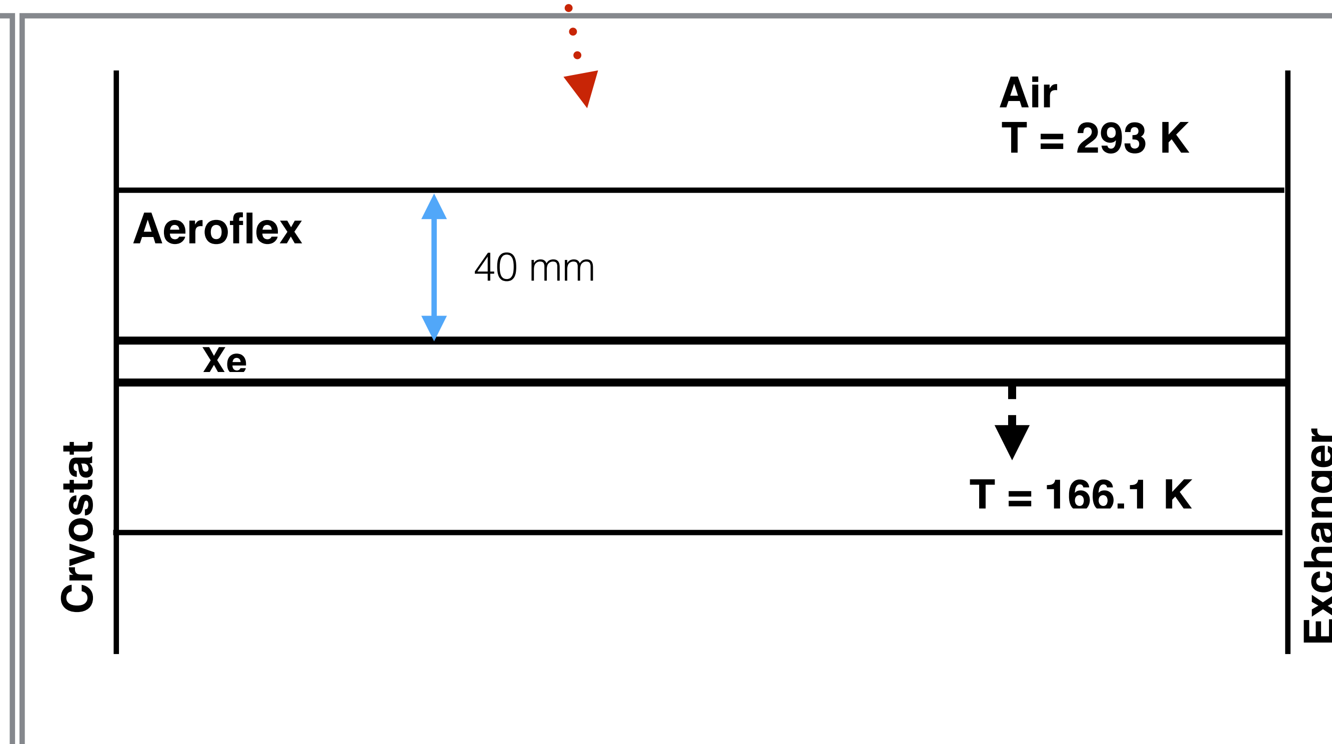
Thermal Losses



By courtesy of Eric Morteau

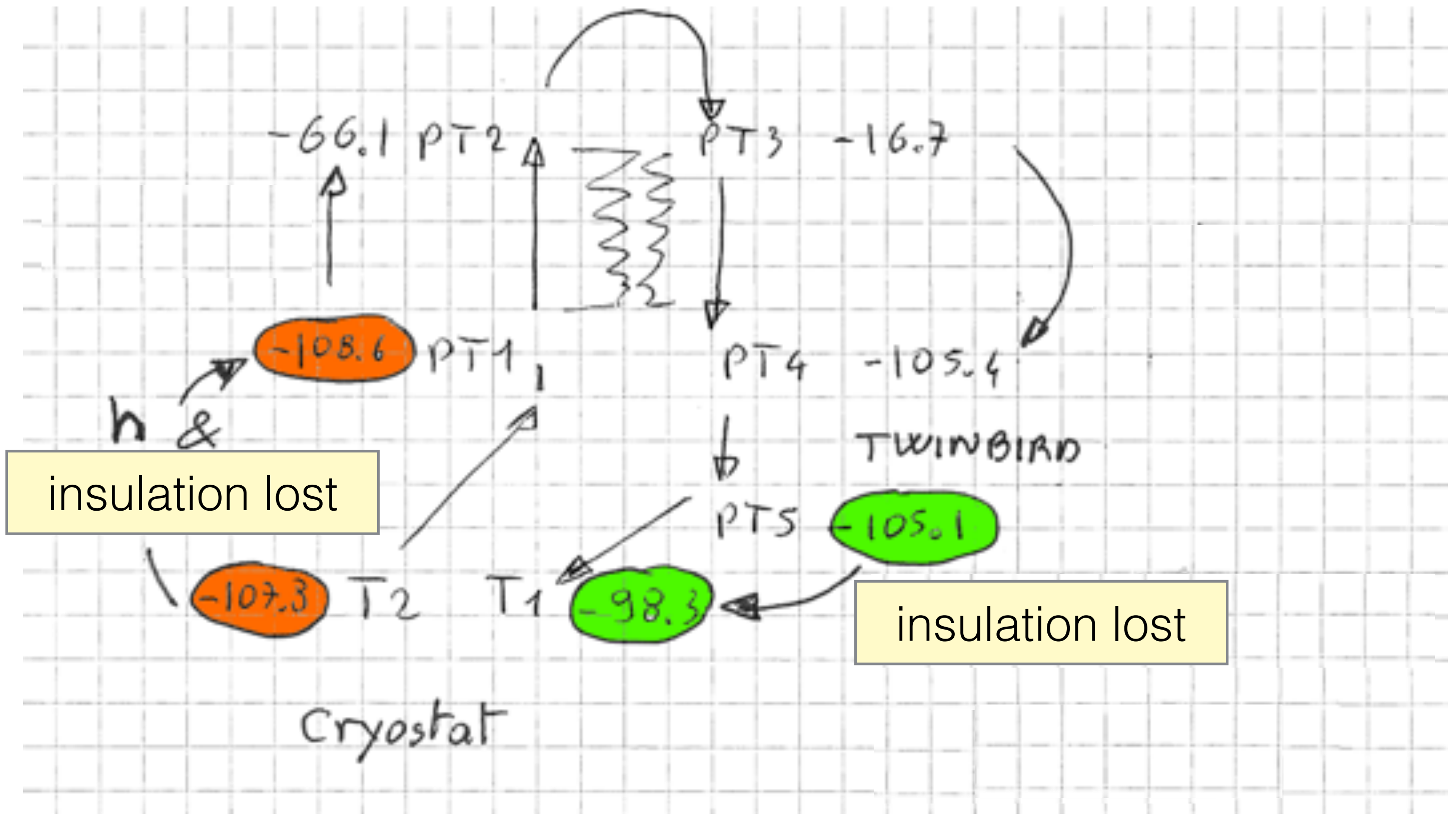




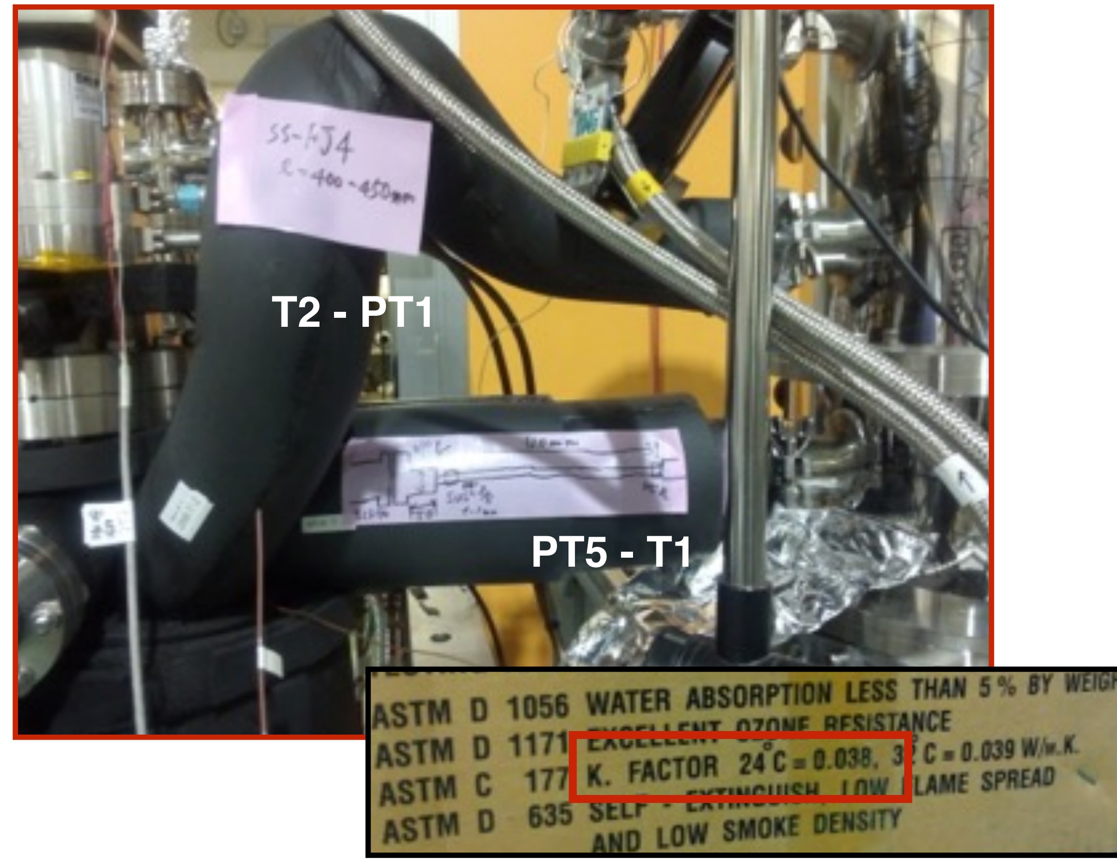


*Temperature values for a gas flow of 4.5 l/min

Thermal Losses



By courtesy of Eric Morteau



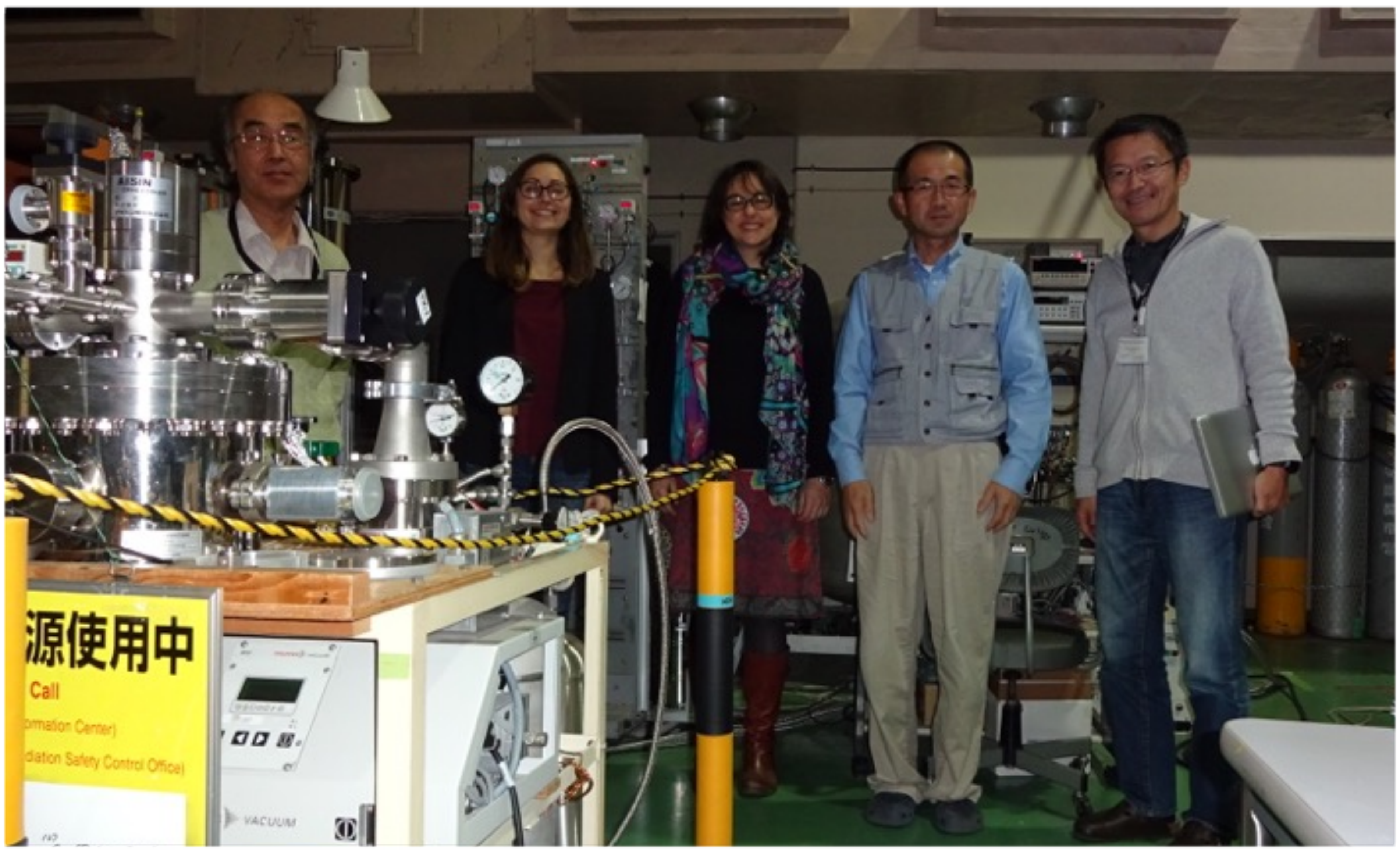
Assumptions:

- Negligible resistance between the tube wall and the LXe.
- Constant properties
- Negligible radiation heat loss
- Stability

	Thickness insulator (mm)	
	40	**60**
T2 - PT1	1.80 W	1.57 W
PT5 - T1	2.48 W	-

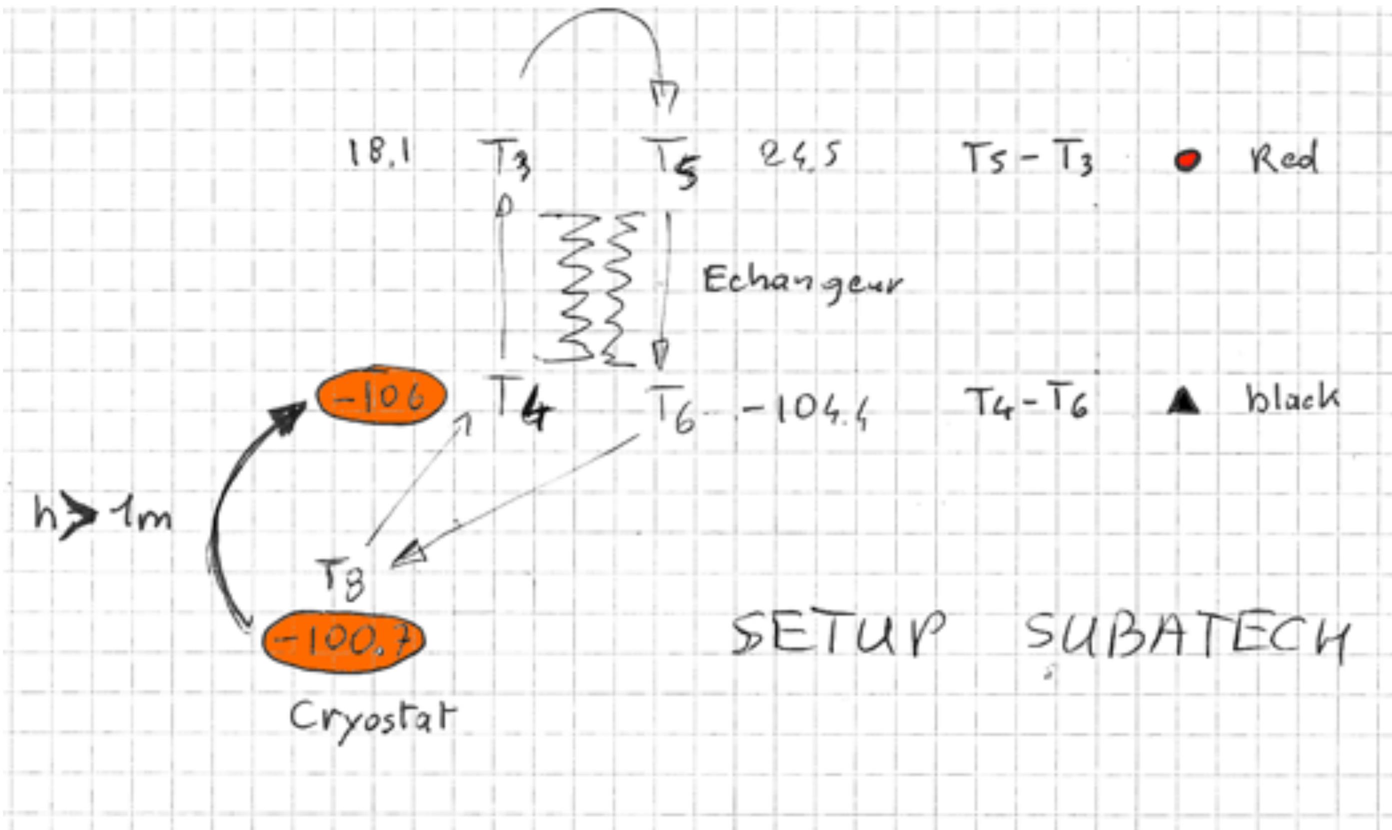
ありがとう

Thank you!



Slow Control

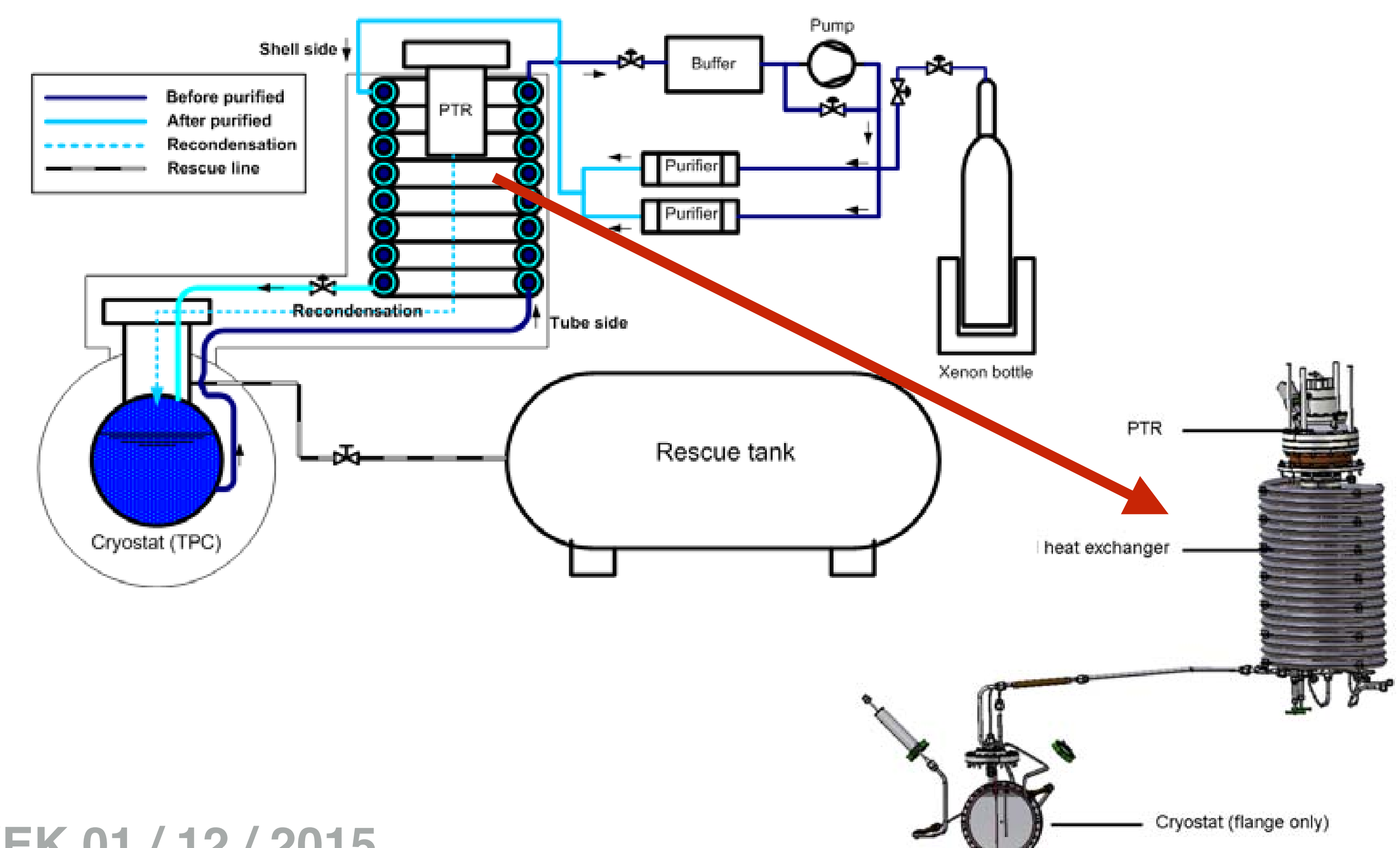
SUBATECH Set-up

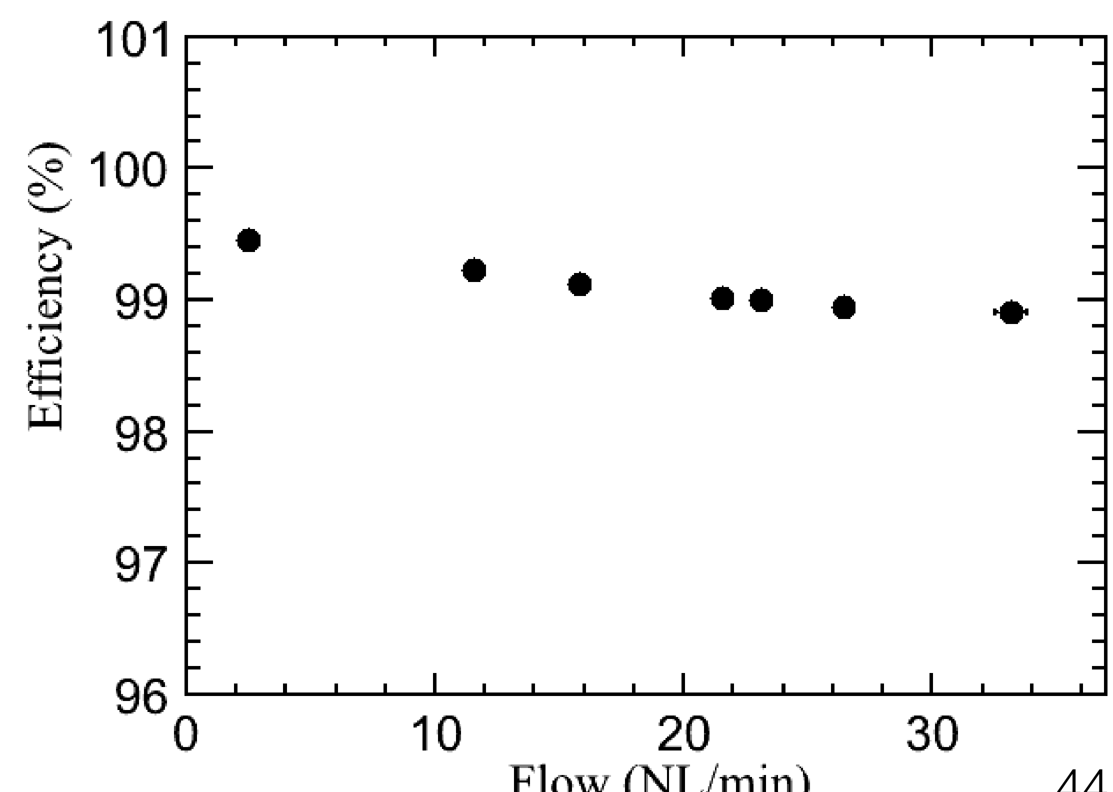


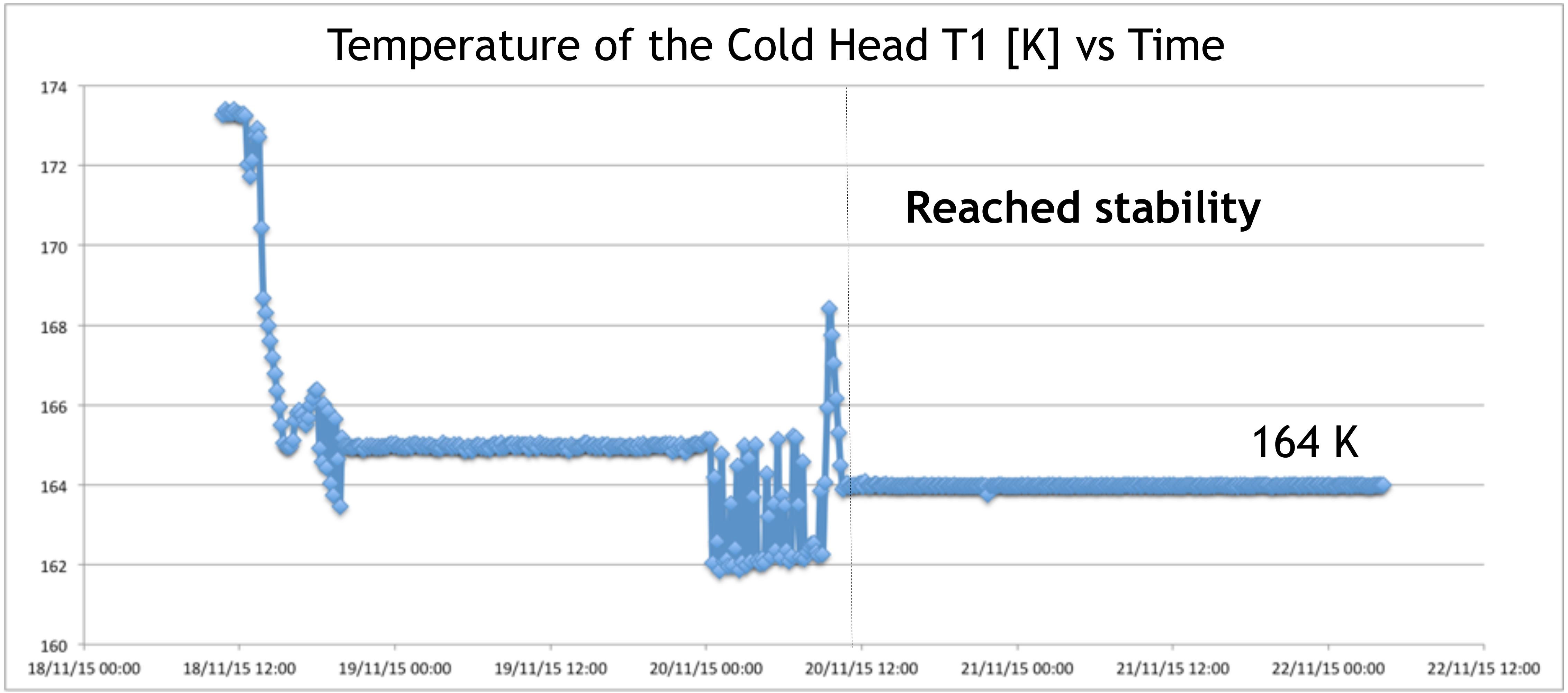
By courtesy of Eric Morteau

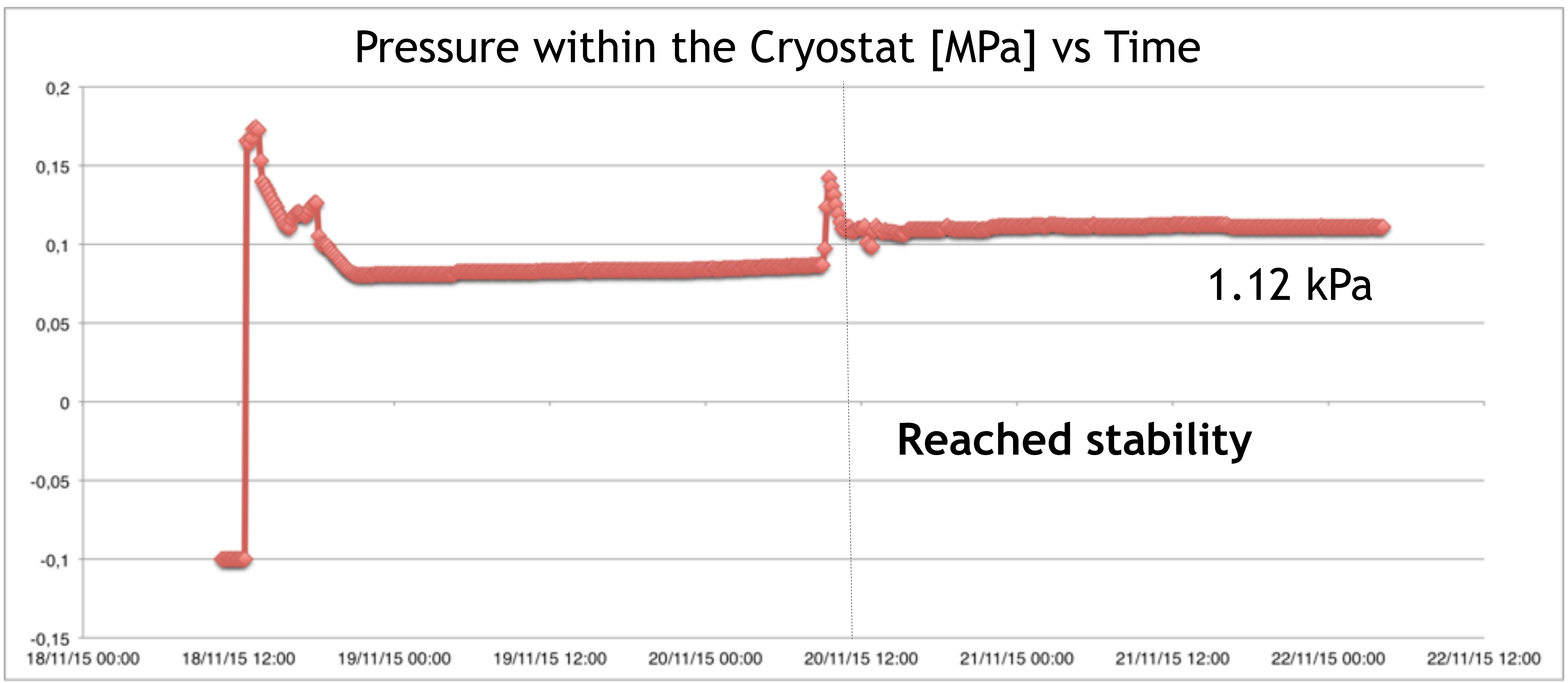
	PTR (200W@164K)
Gas flow (l/min)	31
Cooling Power (W)	70

	Coaxial Heat Exchanger
Gas flow (l/min)	31
Efficiency (%)	99

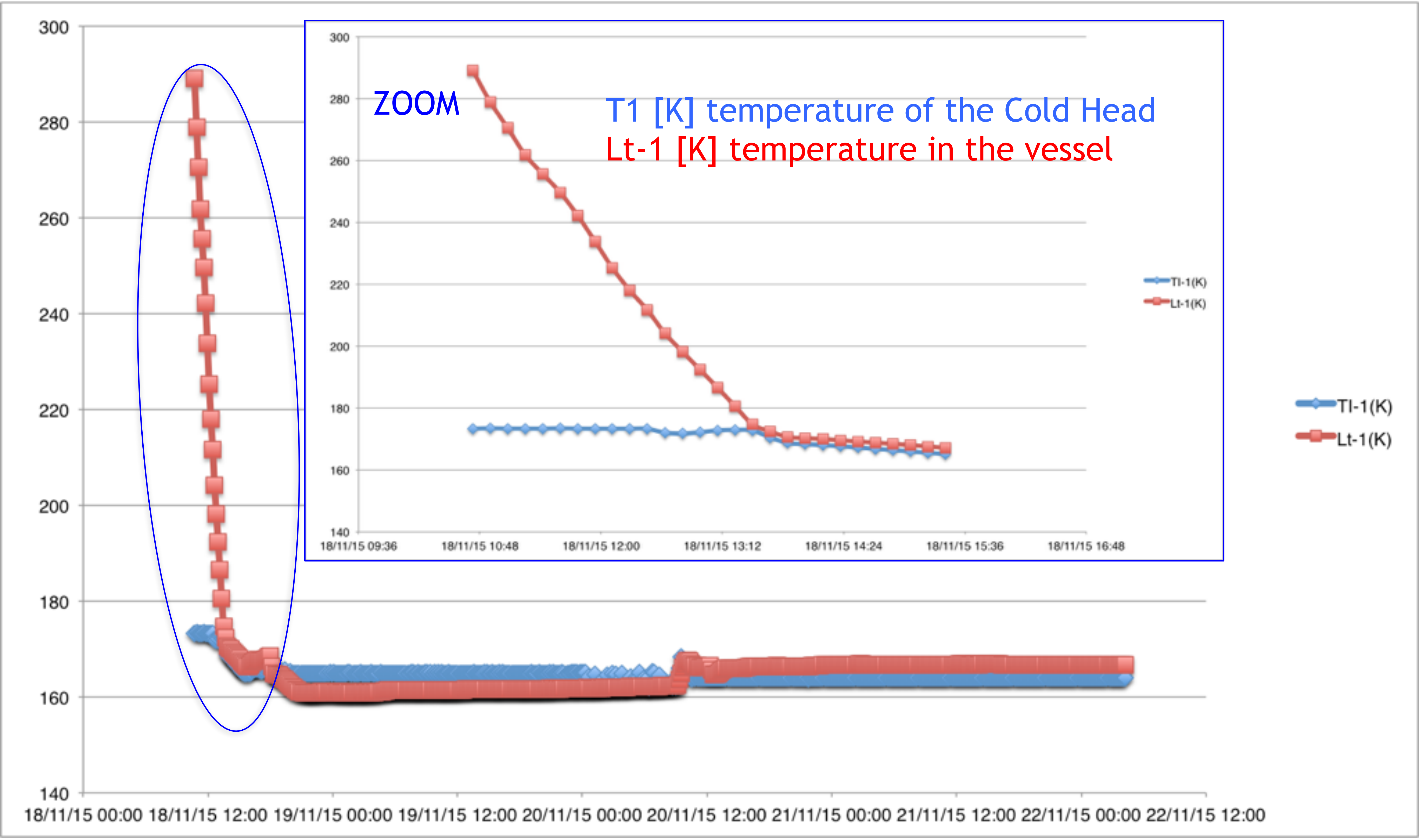




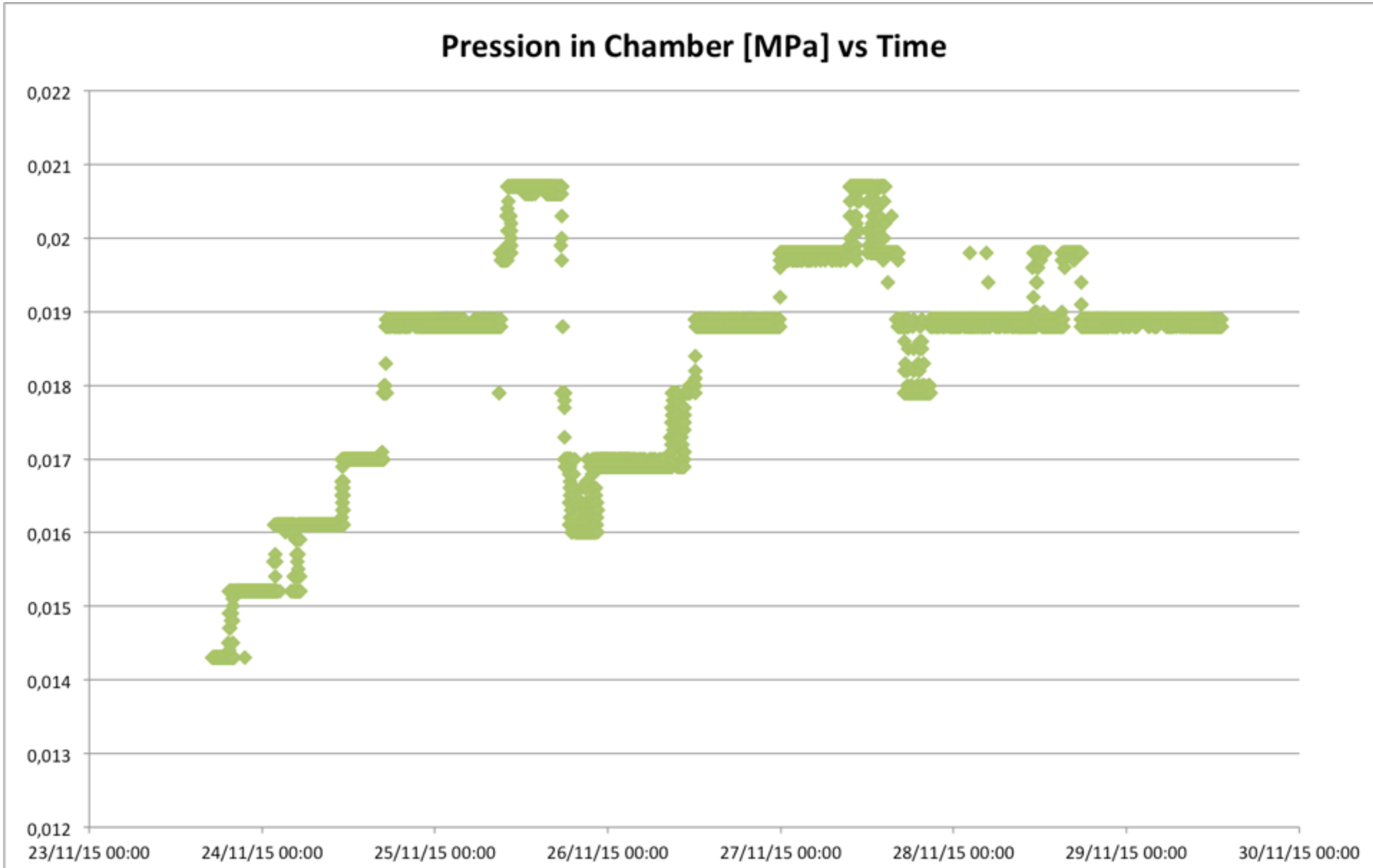

Temperature of the Cold Head T1 [K] vs Time
Reached stability
164 K
174
172
170
168
166
164
162
160
18/11/15 00:00
18/11/15 12:00
19/11/15 00:00
19/11/15 12:00
20/11/15 00:00
20/11/15 12:00
21/11/15 00:00
21/11/15 12:00
22/11/15 00:00
22/11/15 12:00


Pressure within the Cryostat [MPa] vs Time
1.12 kPa
Reached stability
0,2
0,15
0,1
0,05
0
-0,05
-0,1
-0,15
18/11/15 00:00
18/11/15 12:00
19/11/15 00:00
19/11/15 12:00
20/11/15 00:00
20/11/15 12:00
21/11/15 00:00
21/11/15 12:00
22/11/15 00:00
22/11/15 12:00

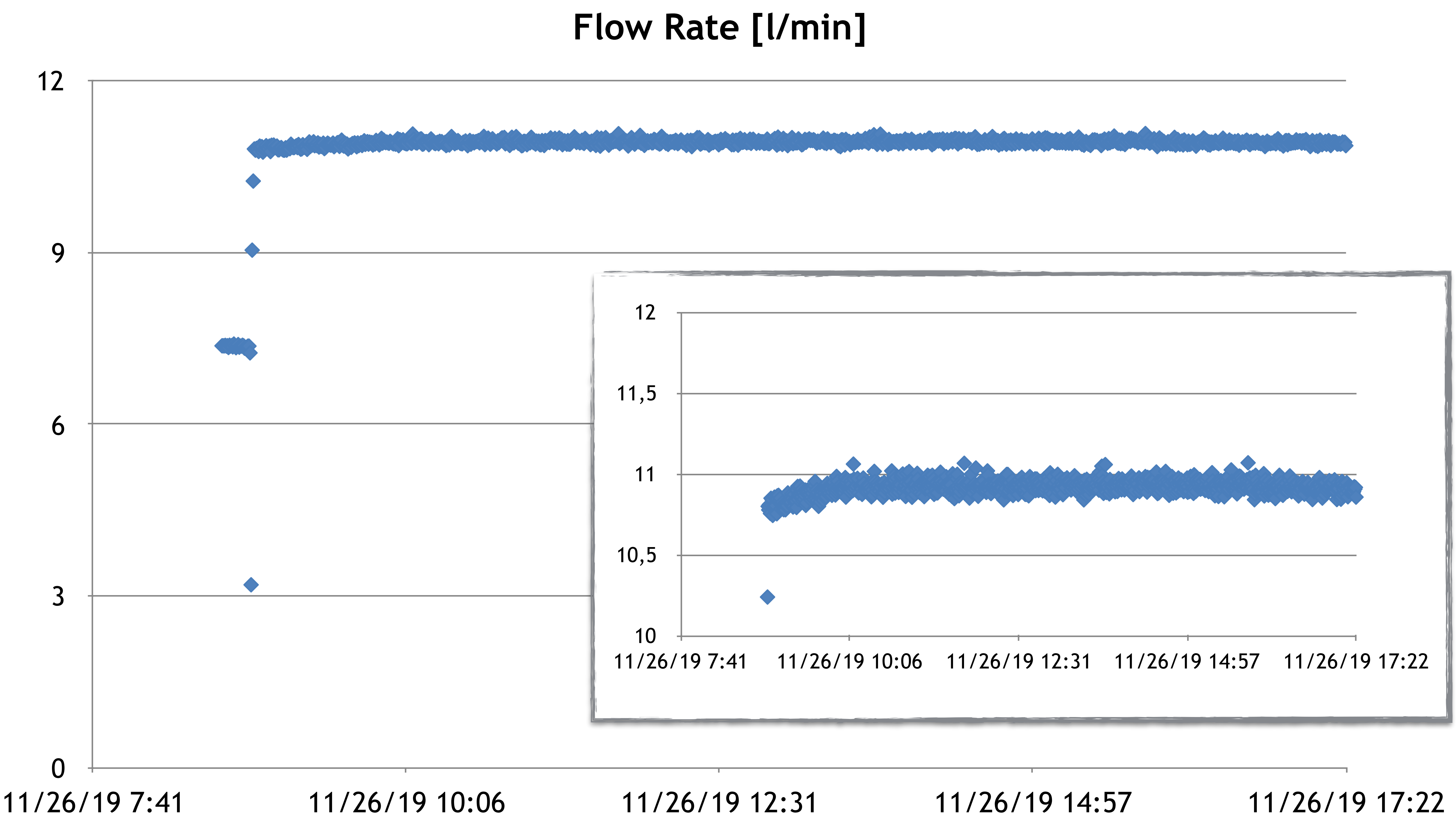
Temperature profile during liquefaction



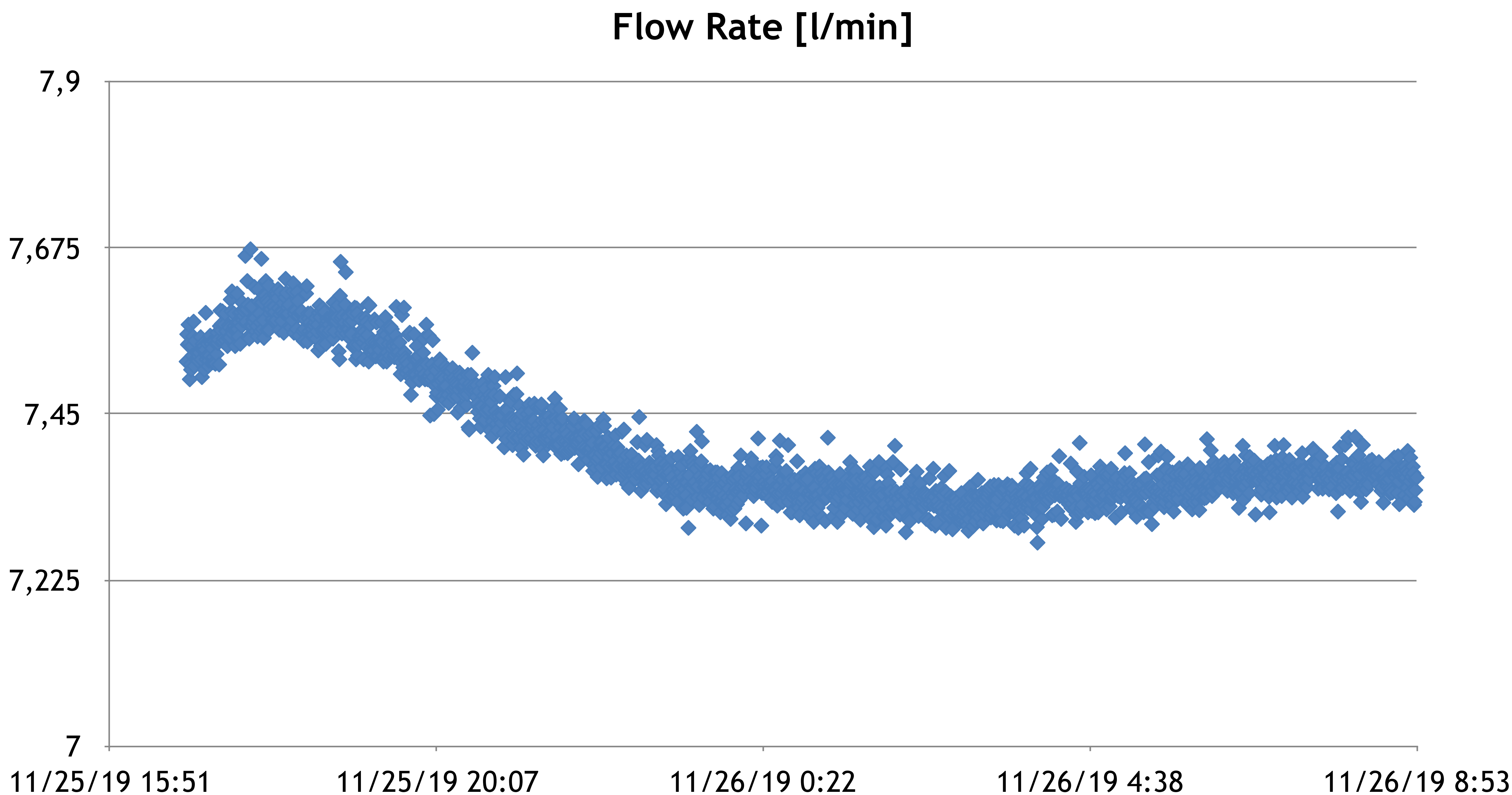
Pressure in the chamber VS Time



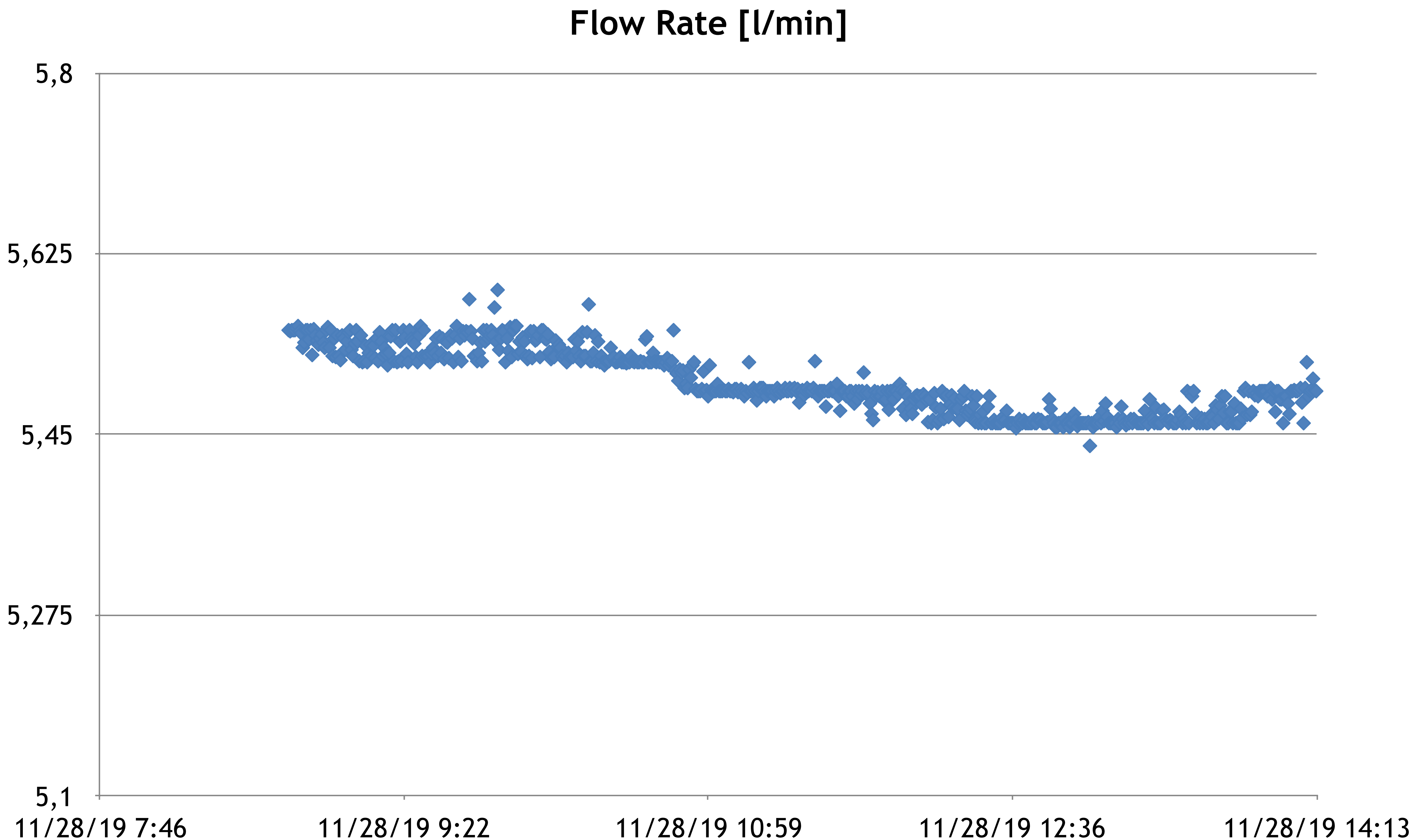
Flow rate 11 l/min : 8h 30min



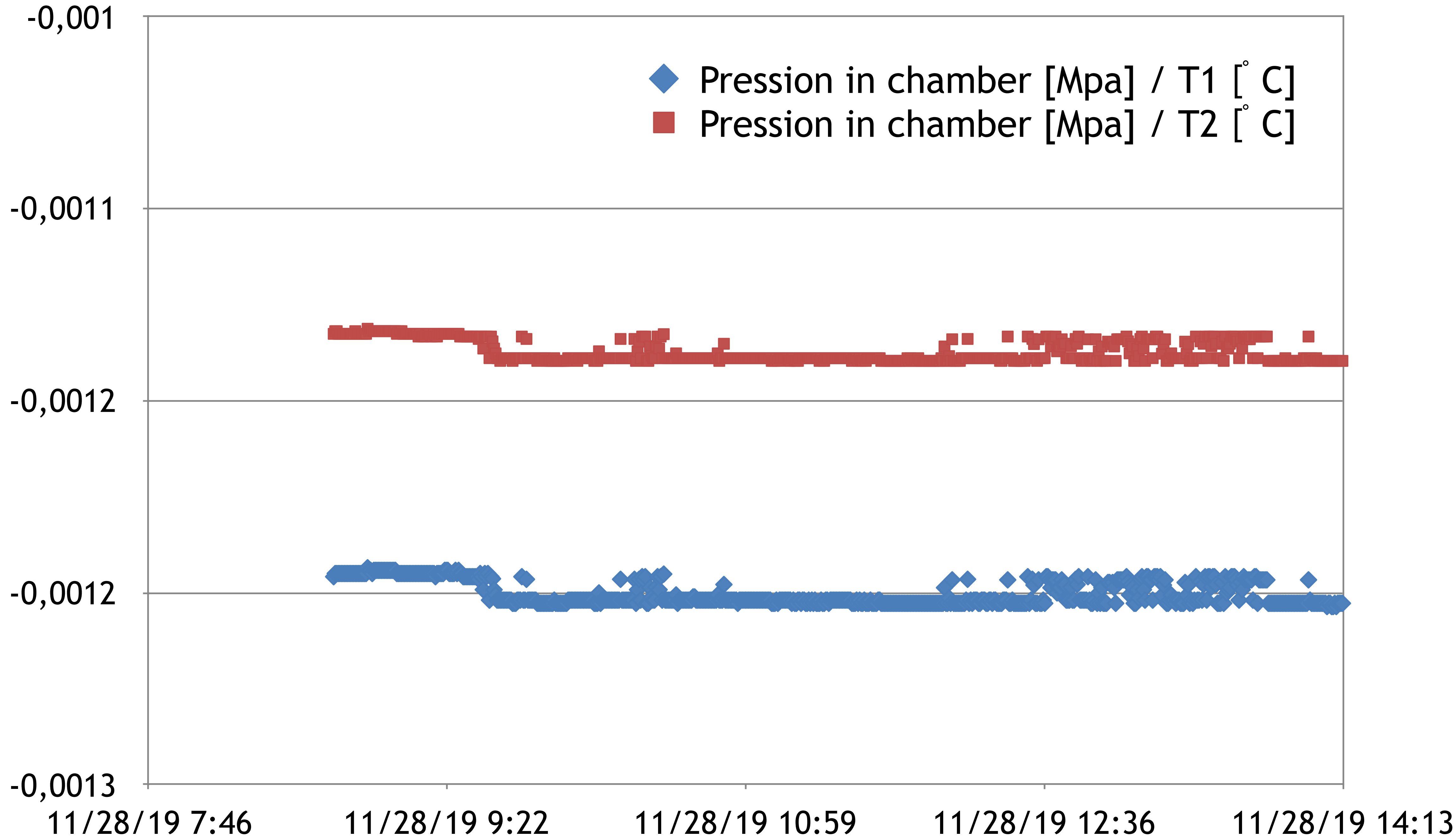
Flow rate 7.5 l/min : 16h



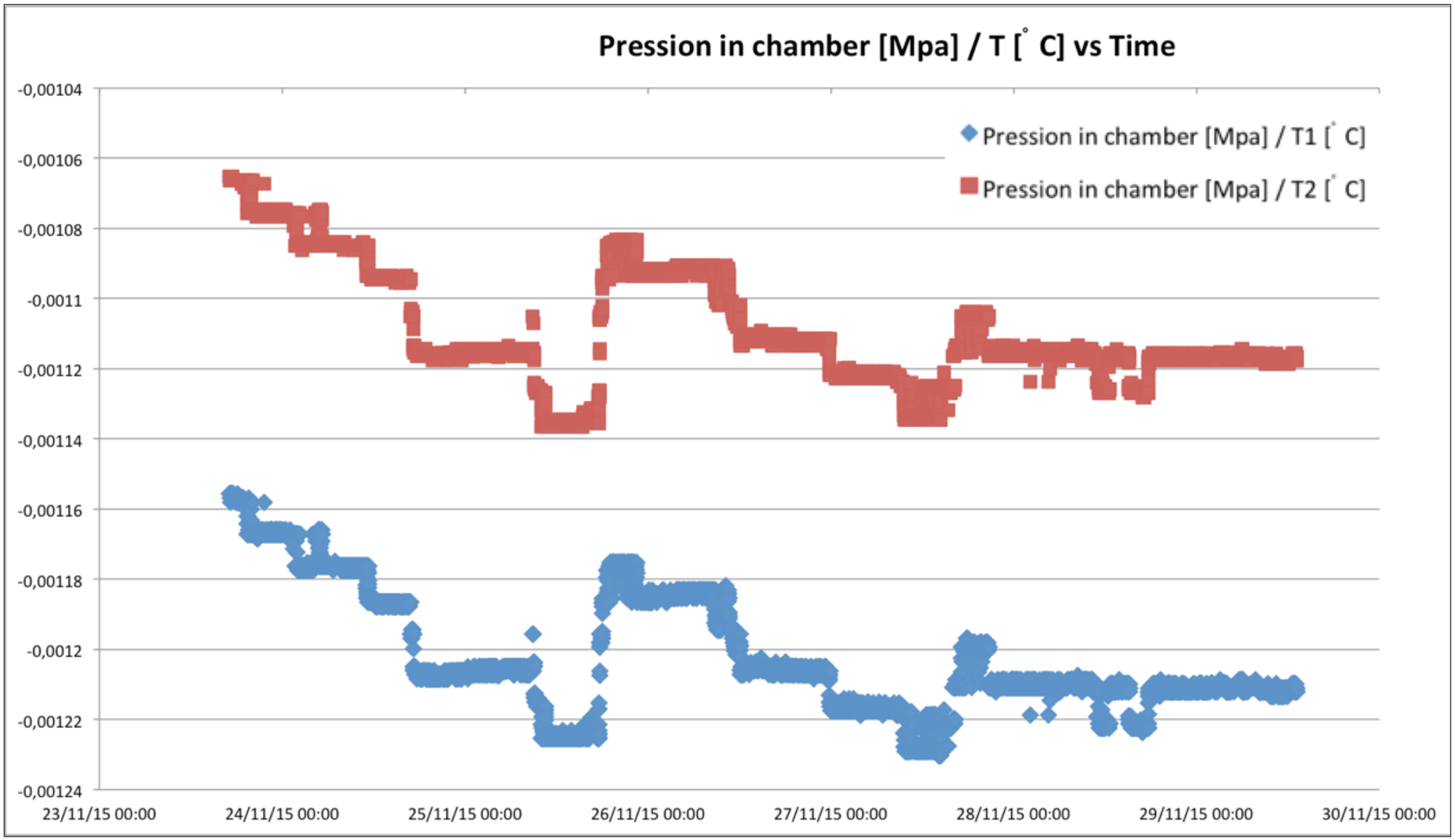
Flow rate 5.5 l/min : 5h 30min



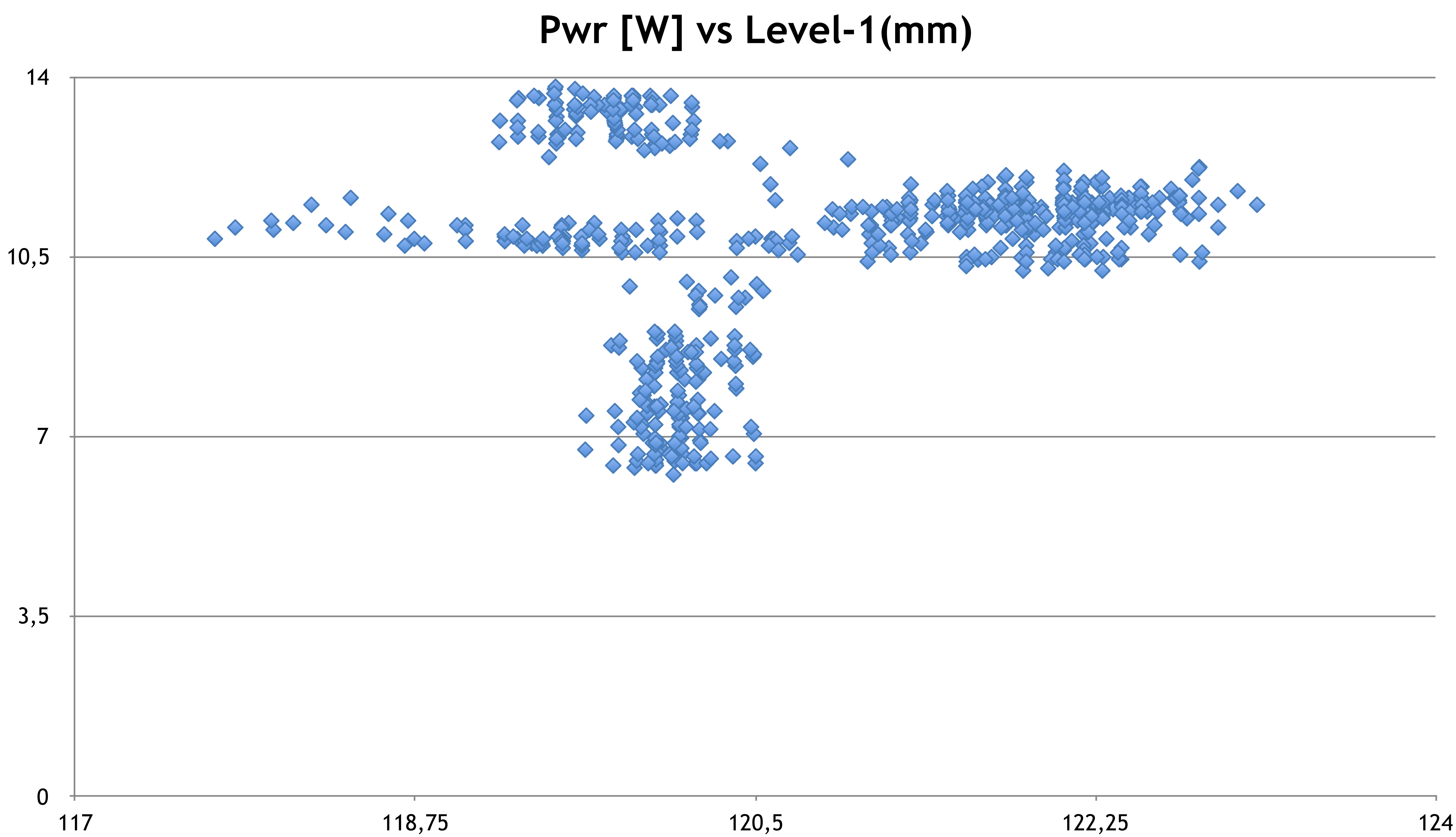
Flow rate 5.5 l/min : Ratio pressure/temperature VS time



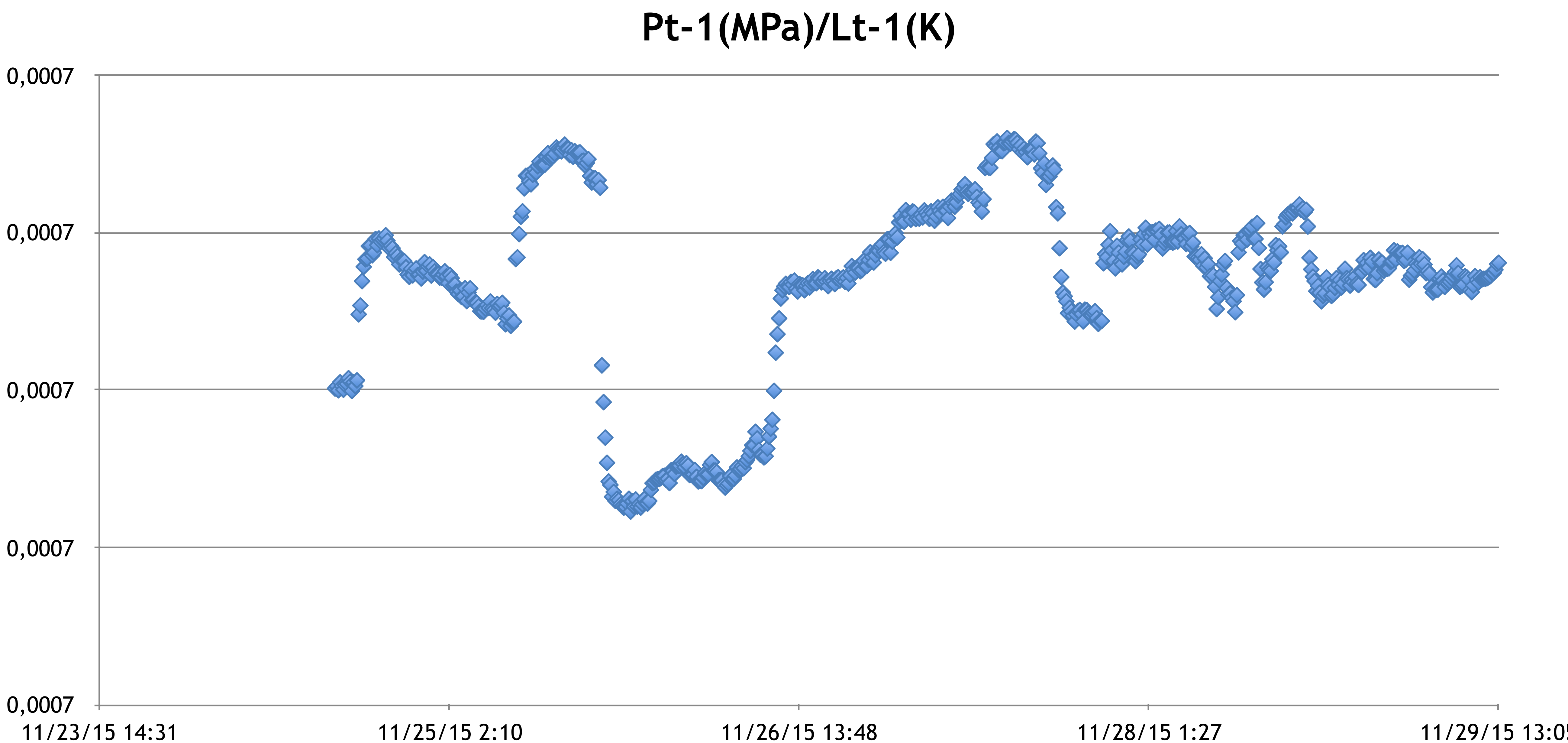
Pressure in the chamber / Temperature VS Time



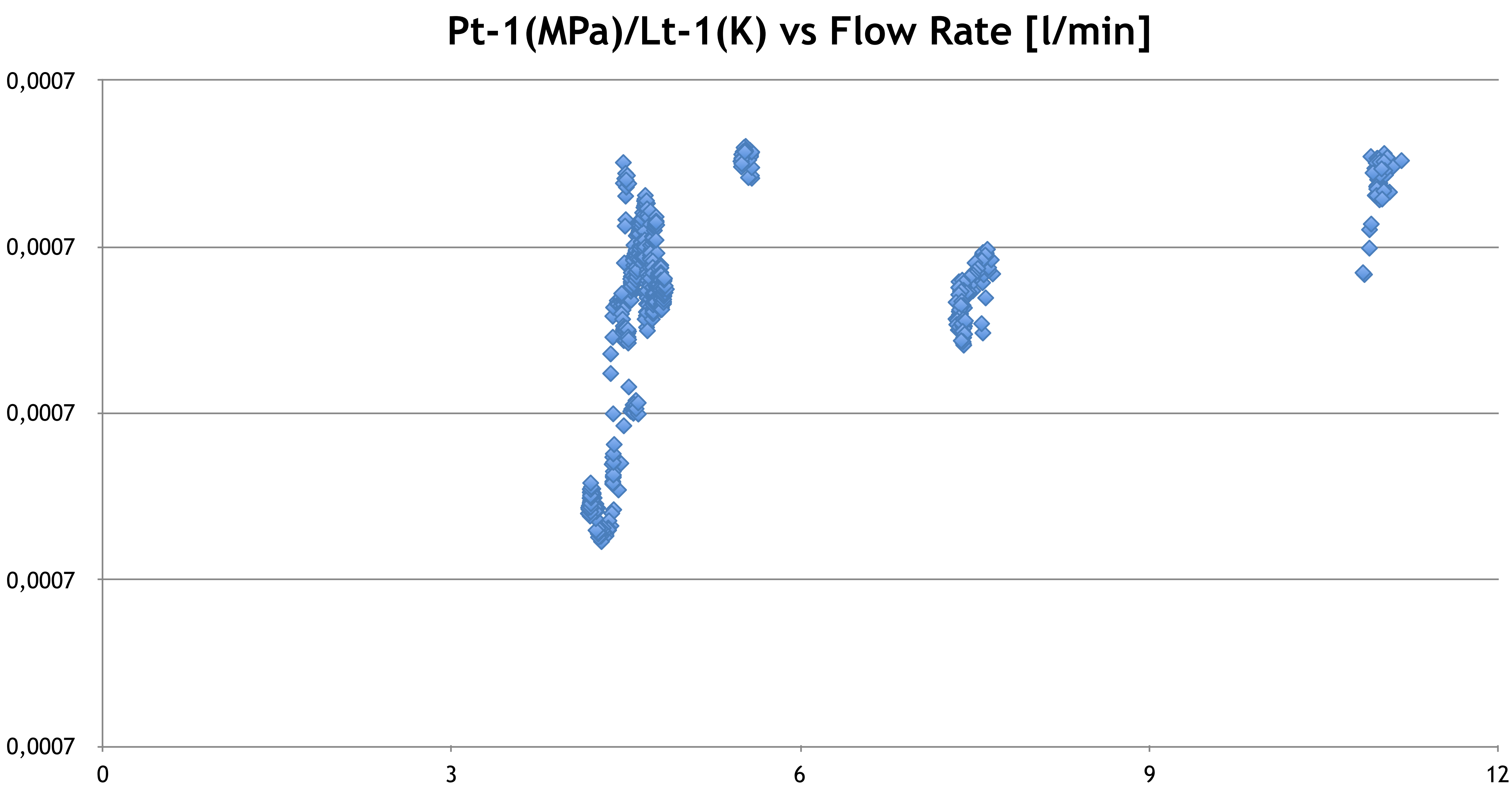
Power (W) VS LXe level



Pressure in the chamber / Temperature in the vessel (low) VS Time

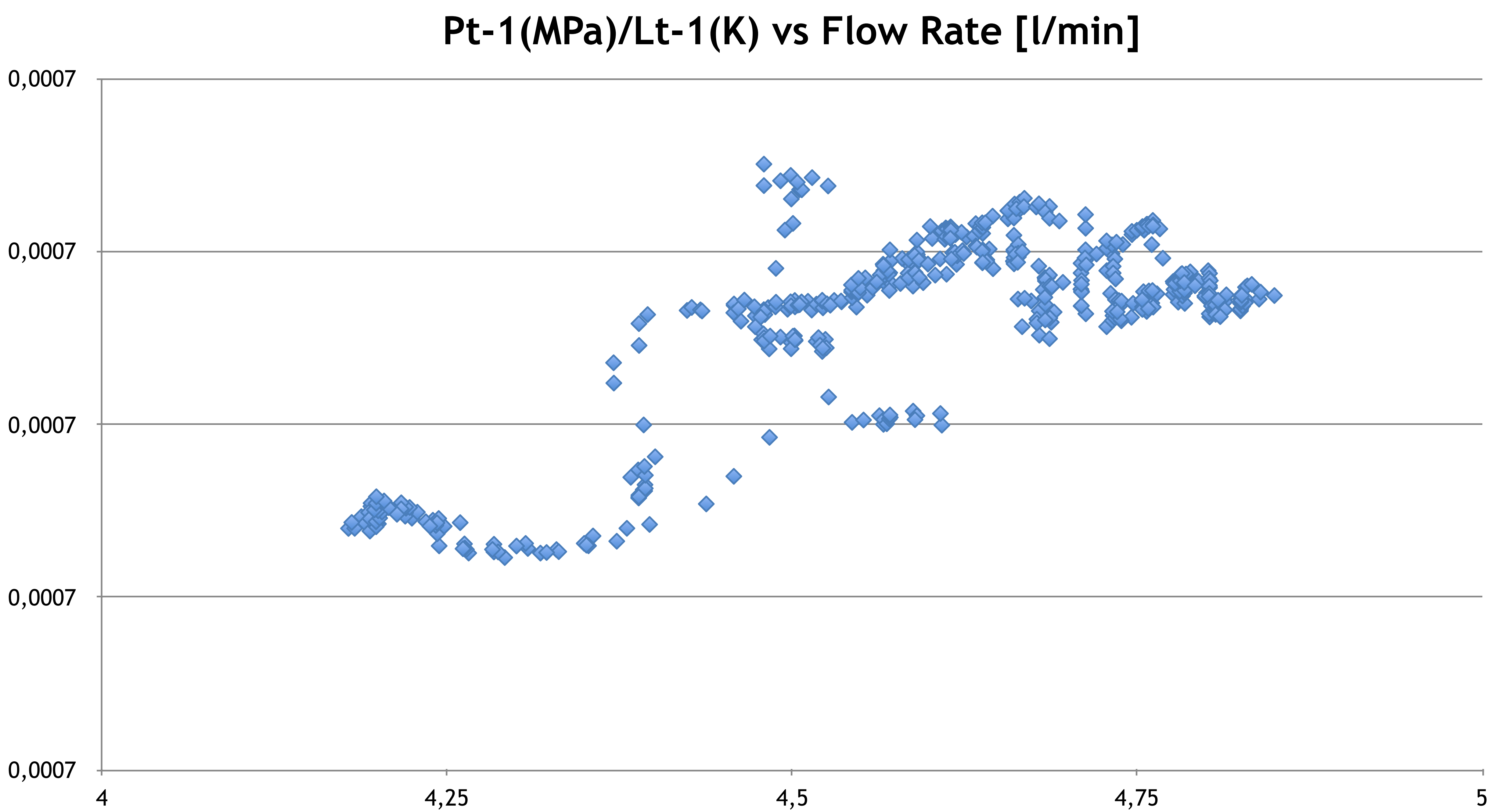


Pressure in the cryostat / Temperature in the vessel (low) VS Flow Rate



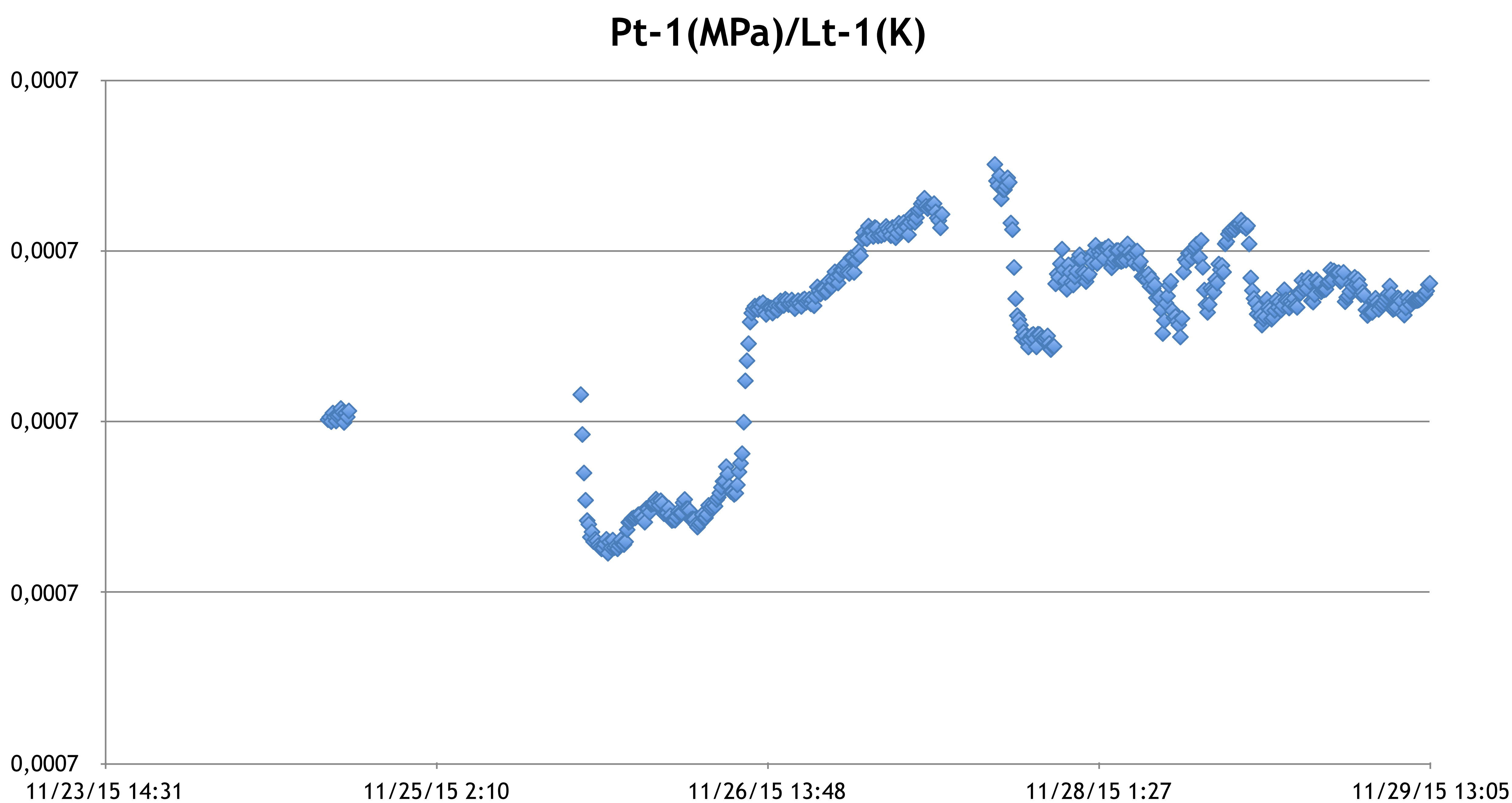
Pressure in the chamber / Temperature in the vessel (low) VS Flow Rate

Region 4.2-4.7 l/min



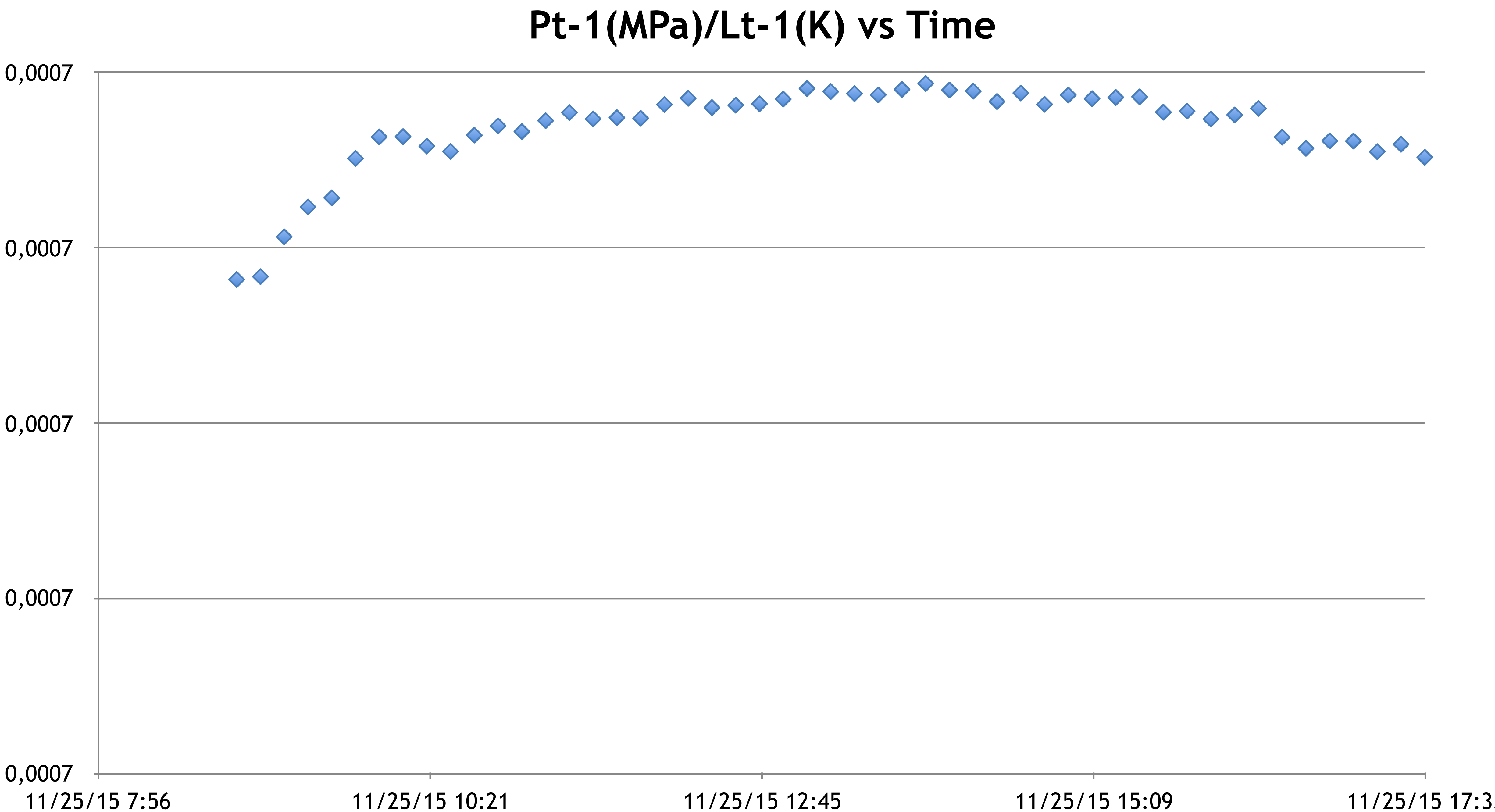
Pressure in the chamber / Temperature in the vessel (low) VS Time

Region 4.2-4.7 l/min



Pressure in the chamber / Temperature in the vessel (low) VS Time

11 l/min



Pressure in the chamber / Temperature in the vessel (low) VS Flow Rate

11 l/min