液体キセノングループ報告

2015年度後半以降を含めて報告

KEKDTP重点レビュー、2016年11月8日、KEK

田内利明

2015年度

2015年度　後半

11/18 - 12/1　SubatechからSara Diglio(postdoc) とLucia Gallego(PhD student) がKEKに滞在し、主に、予冷装置の性能評価試験（熱交換の効率、外部からの熱侵入の評価など）を行った。

2016
年末年始、液化のまま維持した。この時、TPC、PMT、ASICチップなどのエレクトロニクスの電源を印加していた。
1/19　 Xe液中、テストパルスでチェックしたところ、出力のあったのはch2,3,4,5,13のみであった。

3月　ASICチップを最後のものに交換（GND)

2016年度

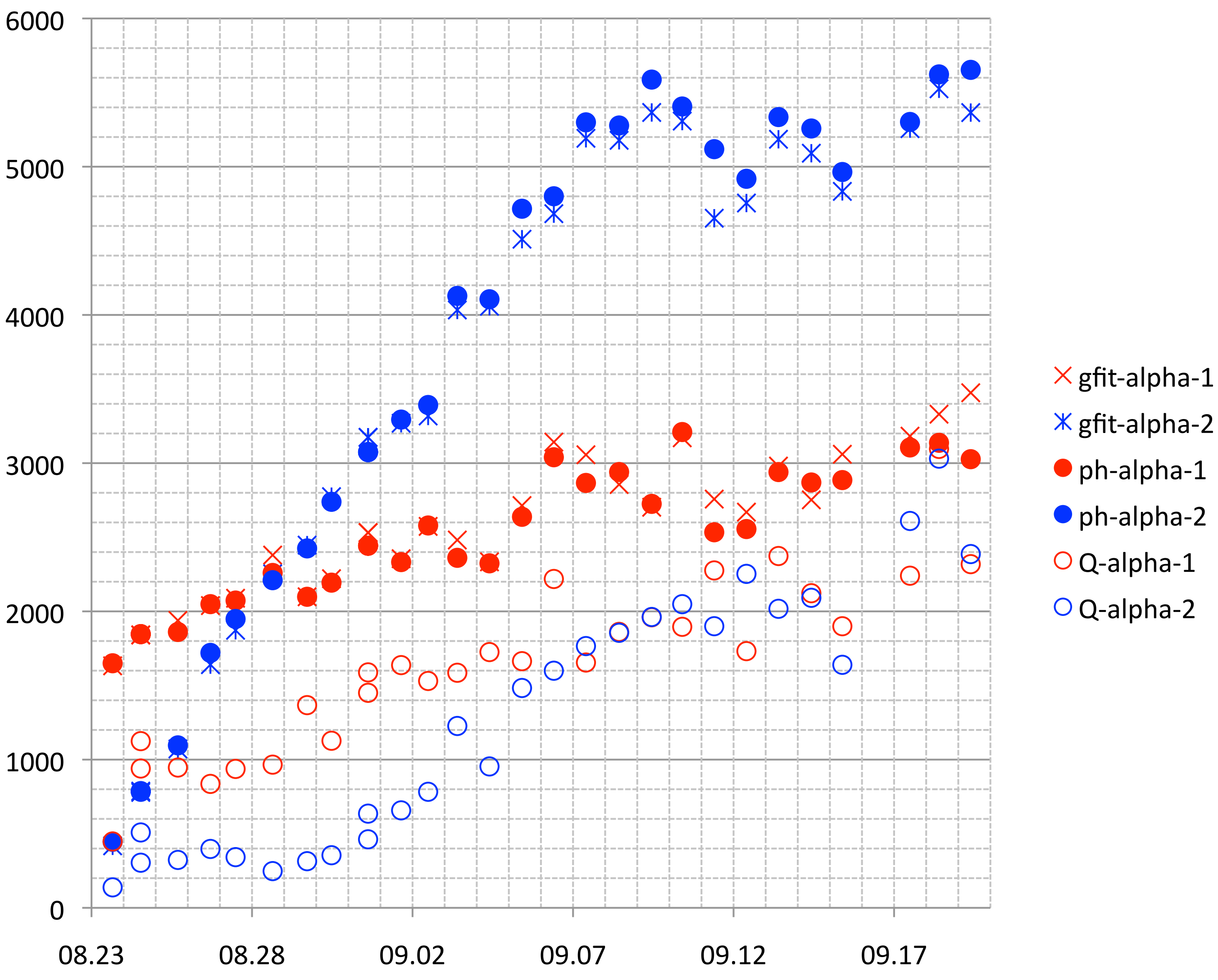
2016年度

4/8 : ASICチップ交換後のボードをチェンバー内に設置。
常温で全チャンネルのテストパルス出力を確認
4/12~19 真空引き開始、液化完了
4/20 - 4/27 : ガス循環速度 3ℓ/分で純化
4/25以降に電荷シグナル（α2とγ線）を確認。これは液体Xe中のASICチップでの初観測。
連休中、加温
5/9 再液化開始
5/11 - 5/28 : ガス循環速度 4ℓ/分で純化、電荷シグナルの増大を観測できなかった。エレクトロニクスは全ch動作。

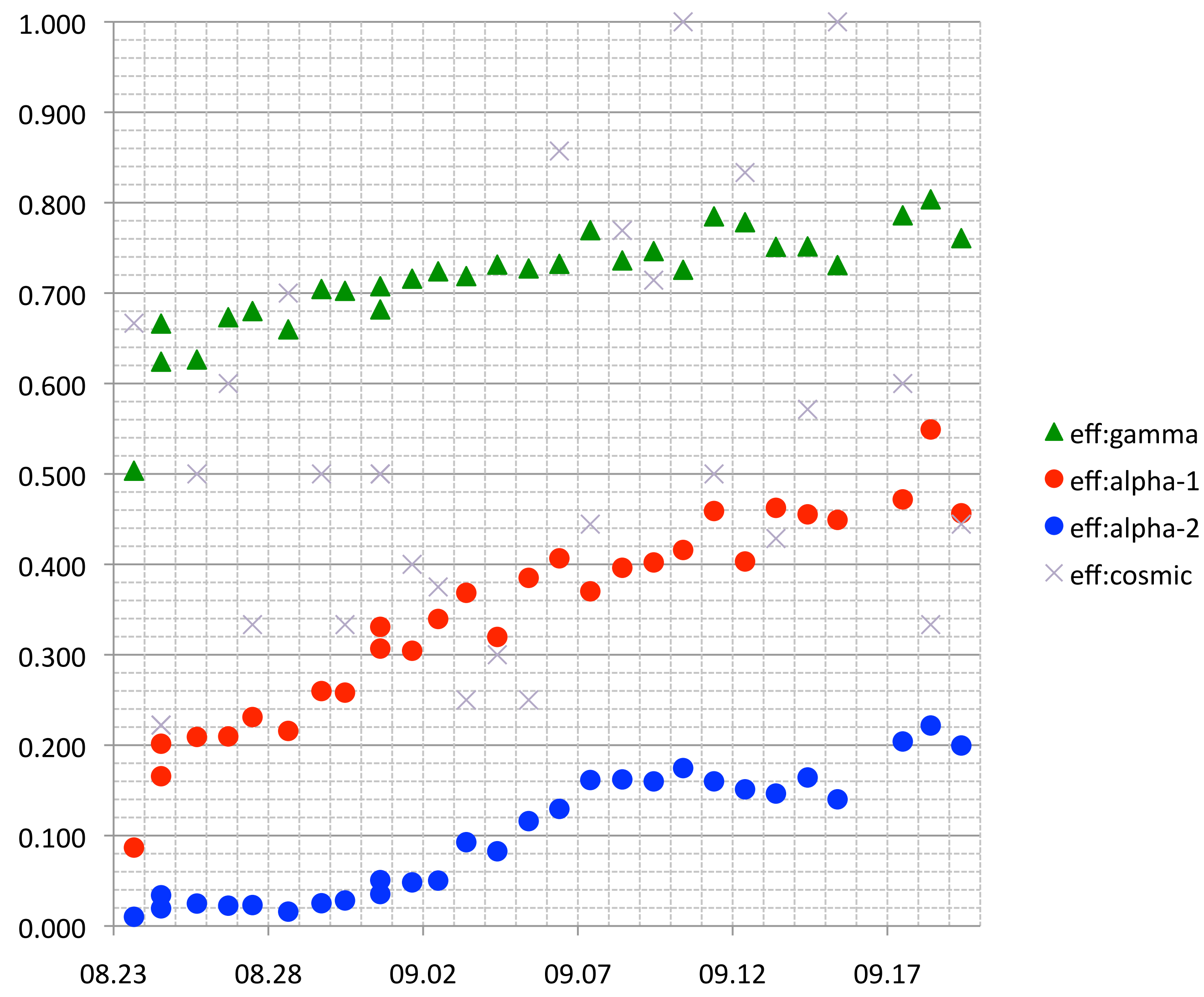
9月、純化向上のため、ゲッターの吸着筒を新品に交換。
9/12: 液化開始
9/13: ガス循環速度 3.5ℓ/分で純化
9/14 - 11/8　ガス循環速度 4.5ℓ/分で安定に運転
電荷シグナルは非常に緩やかに増大している。

LXe-TPC試験
FE-A250

Growth of charge from α sources



Efficiency of charge from α, γ sources and cosmic rays



efficiency=charge signals / signals identified by PMTs

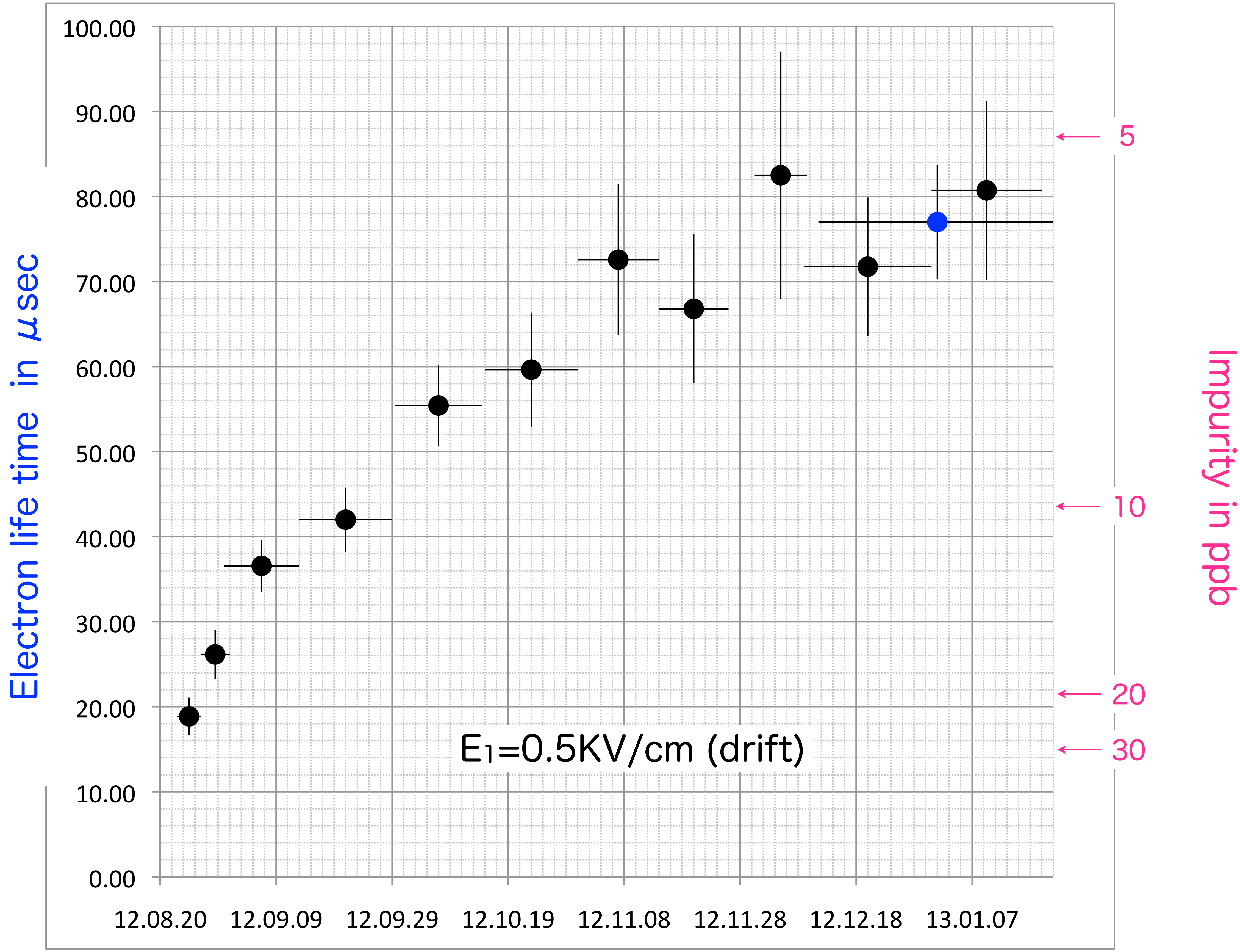
gfit-alpha-1,2 : Gaussian fit w/o baseline subtraction

ph-alpha-1,2 : Double Gaussian fit w/ baseline subtraction to raw charges summing the 6,7,10 and 11 pads

Q-alpha-1,2 : Double Gaussian fit w/ baseline subtraction to individual pad for each event

Electron life time and impurity in Liquid Xe

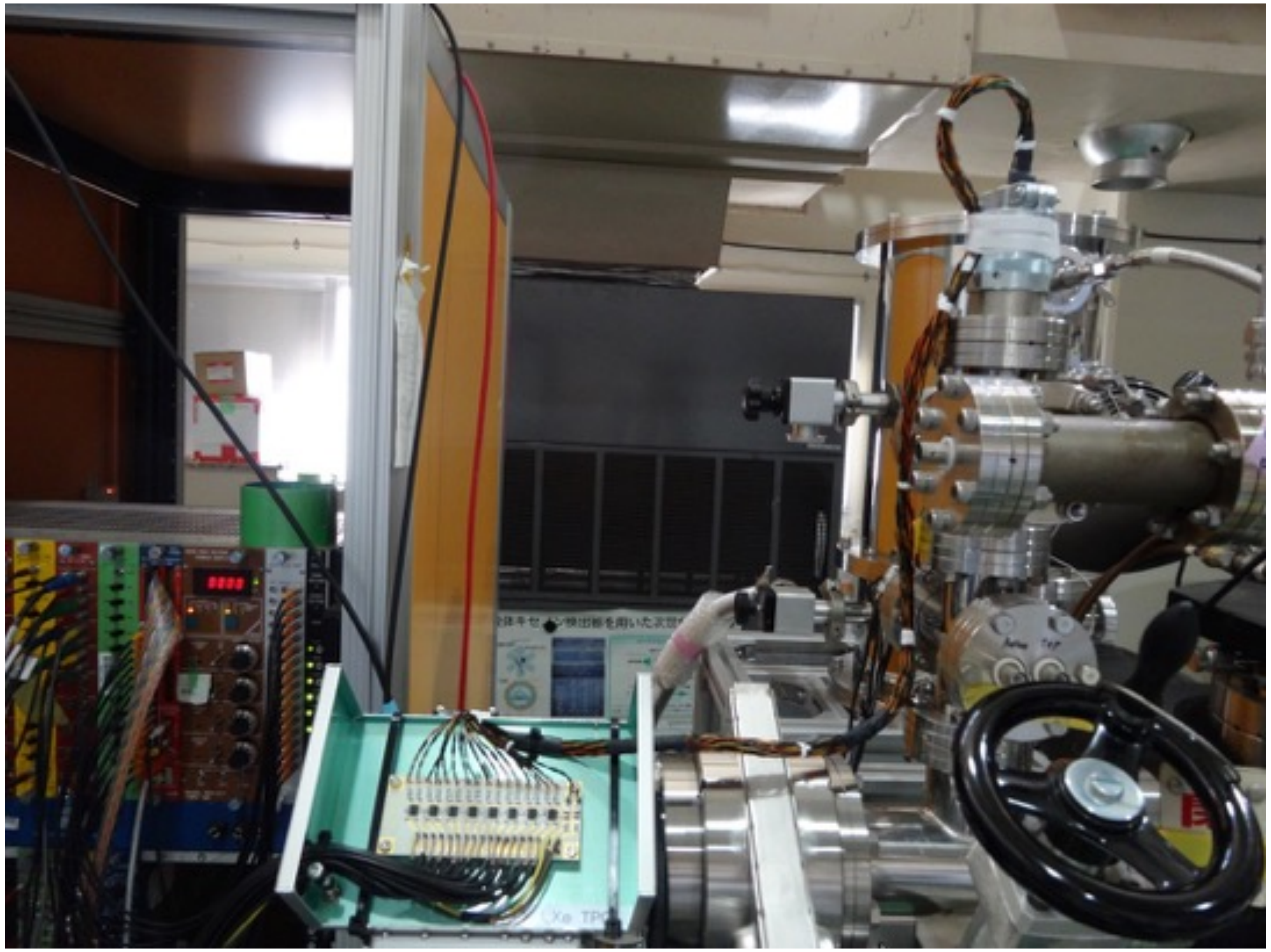
2012.8.23-2013.1.19

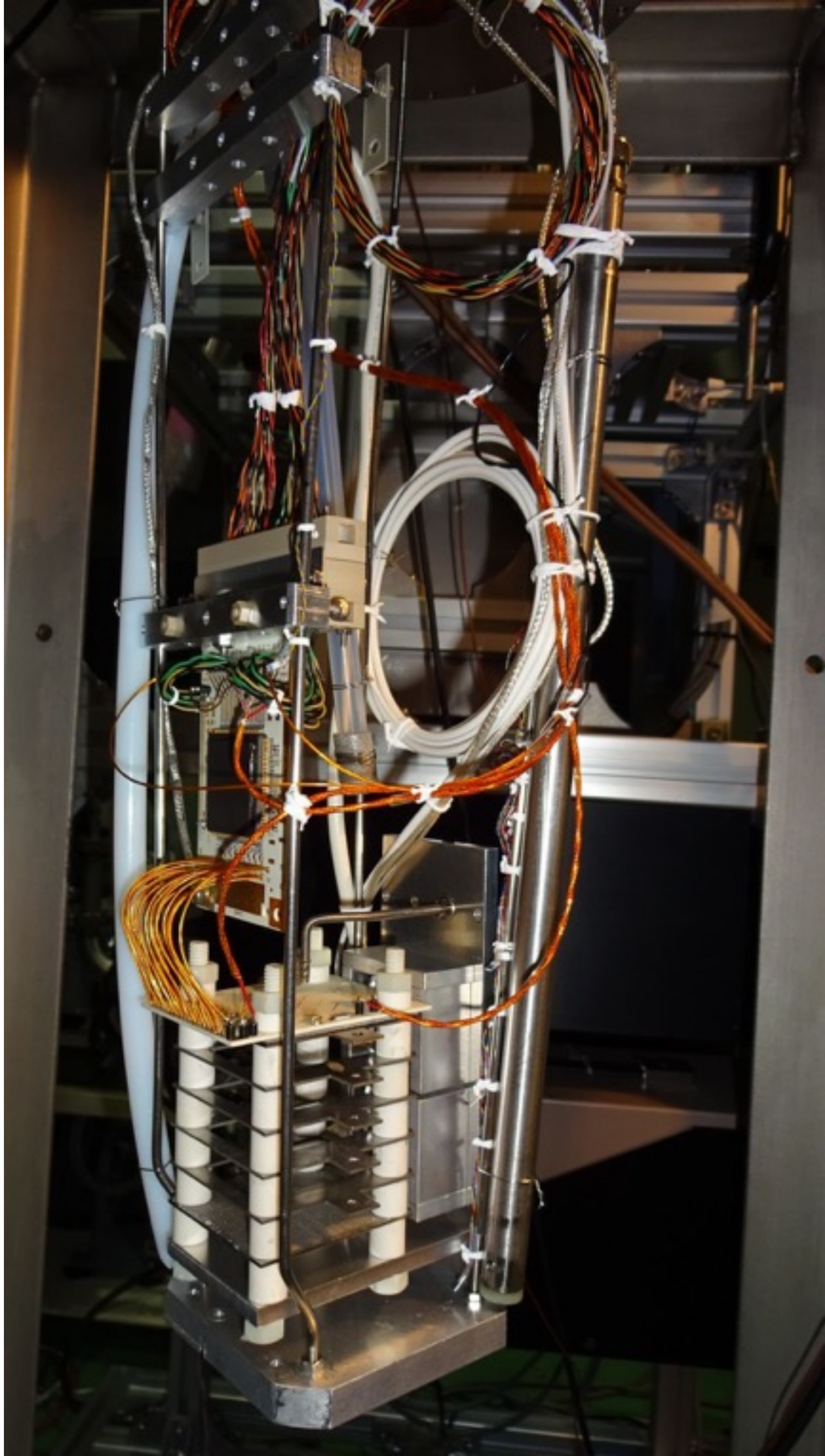


ASIC・TPCFE09 フロントエンド・エレクトニクス

Frontend Electronics

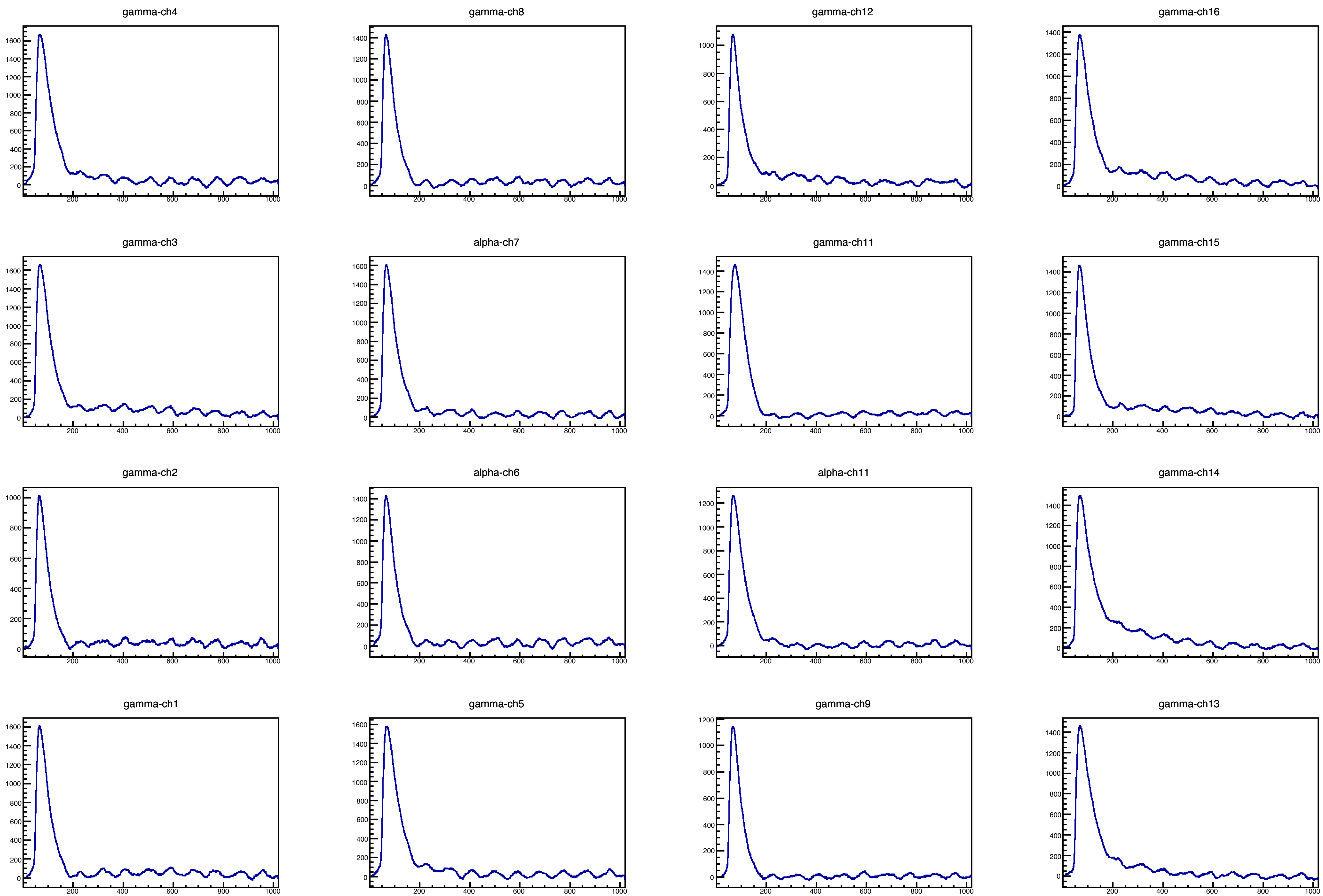
Optimized setup, 22 October, 2015





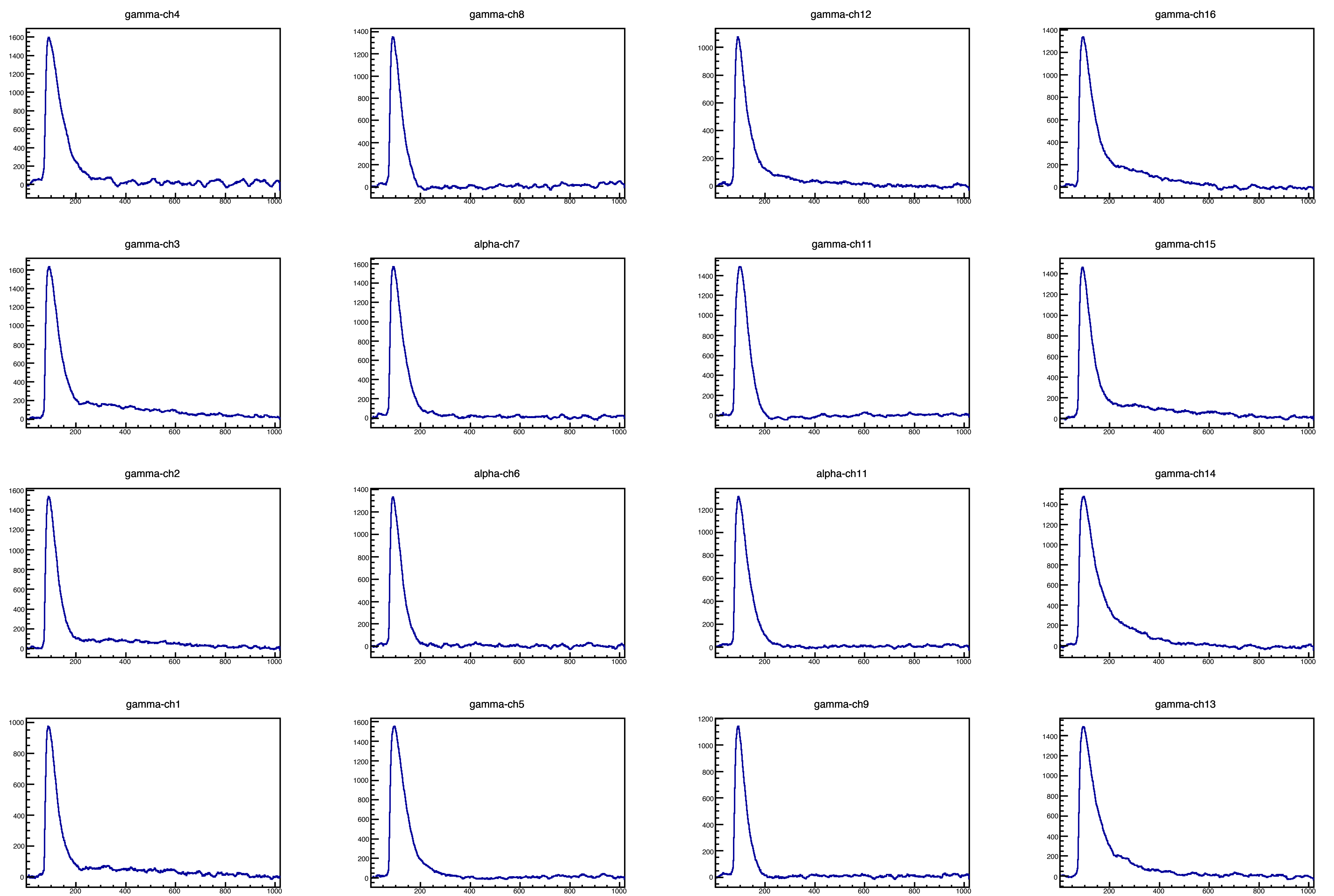
Test pulse results at -100°C

waveform summed 100events, 11 May 2016

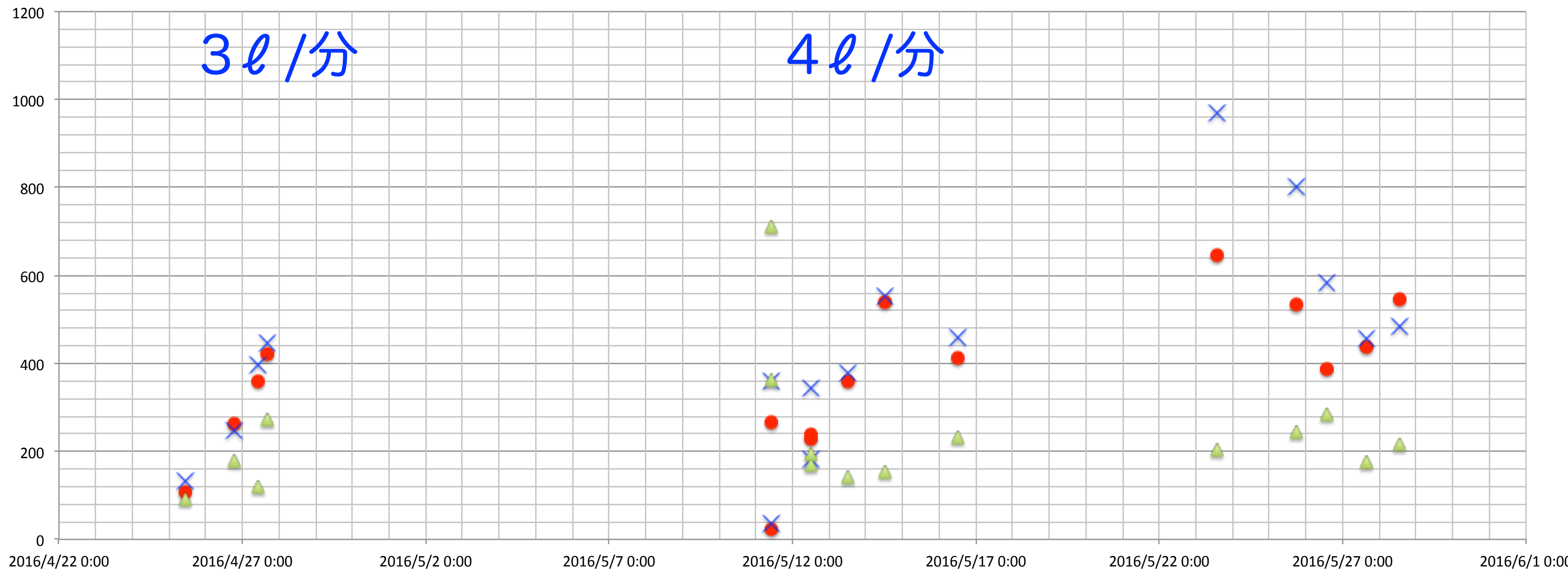


Test pulse results at -100℃

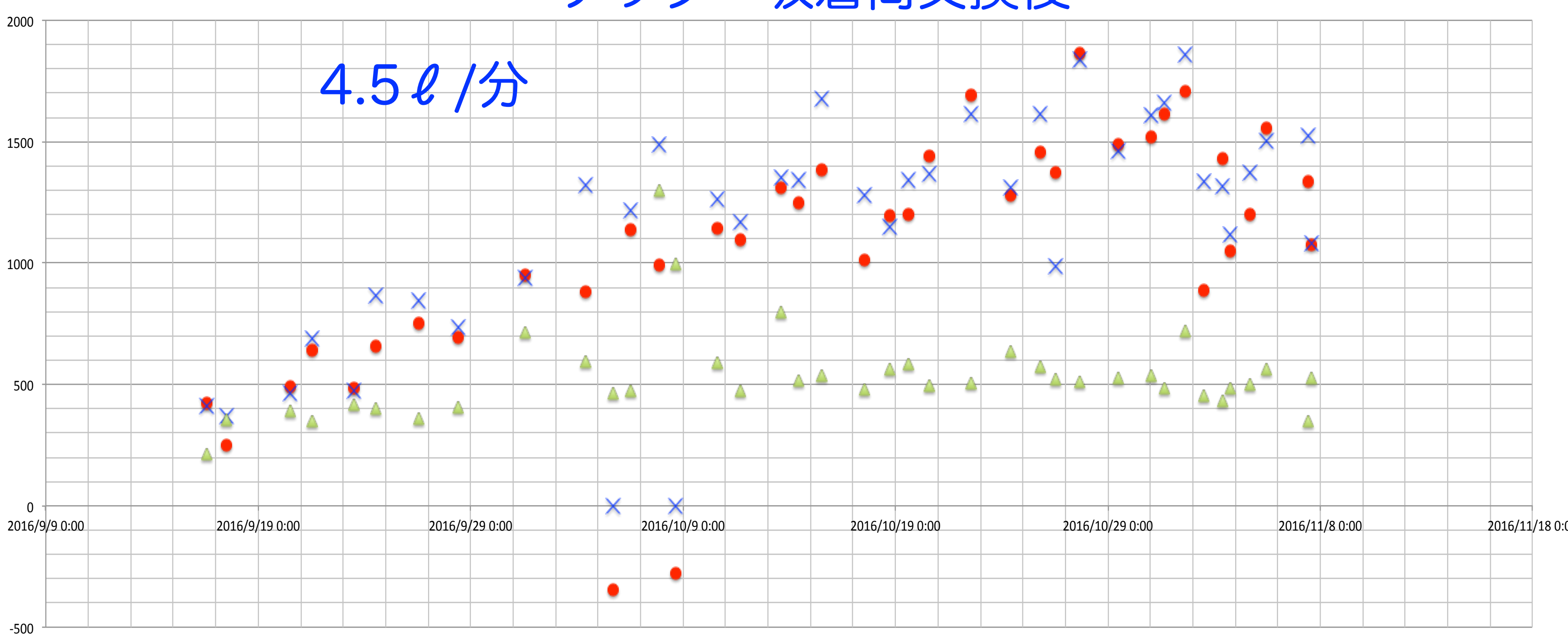
waveform summed 100events, 7 Nov. 2016



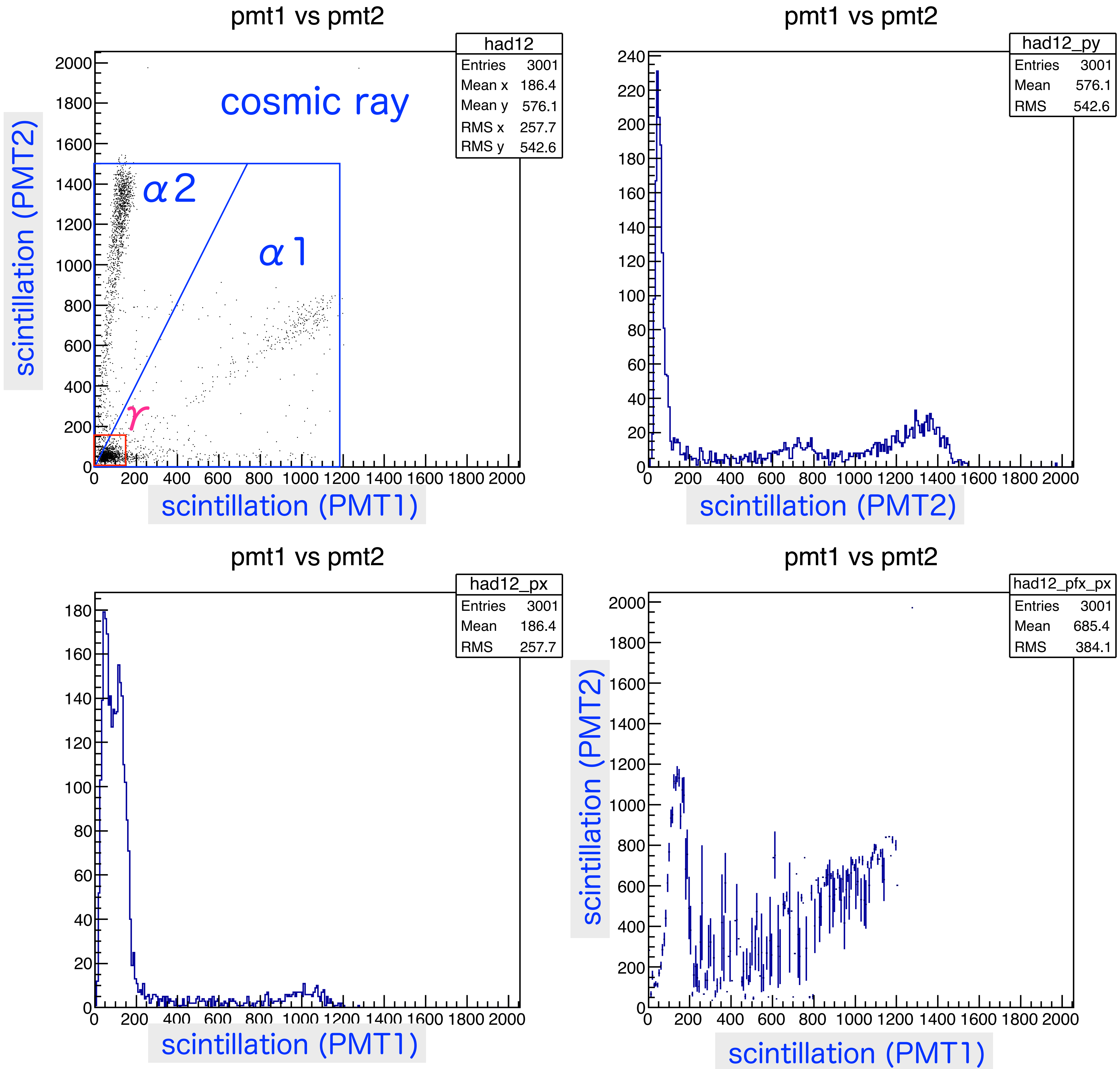
電荷シグナル(α2)の推移



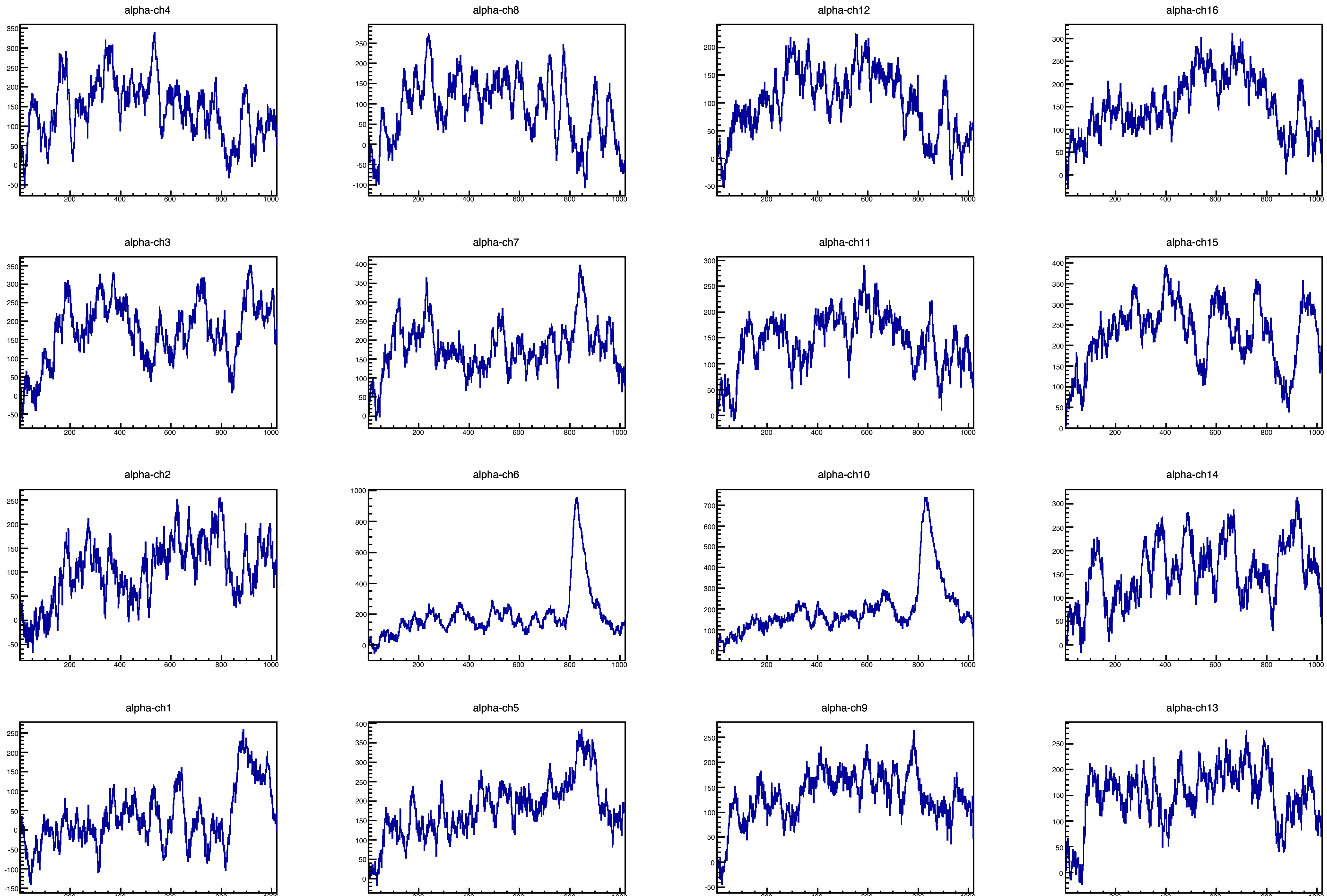
ゲッター吸着筒交換後



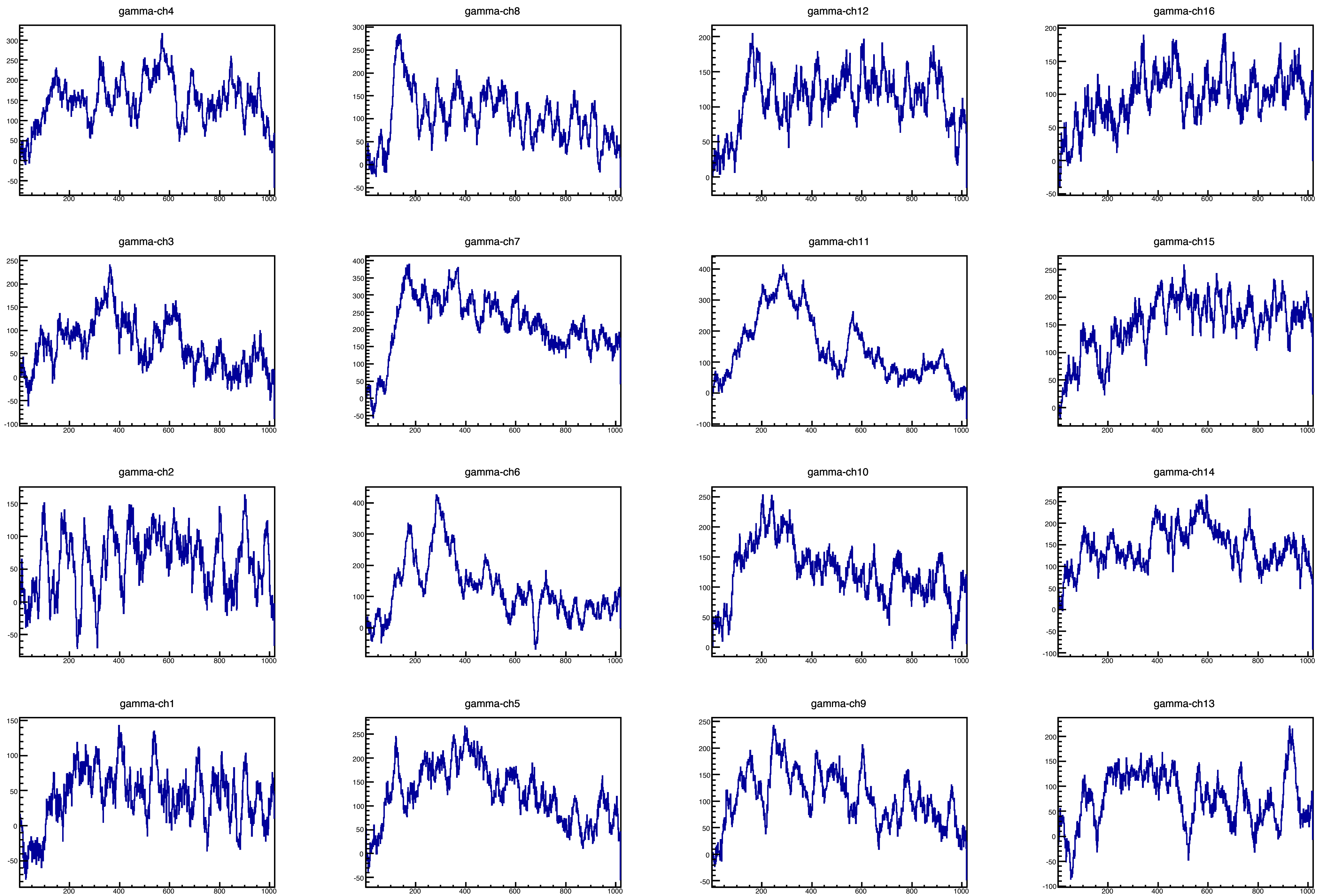
シンチレーション光(PMT)シグナル，2016/11/1



電荷シグナル（α1,α2）シグナル，2016/11/1



電荷シグナル（γ）シグナル，2016/11/1

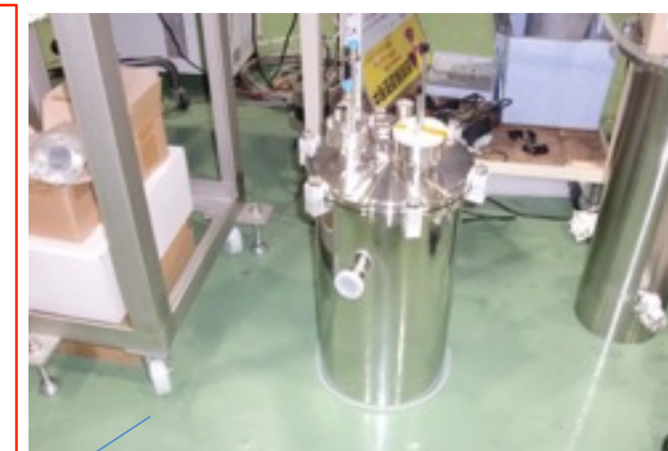


予冷装置

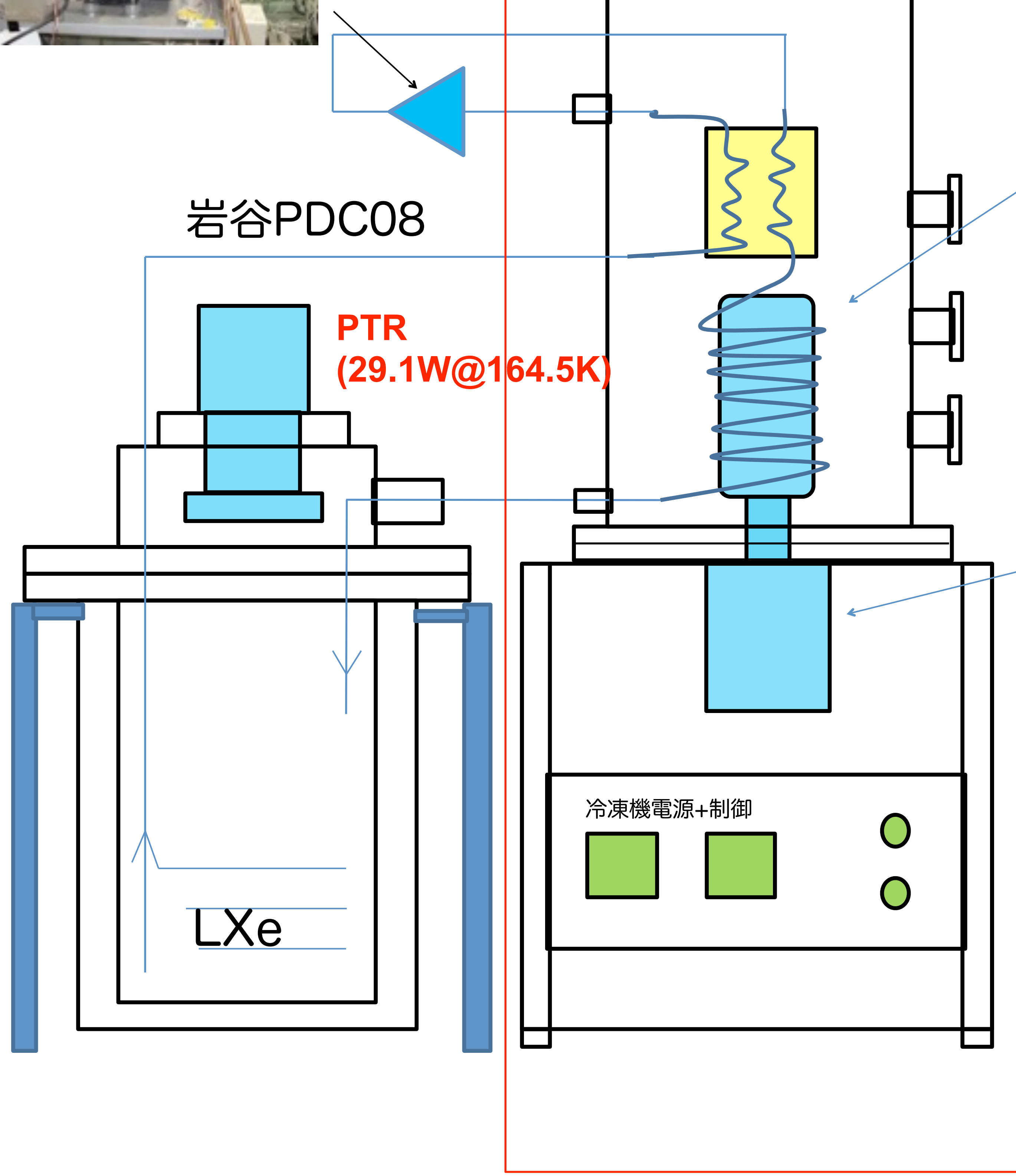
ガスハンドリングパネル

ガス循環サーキュレーター

真空断熱・熱交換器

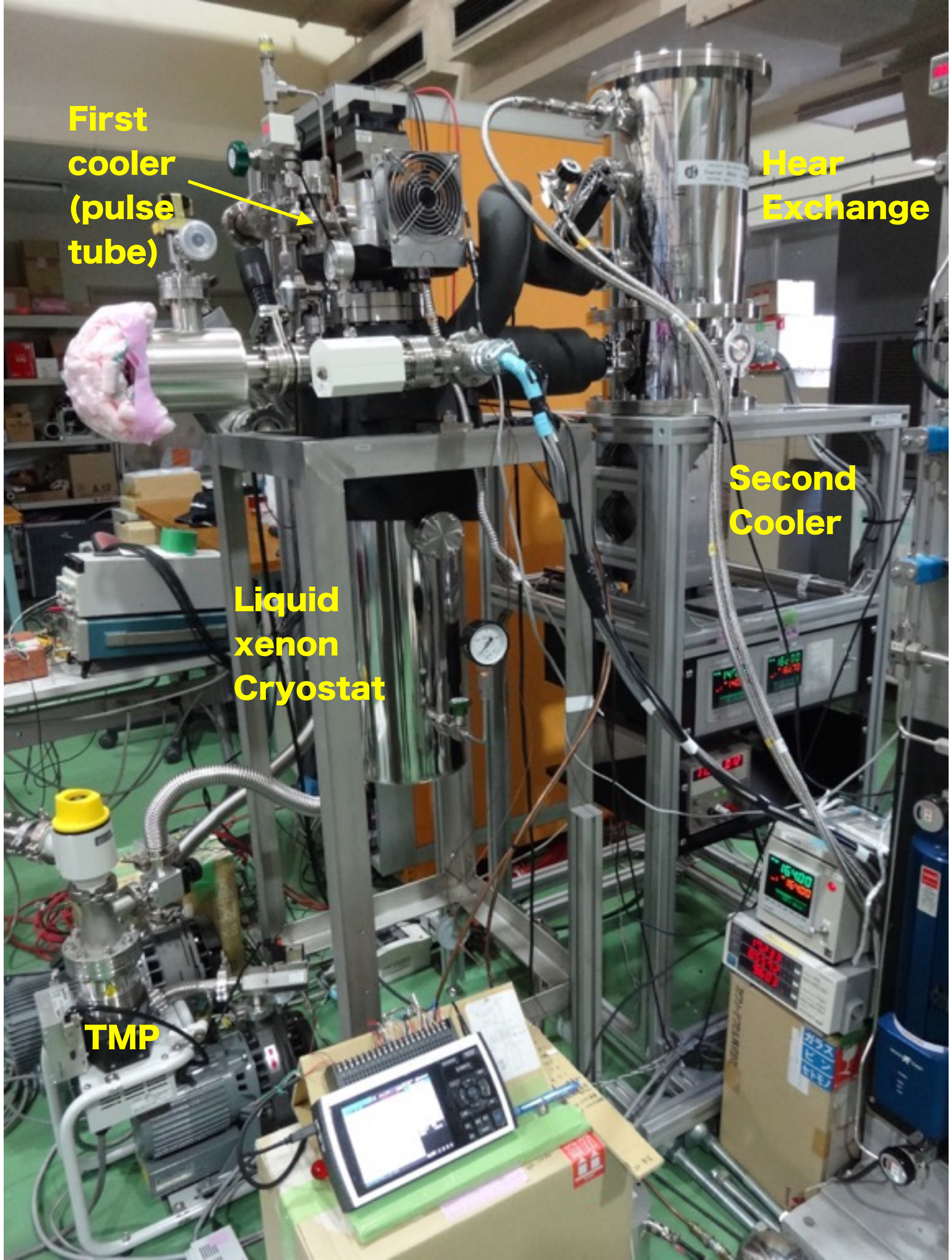


LXeクライオスタット

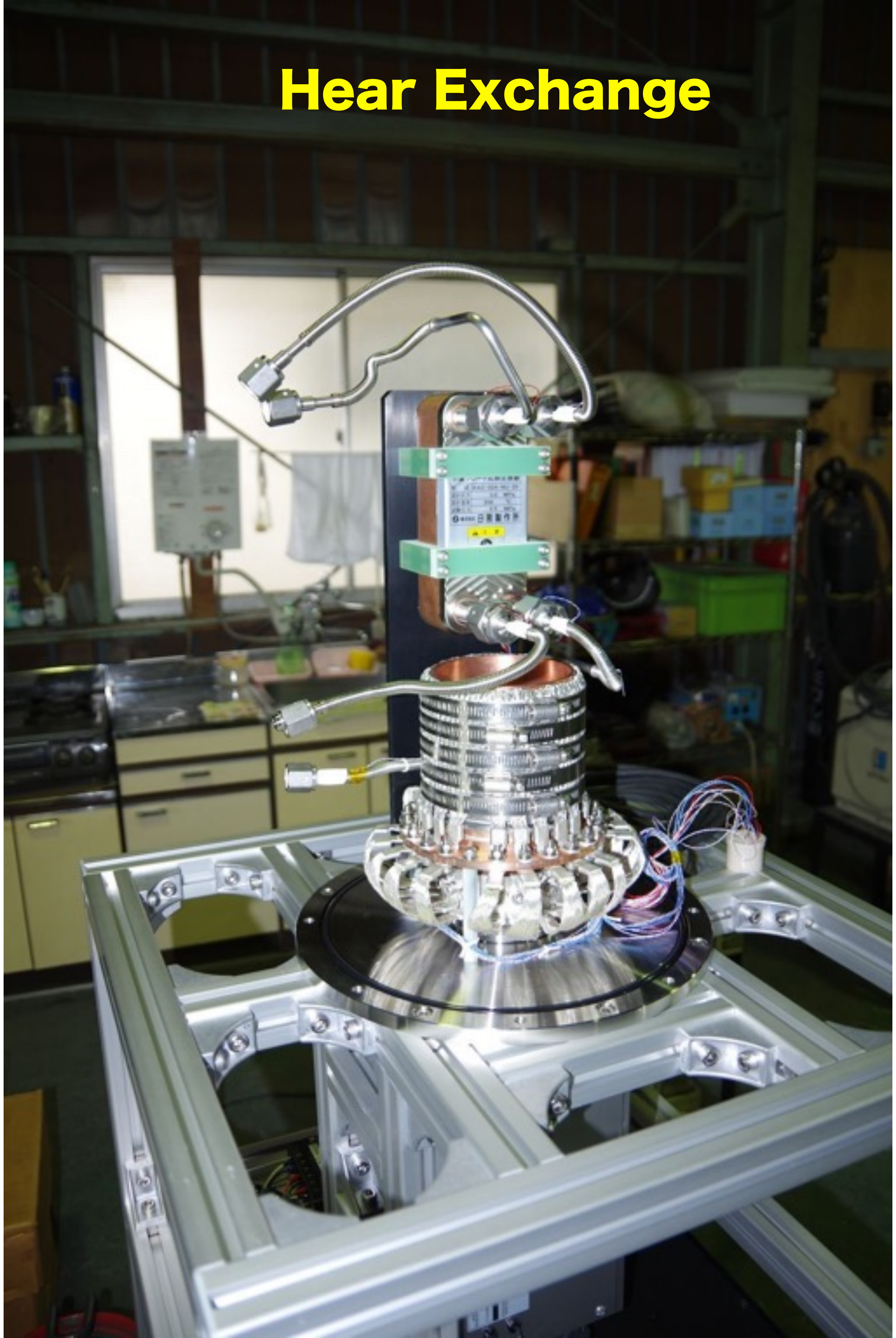


TWINBIRD SC-UE15
173K@30W

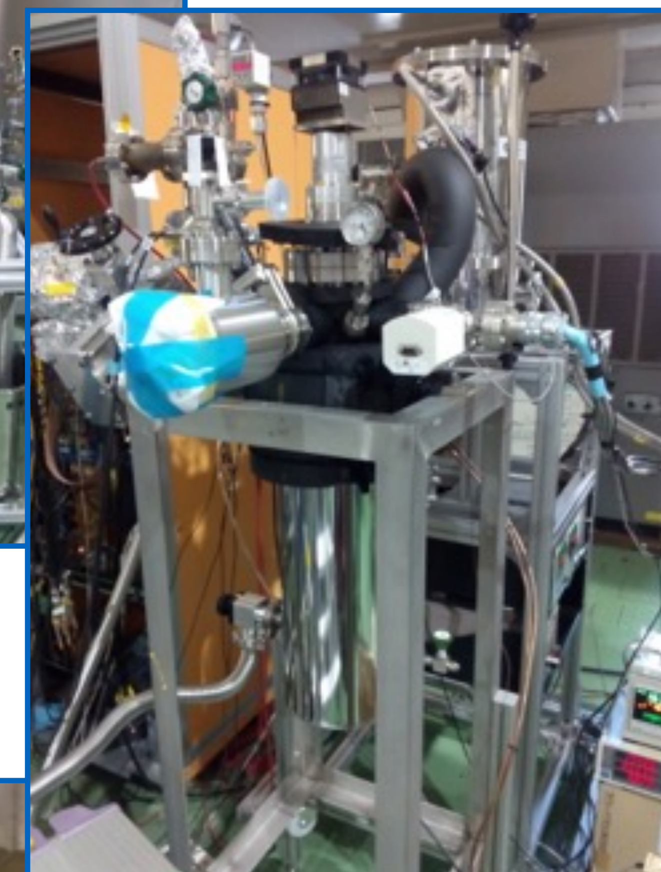
冷凍機インバーター
ノイズ調査必要。


First cooler (pulse tube)
Hear Exchange
Second Cooler
Liquid xenon Cryostat
TMP

Hear Exchange



Cryogenic Study of the LXe TPC at KEK



Sara Diglio and Lucia Gallego

KEK December 1st 2015

Cryogenic Study of the LXe TPC at KEK

December 2nd 2015
Sara Diglio and Lucia Gallego

In order to characterize the LXe TPC system at KEK, we analyzed data taken between November the 18th and the 30th.

The data include a first phase of system pre-cooling and Xenon liquefaction, as well as a second stable recirculation phase consisting of several deliveries during different periods.

The gas injection was stopped when ~120 mm of LXe have been filled into the cryostat.

By studying the first phase, we estimated that the time needed to increase the liquid Xenon level of ~100 mm is ~12h. The same amount of time is needed to reach the internal temperature stability of the cryostat (164 K) as well as to cool down the cold head of the PTR to 164 K.

Once the stability has been reached, we measured the relevant parameters of the different parts of the experimental setup: inlet and outlet temperatures of the thermal exchanger in the pre-cooling system, internal and external temperatures and pressures of the cryostat, pressures before and after the gas pump circulation. For most of such parameters we observed a constant behavior within ~2%. Indeed, we noticed a slight increase of the pressure and temperature in the chamber with time: we verified that the ratio between them stays constant with time.

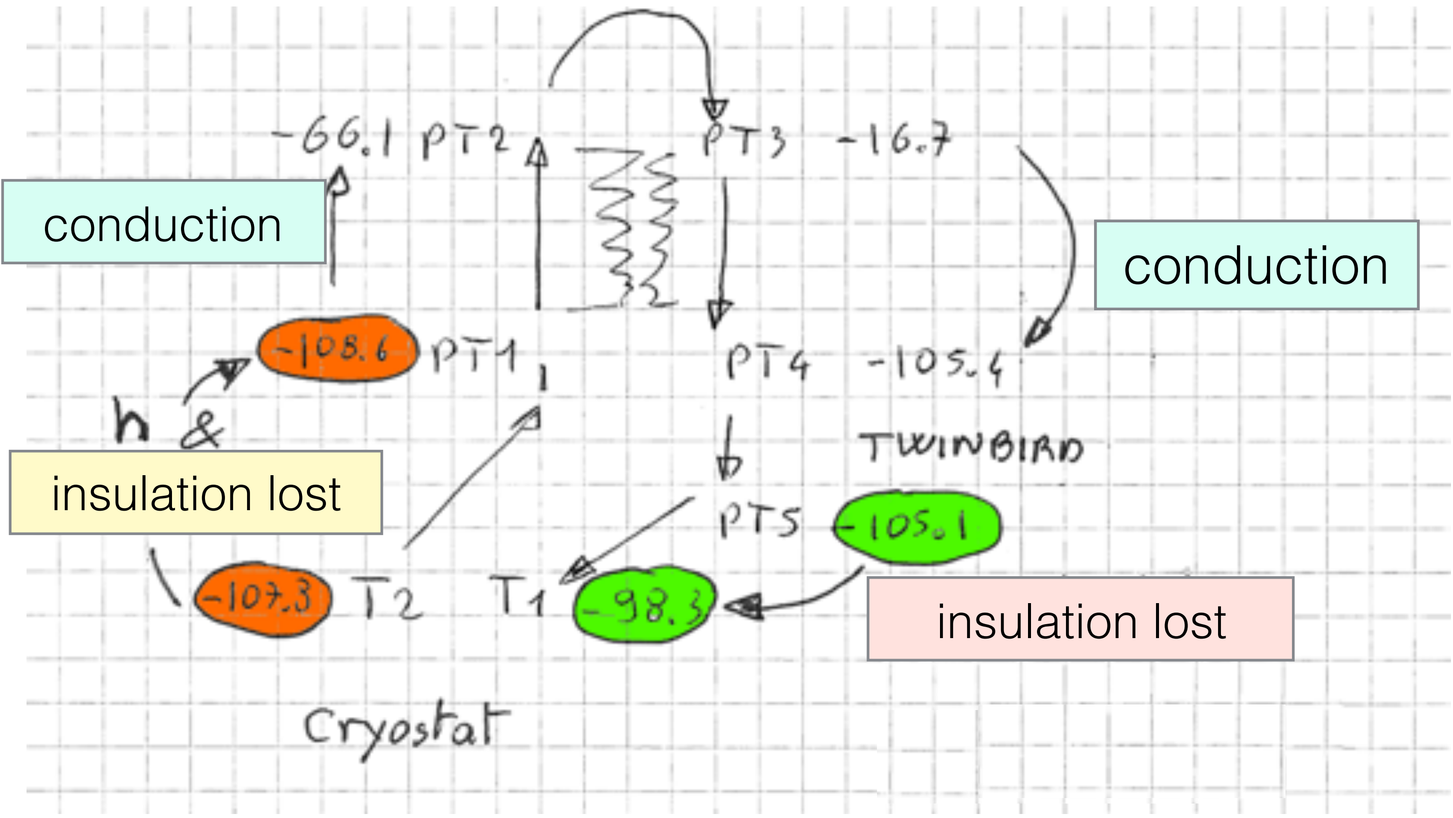
During the re-circulation and purification processes, the detector was operating at different flow rates from 4.2 l/min to a maximum value of 11.0 l/min that allow us to estimate the performance of the system as a function of the gas flow rate. We observed an improved performance in terms of time to reach the steady state as well as a better stability of pressures and temperatures, for higher values of delivery.

The power supplied to the heater was measured for each of the different flow rates. Slide 35 shows the required cooling power as a function of the flow rate. The cooling power is computed as the available cooling power of the PTR to achieve a specific temperature of the cold head, minus the heater power needed to maintain constant the temperature inside the chamber. A required heater power of the PTR of 29 W was measured by KEK to achieve a temperature of 164 K. As we can see, a gradual increase of the cooling power is observed as the flow rate increases. Since the recirculation rate is measured but not controlled, we have observed that the flow rate is not constant during the data-taking period but drift towards equilibrium slowly, together with a slightly increase of temperature and pressure.

We have also estimated the efficiency of the heat transfer process as a function of the flow rate. To measure the performances of the heat exchanger, we have calculated inlet and outlet pressures and temperatures of the heat exchanger as well as the pressure inside the cryostat. The temperature differences at the warm and cold parts of the heat exchanger are presented in slide 36. The temperature at the cold part of the heat exchanger is quite stable with the flow rate, which implies that even for a small flow rate there is heat exchange between the LXe and the GXe. However, high temperature differences are measured in the warm part of the heat exchanger ($\Delta T \sim 57$ K). We observed that the gas exits the heat exchanger with a different temperature, far from the room temperature, with respect to that it re-enters. This high temperature difference may imply an important heat conduction between the bottom and top parts of the heat exchanger. The amount of heat to be transferred between the inlet and outlet of the heat exchanger can be calculated from this temperature difference. The heat capacitance of Xenon is $C_p \sim 0.34\ \mathrm{Jg^{-1}\ K^{-1}}$ at 1 bar and the latent heat is $L_p \sim 96.26\ \mathrm{Jg^{-1}}$. The efficiency of heat exchanger as a function of recirculation rate is presented in slide 37. We estimate that the efficiency of the heat exchanger is 86 %. A drop pressure between the cryostat and the inlet of the heat exchanger of around 300 mbar has been estimated. At such pressure difference, we can assume that the Xenon returns to the cryostat in a liquid state. The result of pressure drop is shown in slide 38.

The cooling power has to compensate for all the thermal losses in the connecting tubes despite the insulation. Outside the vacuum enclosure, the tubes are surrounded by an insulation based on an AEROFLEX tube with k ~ 0.038 W/mK at 24 ºC. A considerable thermal loss of 2.5 W has been estimated in the tube that connects the second cryocooler outlet and the cryostat inlet. Also a thermal loss of 1.8 W for an insulation of 40 mm thickness (1.6 W for 60 mm insulation thickness) has been calculated in the tube that connects the cryostat outlet and the heat exchanger inlet. With such a thermal loss in the connecting tubes, part of the liquid xenon that re-enters into the cryostat may evaporate. The losses of the second cryocooler are estimated to be small since an almost constant temperature has been measured at the inlet and outlet of the cryocooler, and not additional heat power on the Stiring Cooler Twinbird is needed to maintain the temperature.

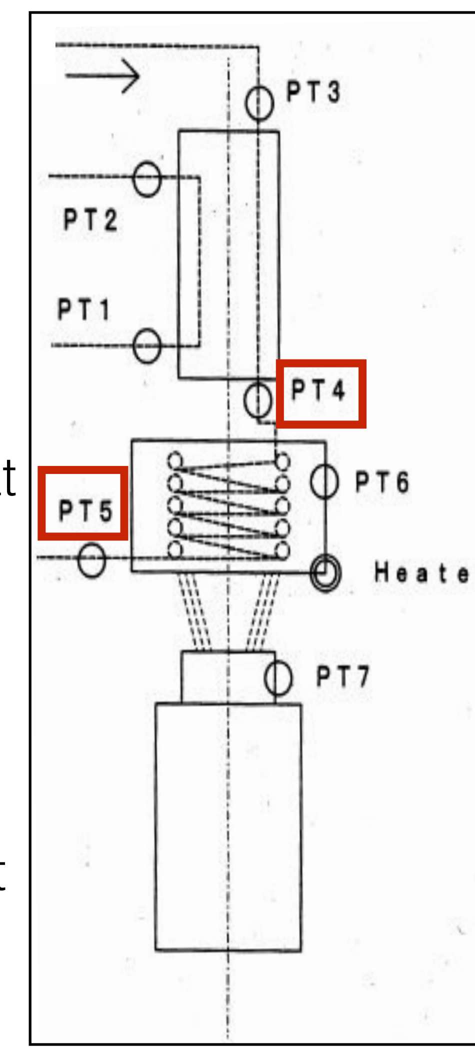
Cryogenics Study



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

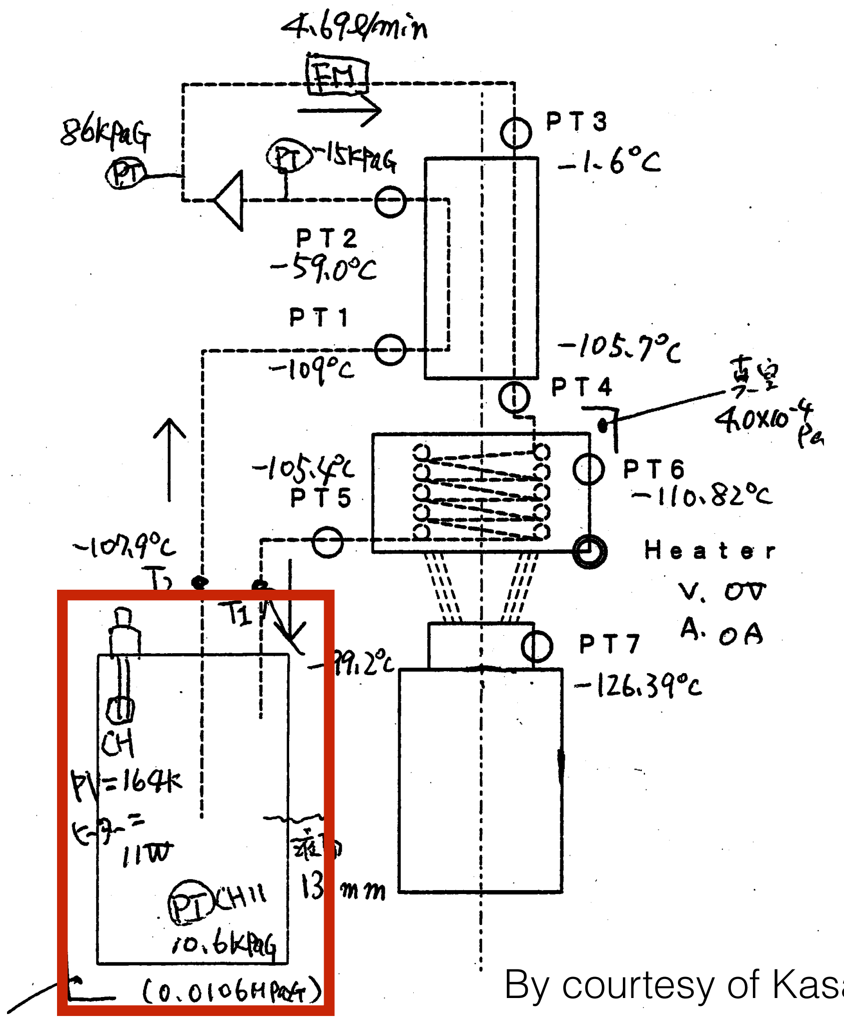
*Average values during stability

Thermal loss between cryostat and heat exchanger

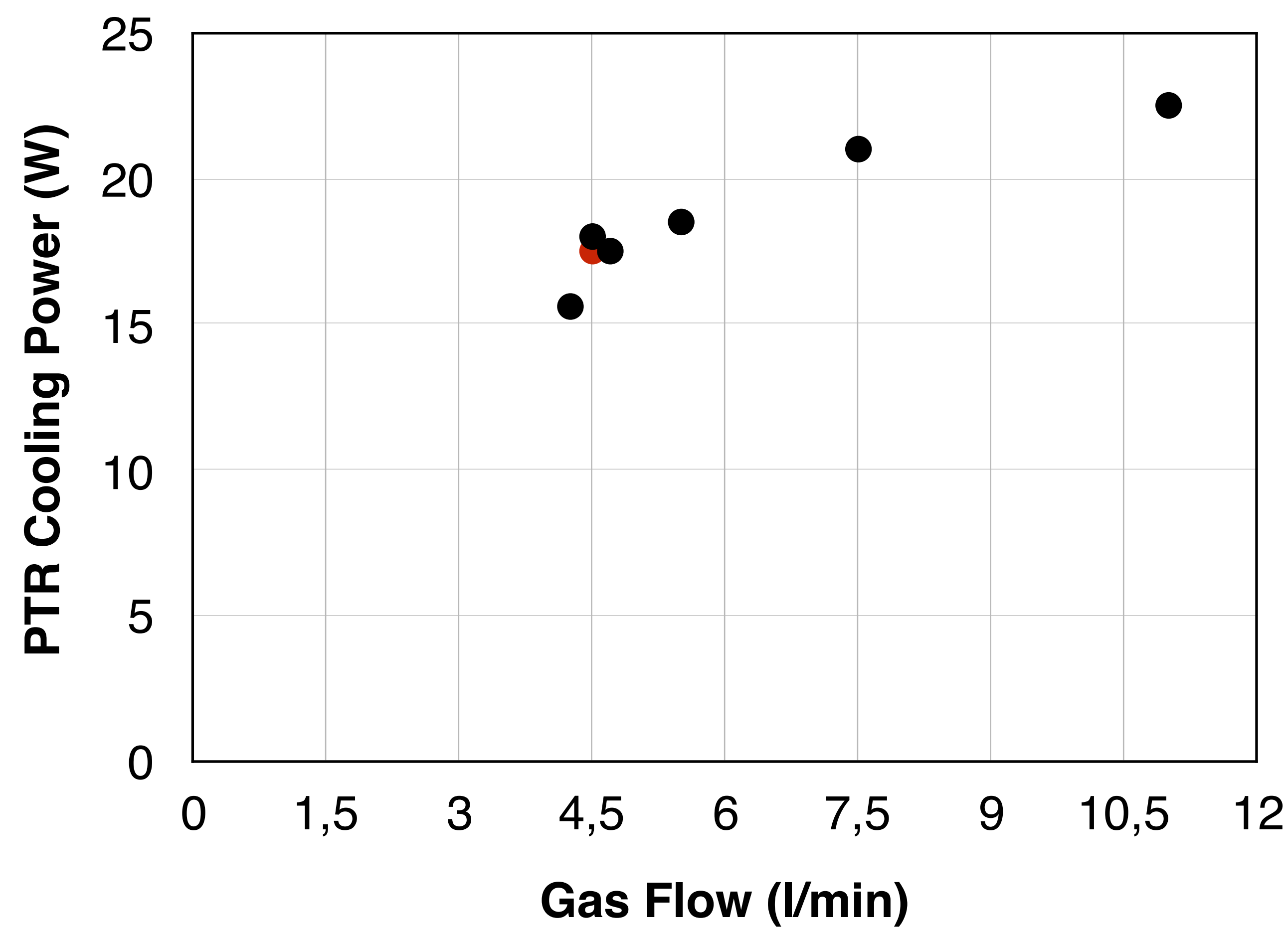
Thermal conduction inside heat exchanger

Thermal loss between exchanger outlet and cryostat inlet

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



By courtesy of Kasami-san



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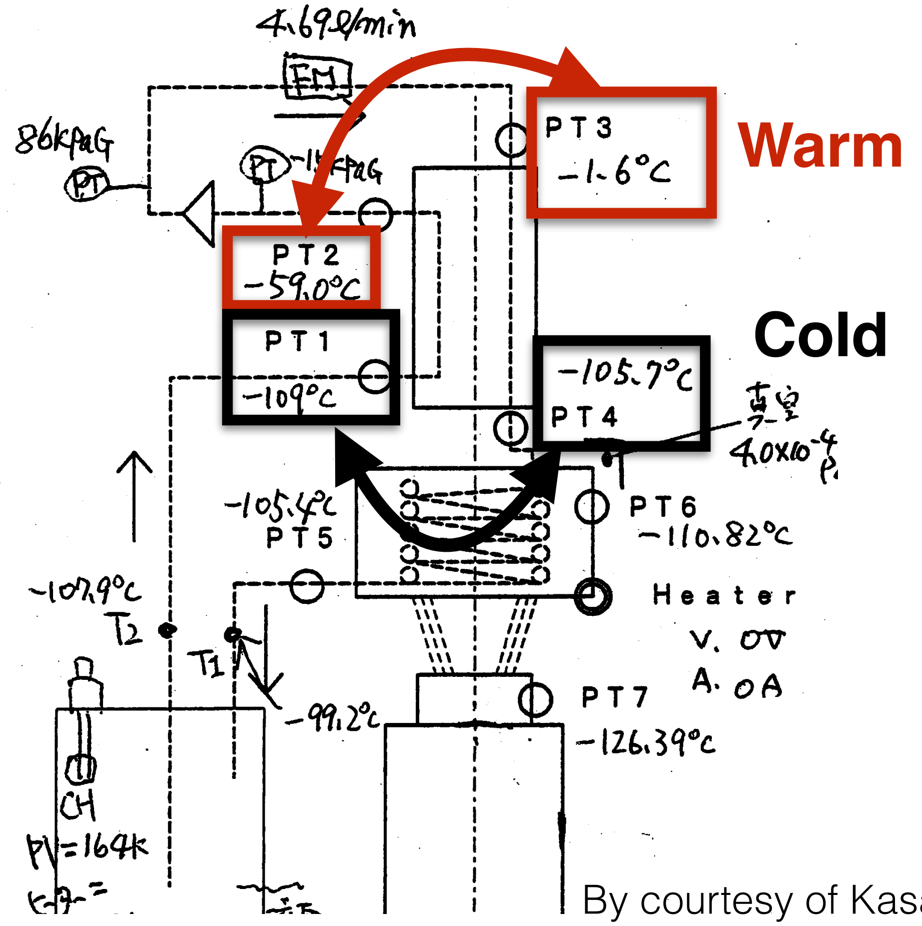
PT5 (°C)	-104.4	-104.7	-104.3	-104.0
T1 (°C)	-104.4	-98.6	-98.5	-98.5

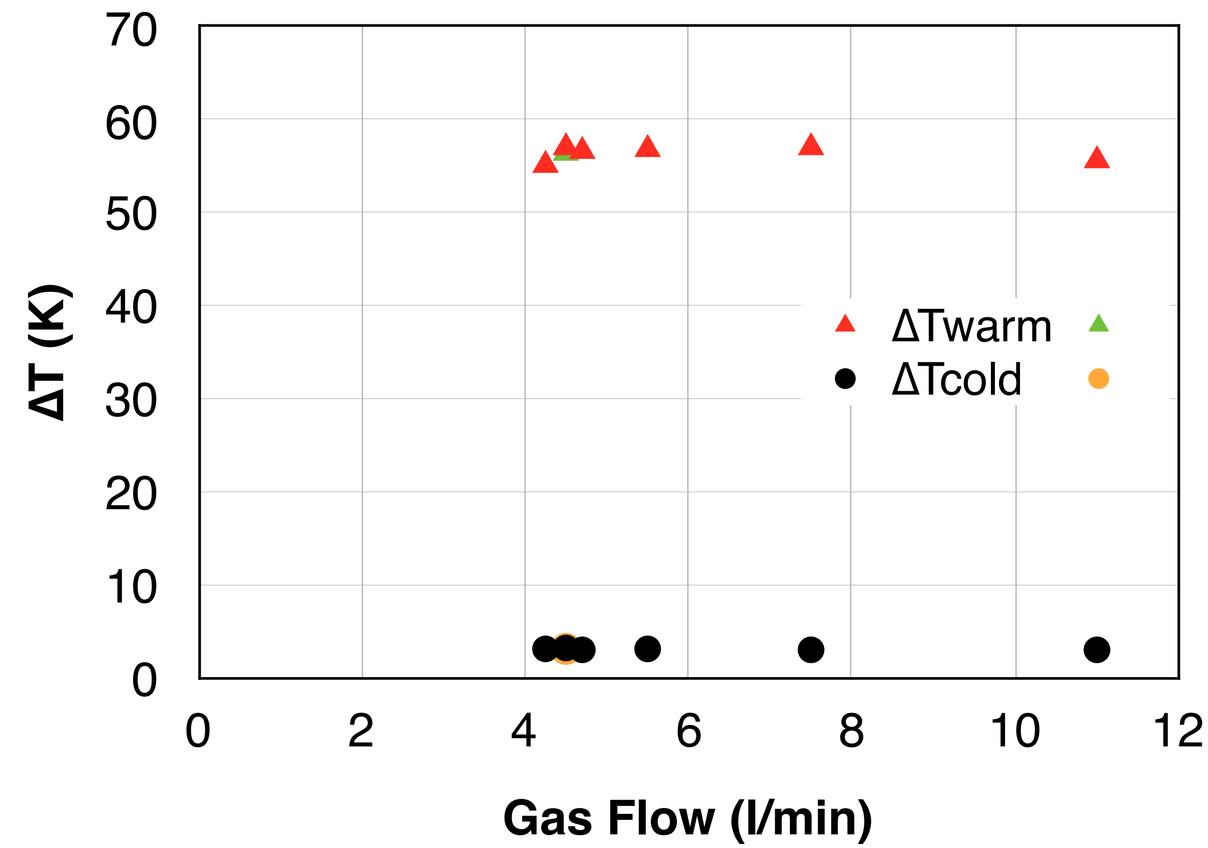
	PTR (164 K@24 W)		
Gas flow (l/min)	**4.5**	**7.5**	**11.0**
Cold Head T (°C)	164	164	164
PTR Power (W)	29	29	29
Heater (W)	11	8	6.5
Cooling Power (W)	**18**	**21**	**22,5**

*Average values during stability
*PTR power from KEK measurements

Heat Exchanger Efficiency



By courtesy of Kasami-san

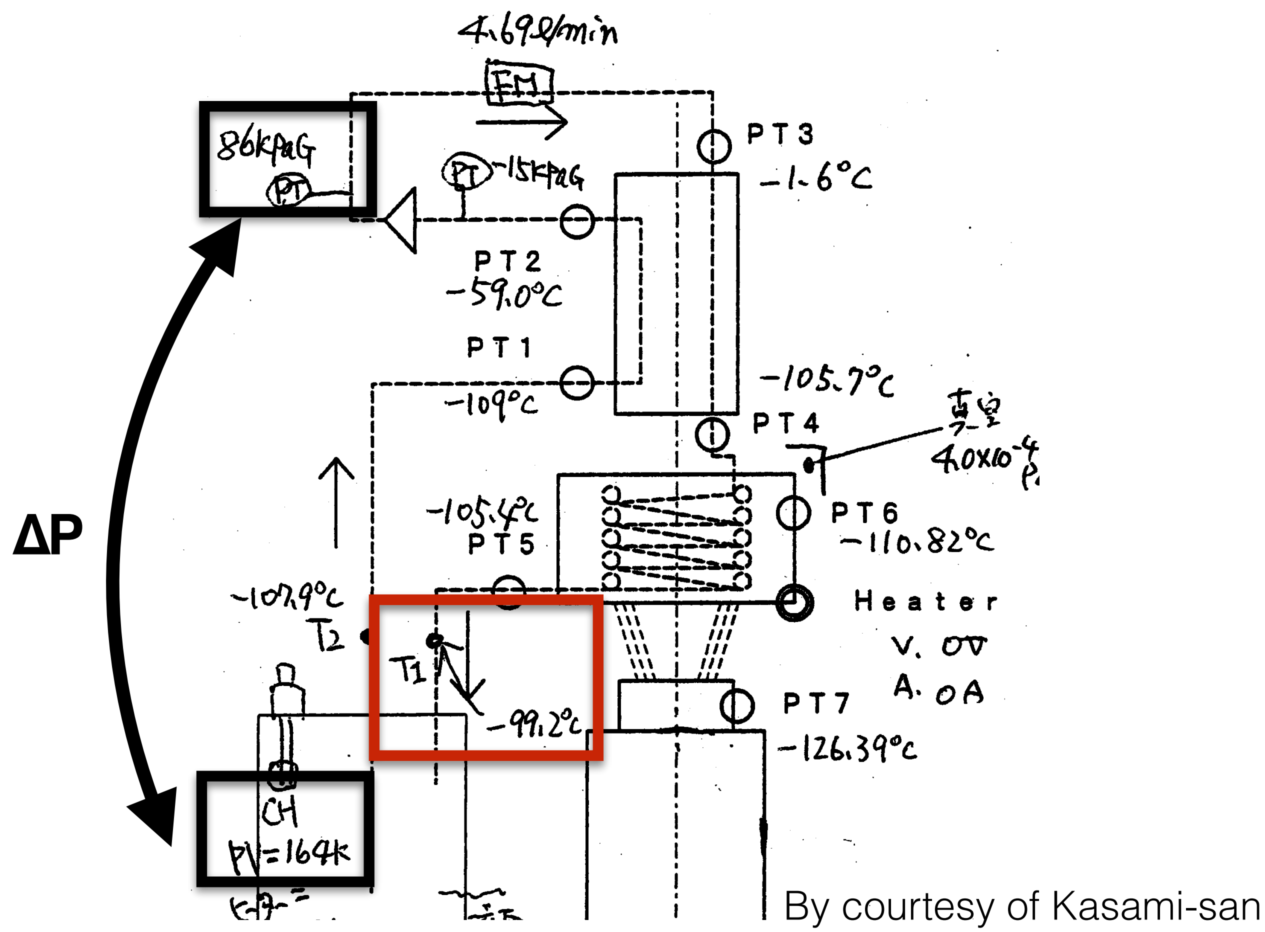


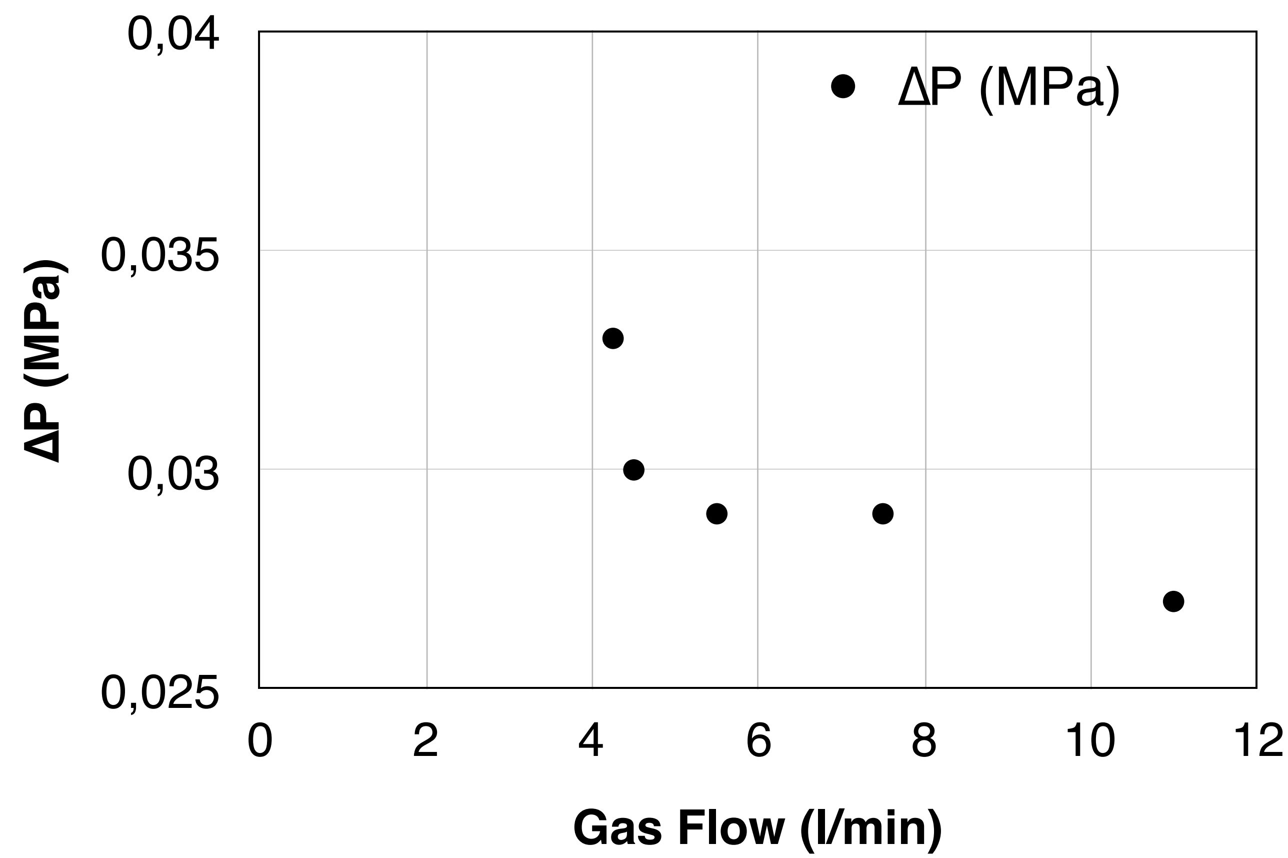
	SUBATECH	KEK			
Gas flow (l/min)	31.3	**4.5**	**7.5**	**11.0**	**4.5**
PT2 (°C)	18.1	-58.5	-50.3	-44.1	-58.5
PT3 (°C)	24.5	-1.5	6.7	11.7	-2.1
Efficiency (%)	99.9	86.1	86.1	86.5	86.3

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





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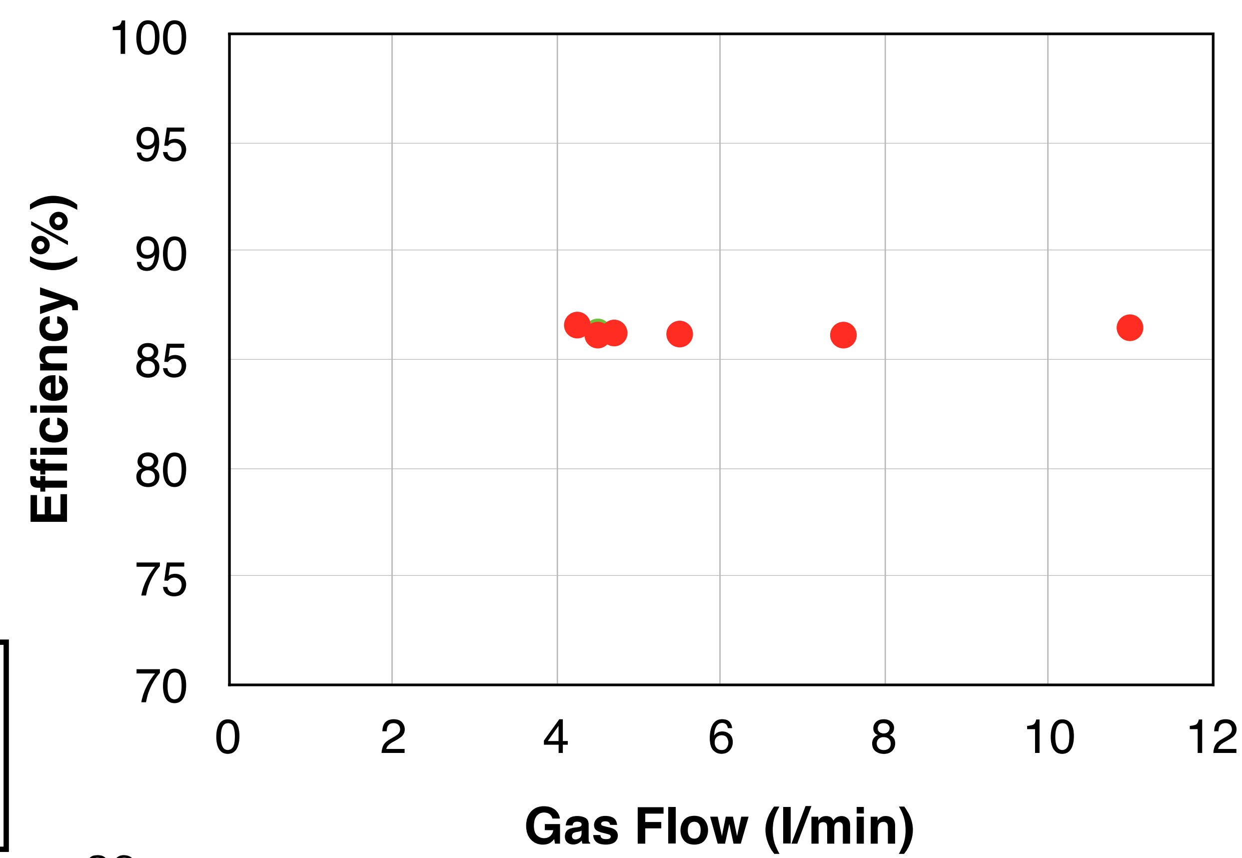
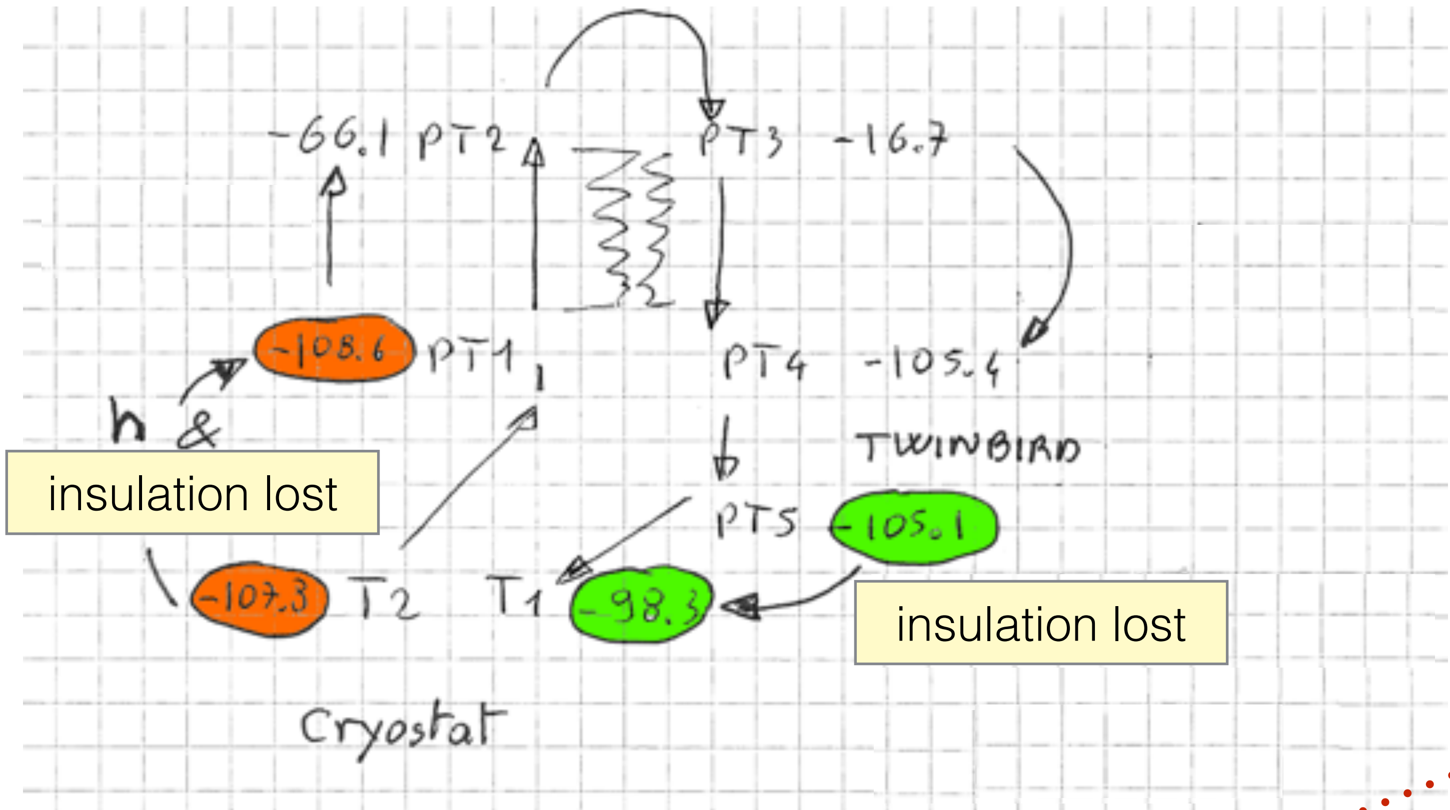
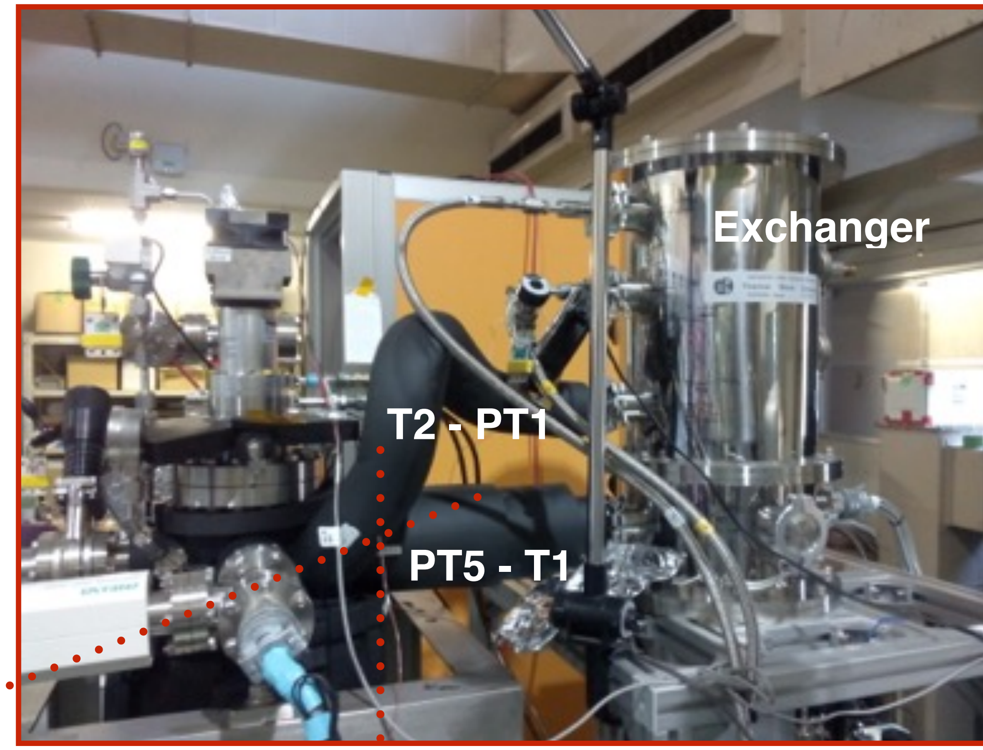
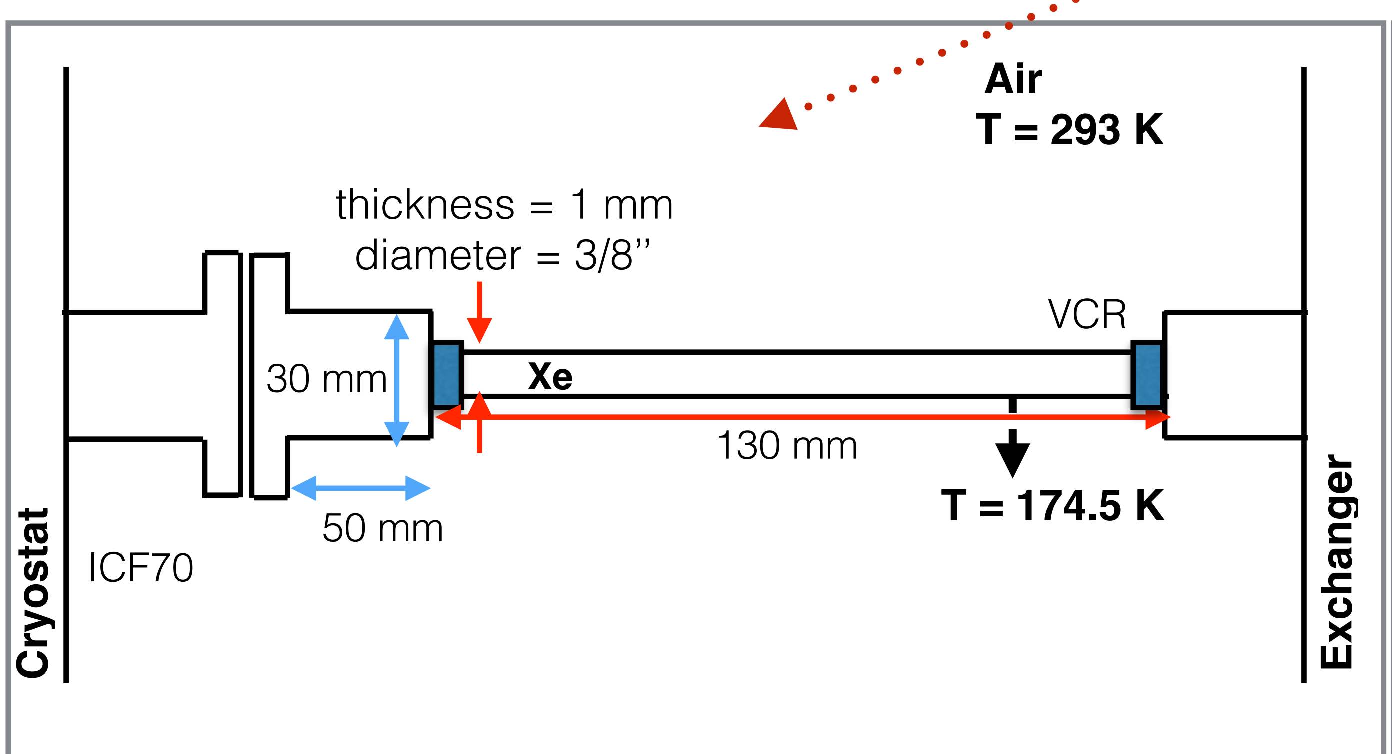


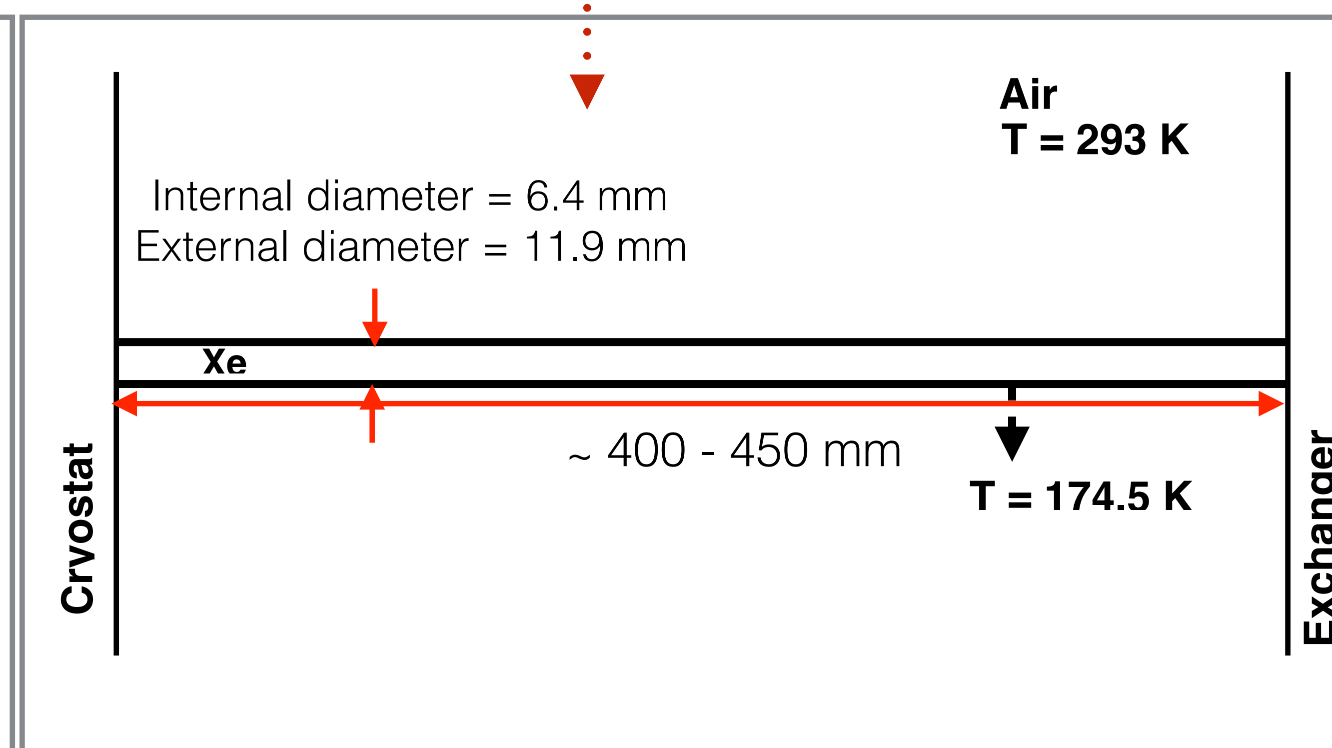
Thermal Losses



By courtesy of Eric Morteau

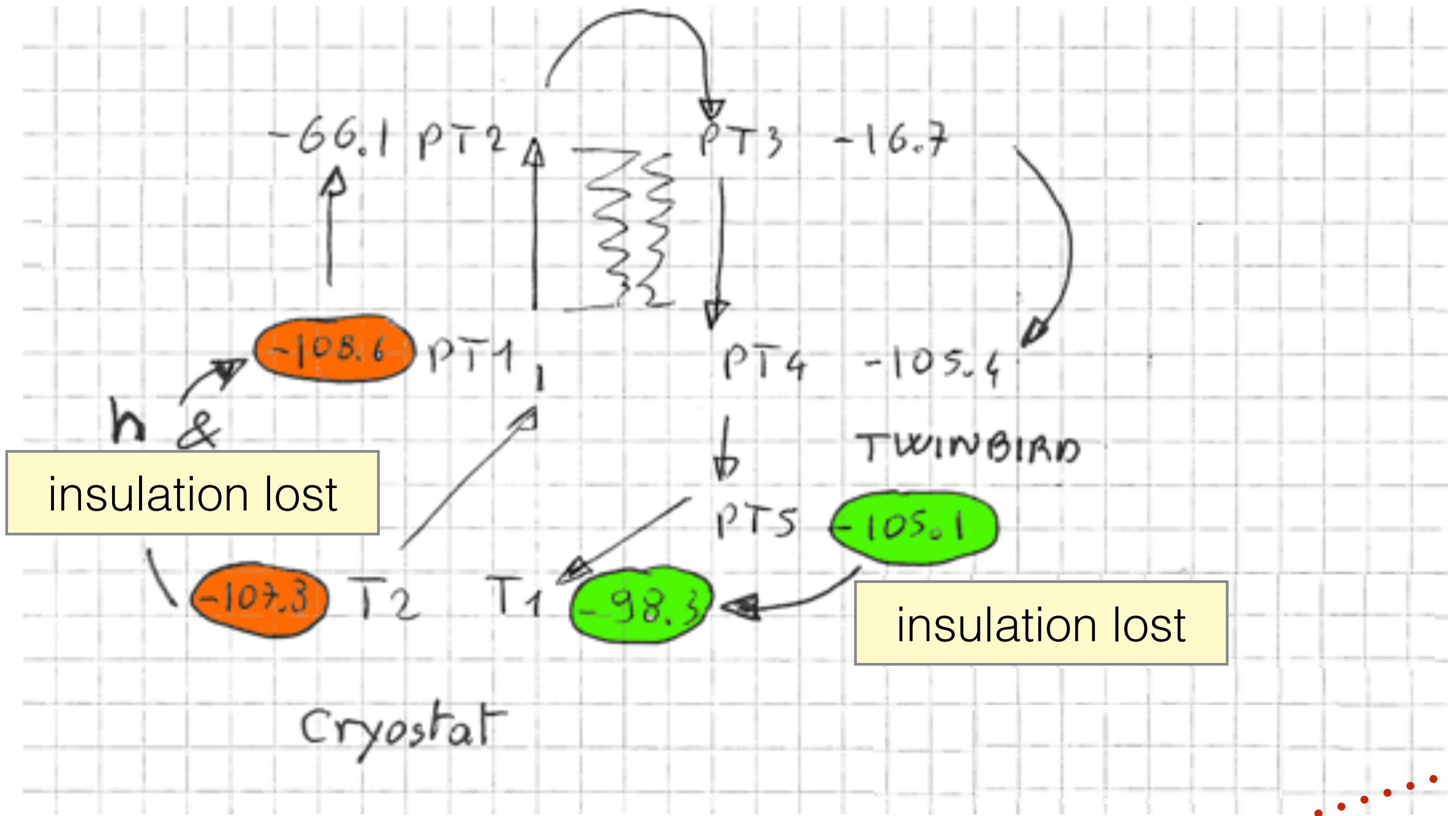




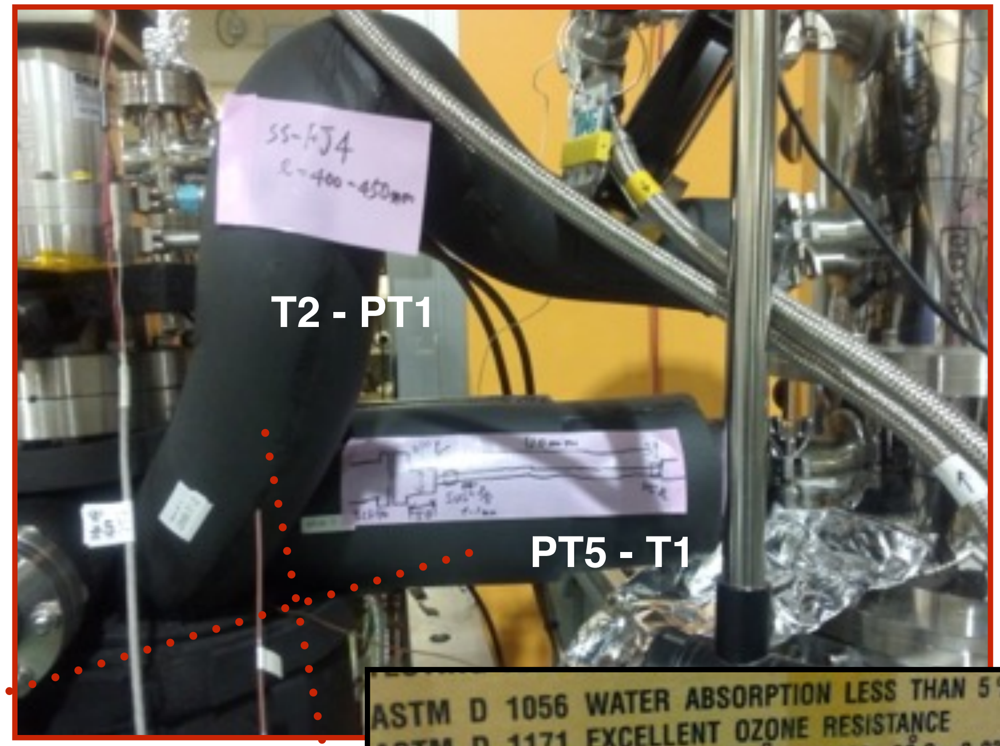


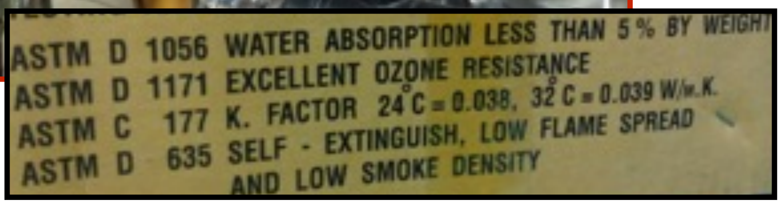
*Temperature values for a gas flow of 4.5 l/min

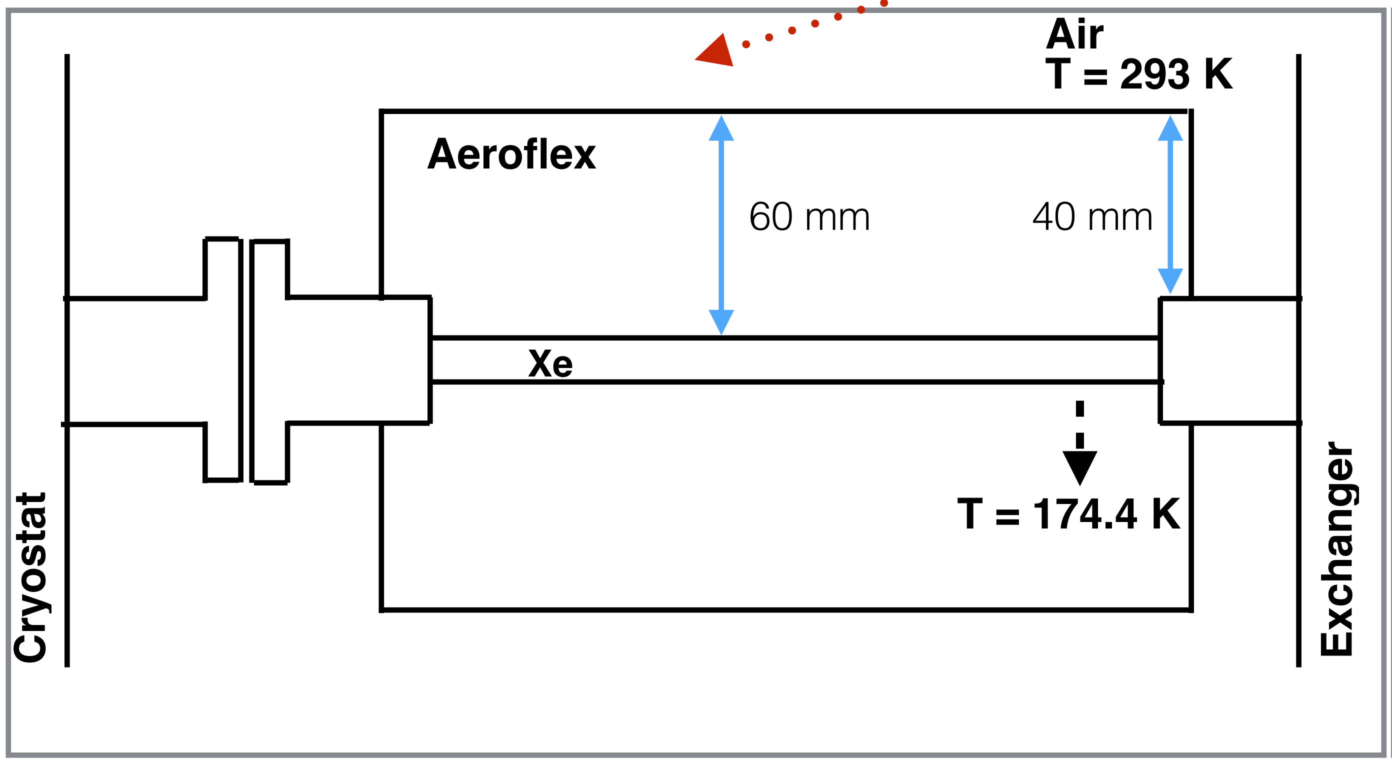
Thermal Losses

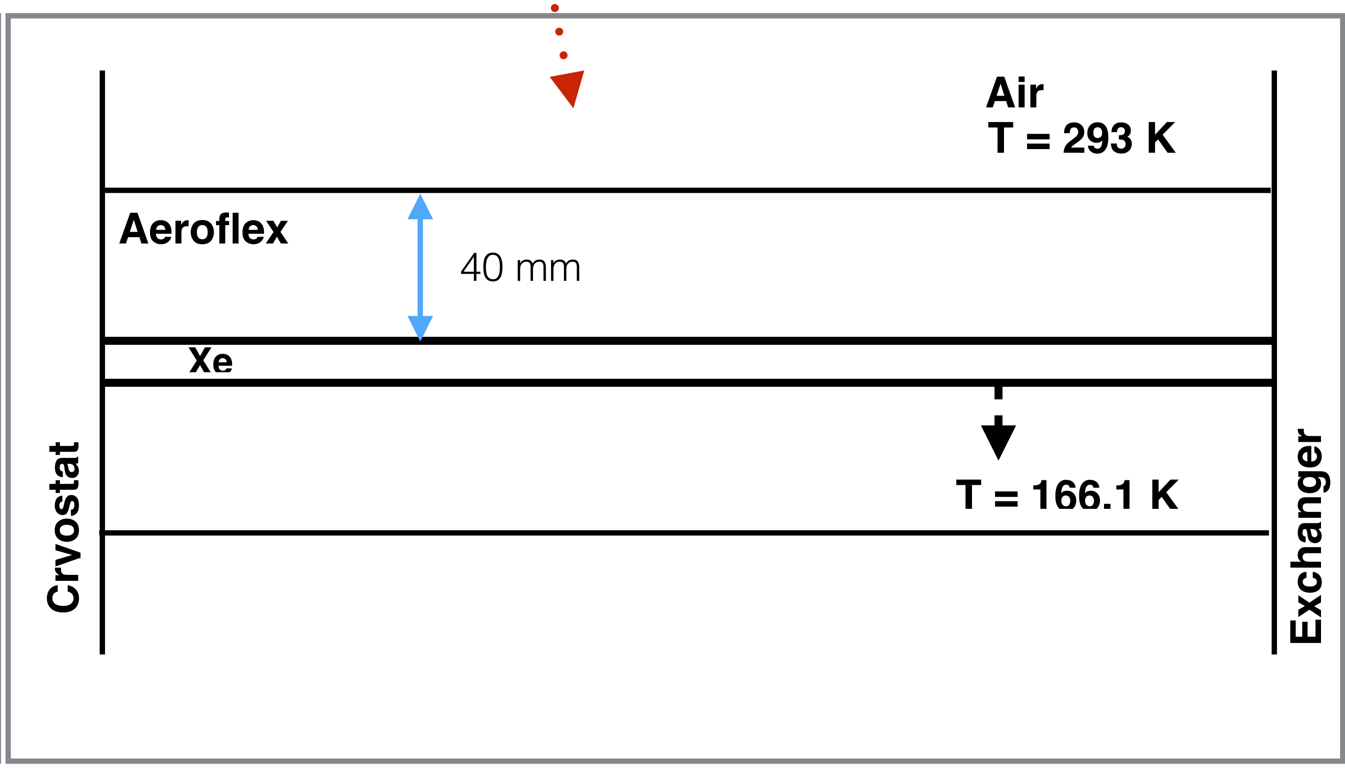


By courtesy of Eric Morteau









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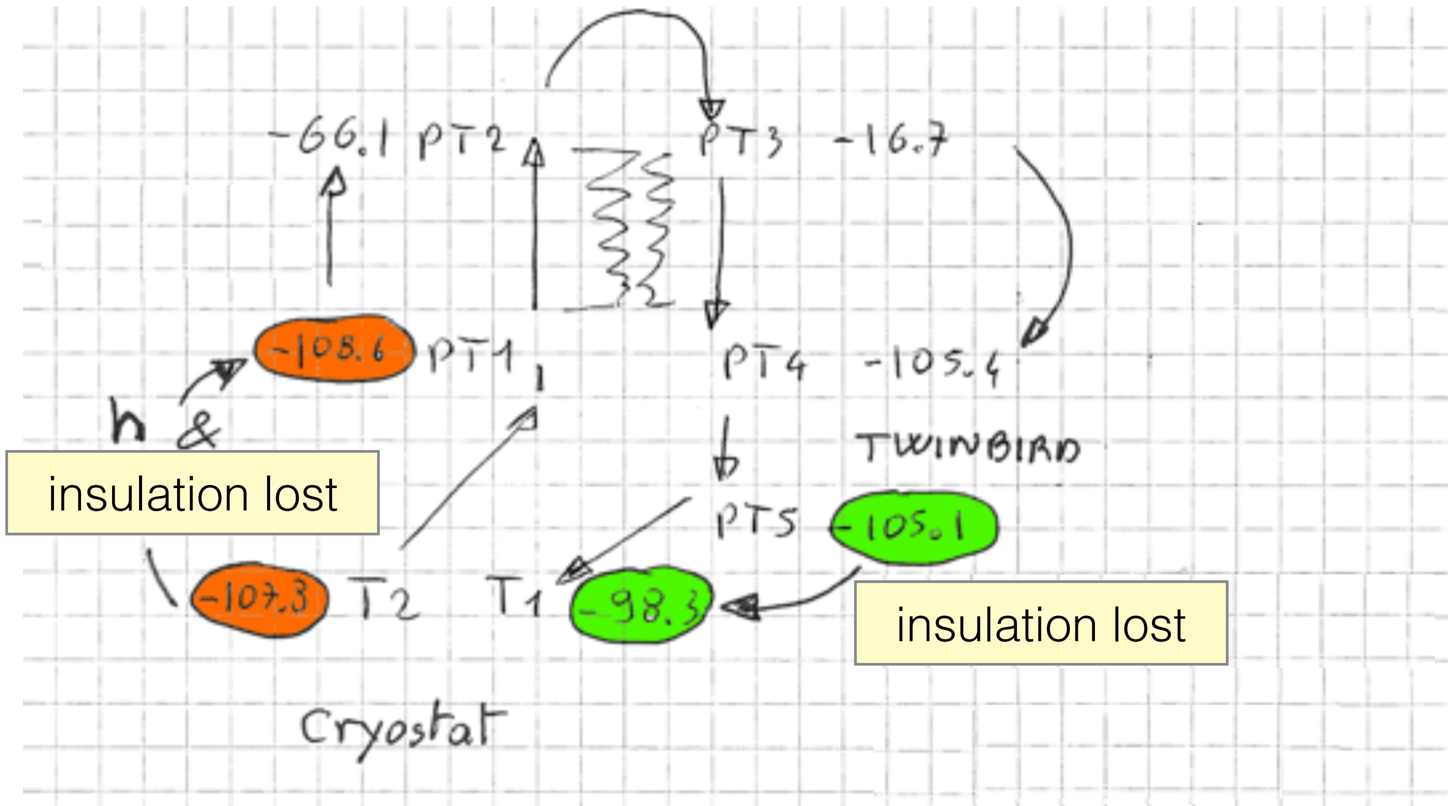
Thermal Losses



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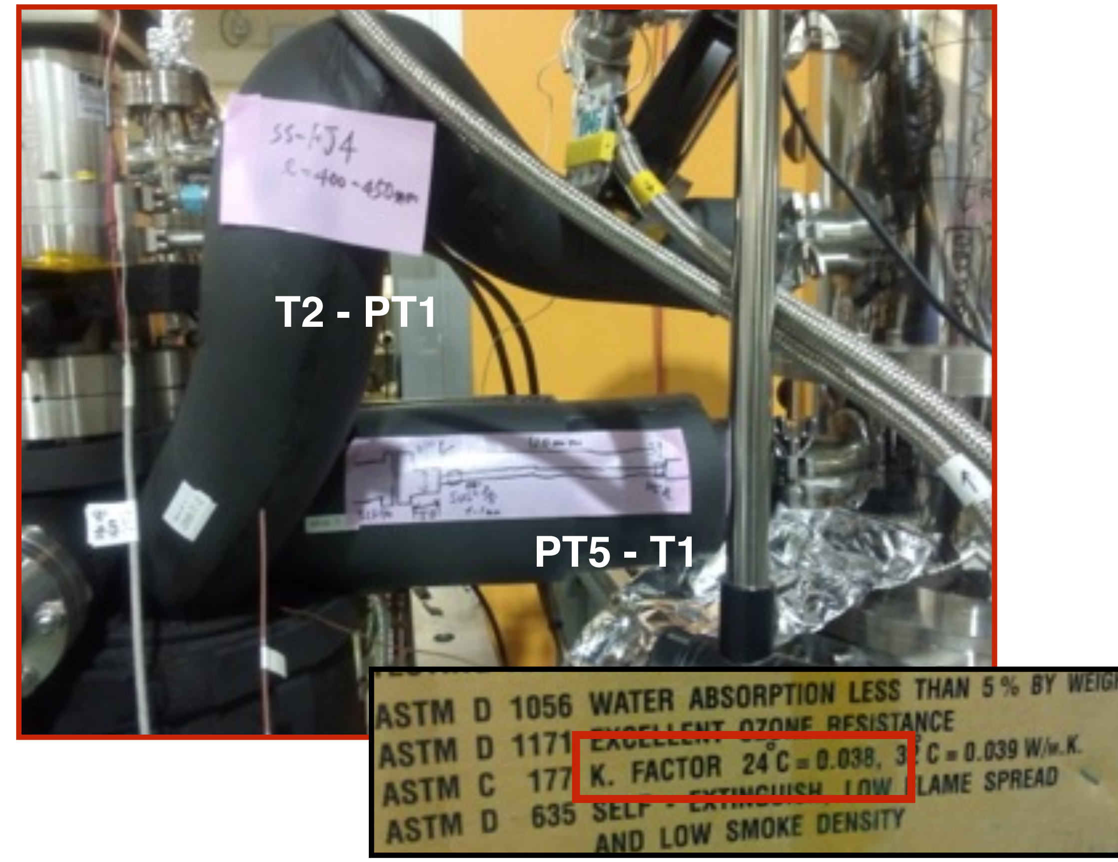


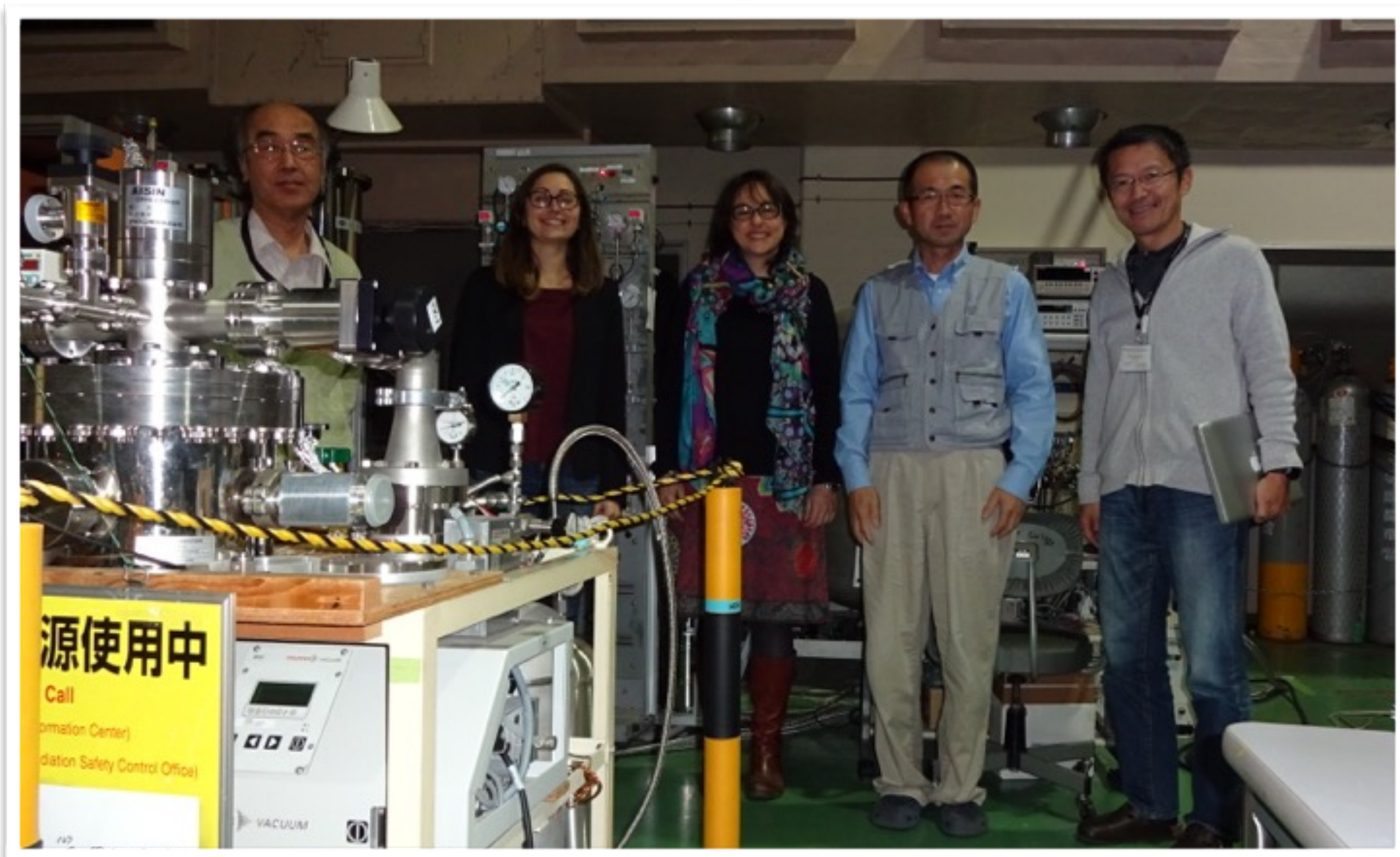
Assumptions:

- 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!



まとめ

2016.11.8

1．キセノン純化等の効率化のため予冷装置の試験；成功

ガス循環速度の>4.5リットル/分で安定運転。

2．新フロントエンドエレクトロニクスシステム

ASICチップ　液体キセノン温度で動作、ただし、常温で動作しても低温で動作しないチェンネルがあったため、3個チップを交換した

ゲッターの吸着筒を新品と交換後、電荷シグナルの非常に緩やかな増大を観測（2012年の9月〜のデータに比べて）

純化装置を追加して電荷シグナルの増大を確認する予定。

3．SubatechとのXEMIS2に関する共同研究

予冷装置試験等のためSubatechよりPhD学生とポストドクの２名来所

熱交換効率、熱ロスの測定を行い、Subatechの装置との比較を行った。