

Liquid Xenon TPC for a gamma detector (LXeTPC)

T. Tauchi (KEK)

4 June 2013

Subatech, Nantes, France

KEK : liquefaction & purification , PMT, TPC, DAQ

T.Tauchi, A.Maki, S.Tanaka, S.Mihara, T.Saeki

K.Kasami, S.Suzuki

Saga univ. : TPC, simulation, FE ASIC chip, test

A.Sugiyama

Tokyo univ. : TPC, PMT, simulation, test

T.Mori

National Institute of Radiological Science : PET

M.Kumada, T.Tomitani, C.Toramatsu

Yokohama National univ. : APD test, Xe-property

S.Nakamura, Y.Iwasaki (M2), S. Ohyama(M2),

R.Hamanishi(M1)

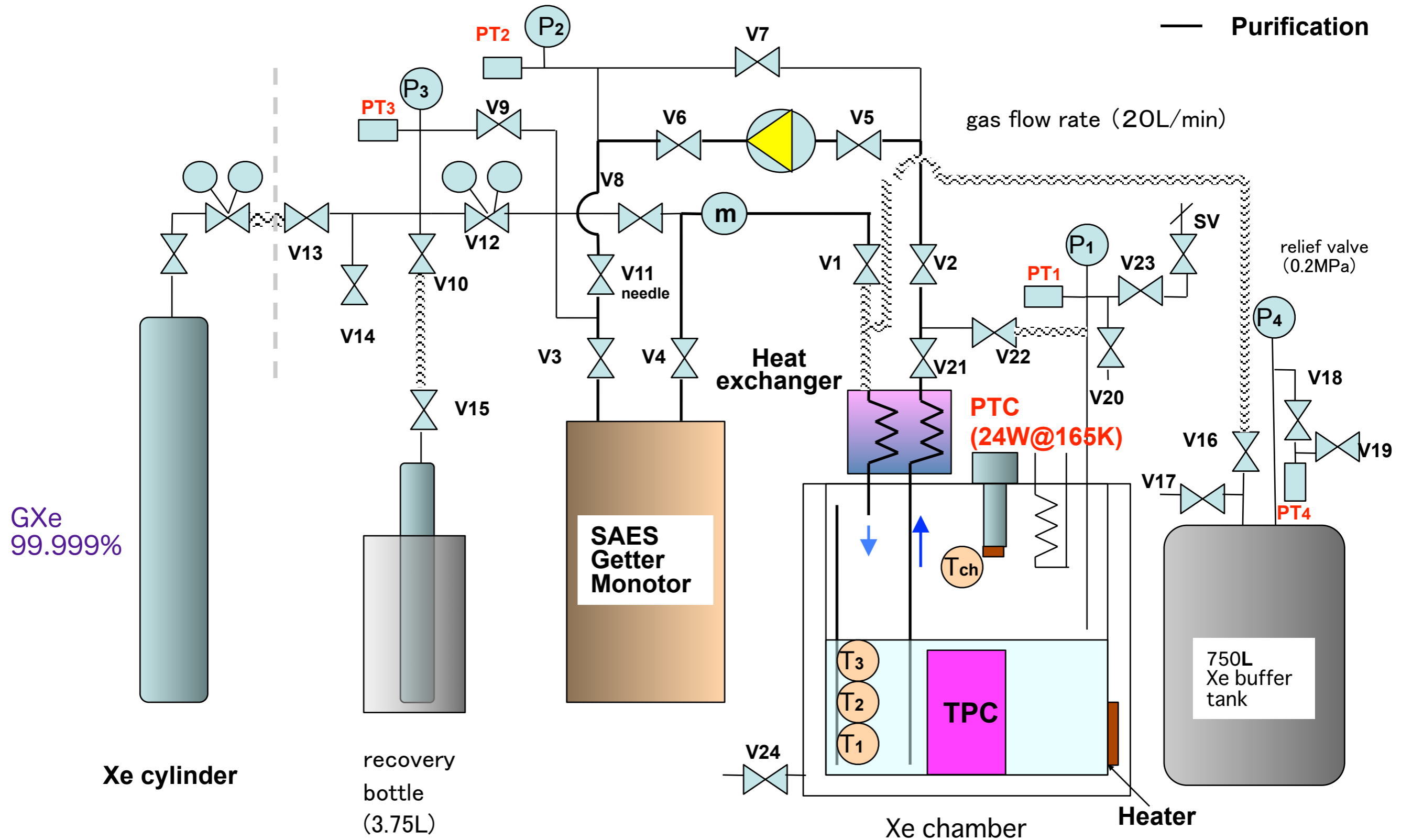
Cooperation : KEK electronics system group , DAQ

M.Tanaka et al.

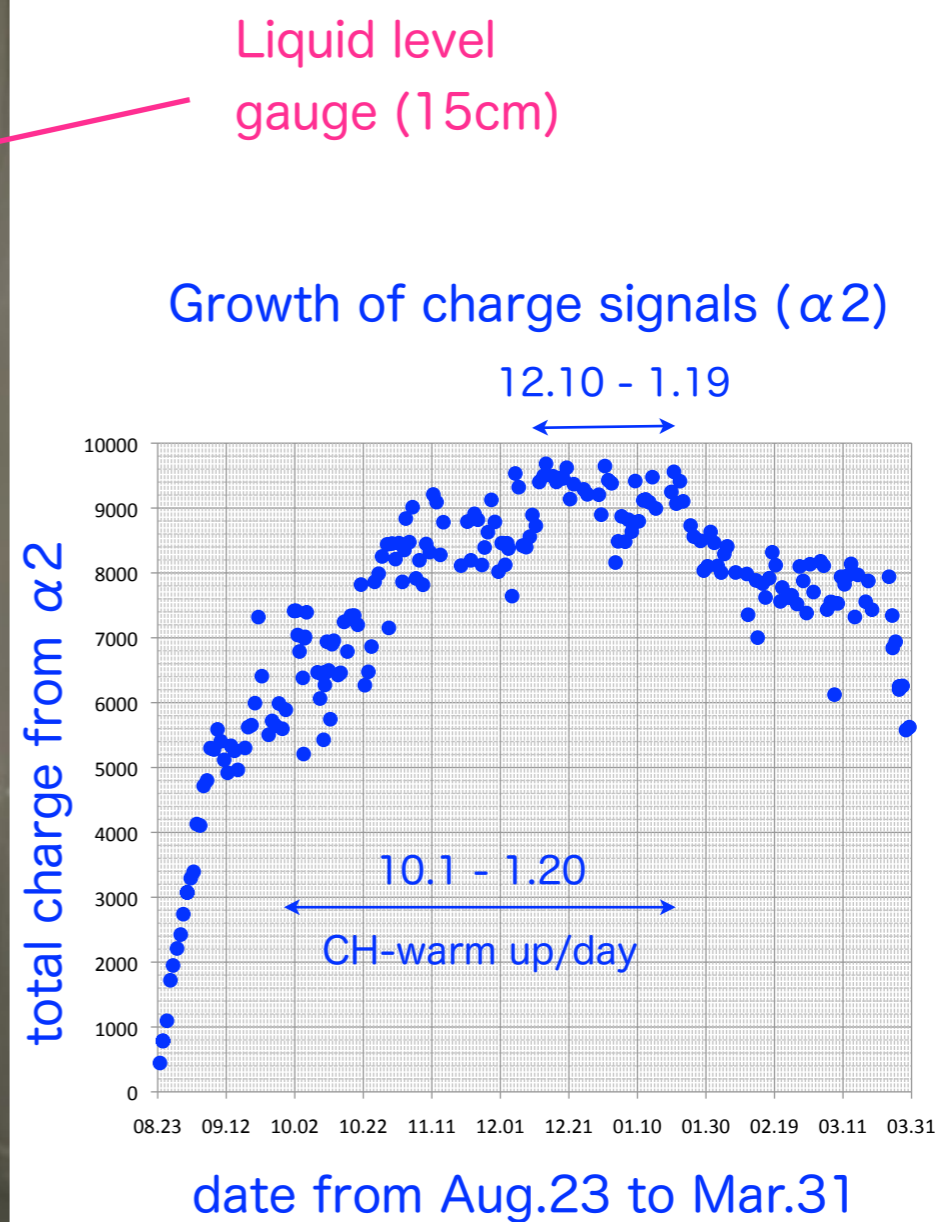
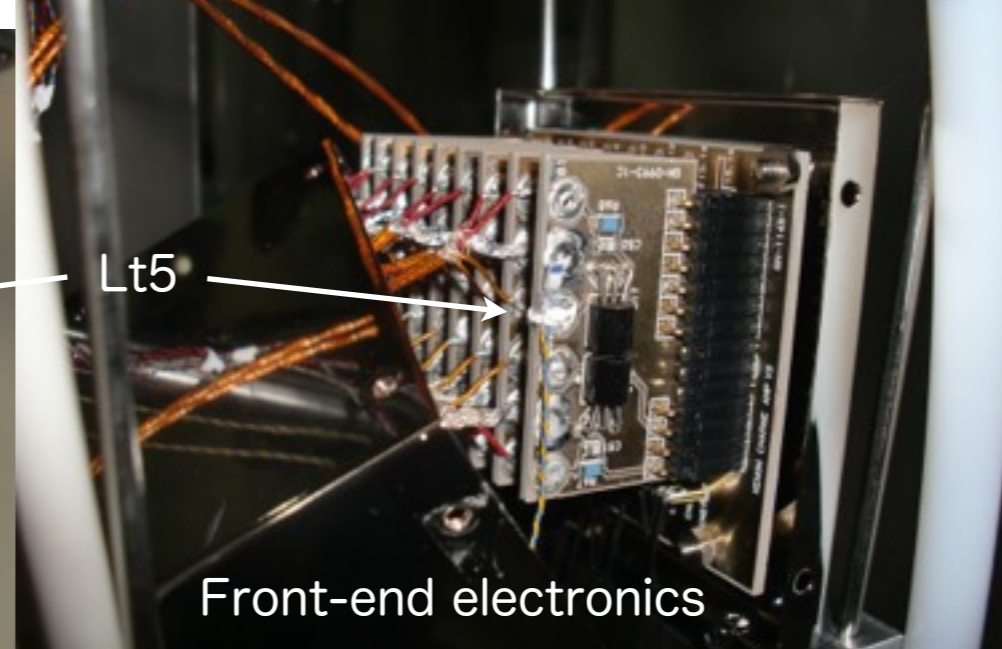
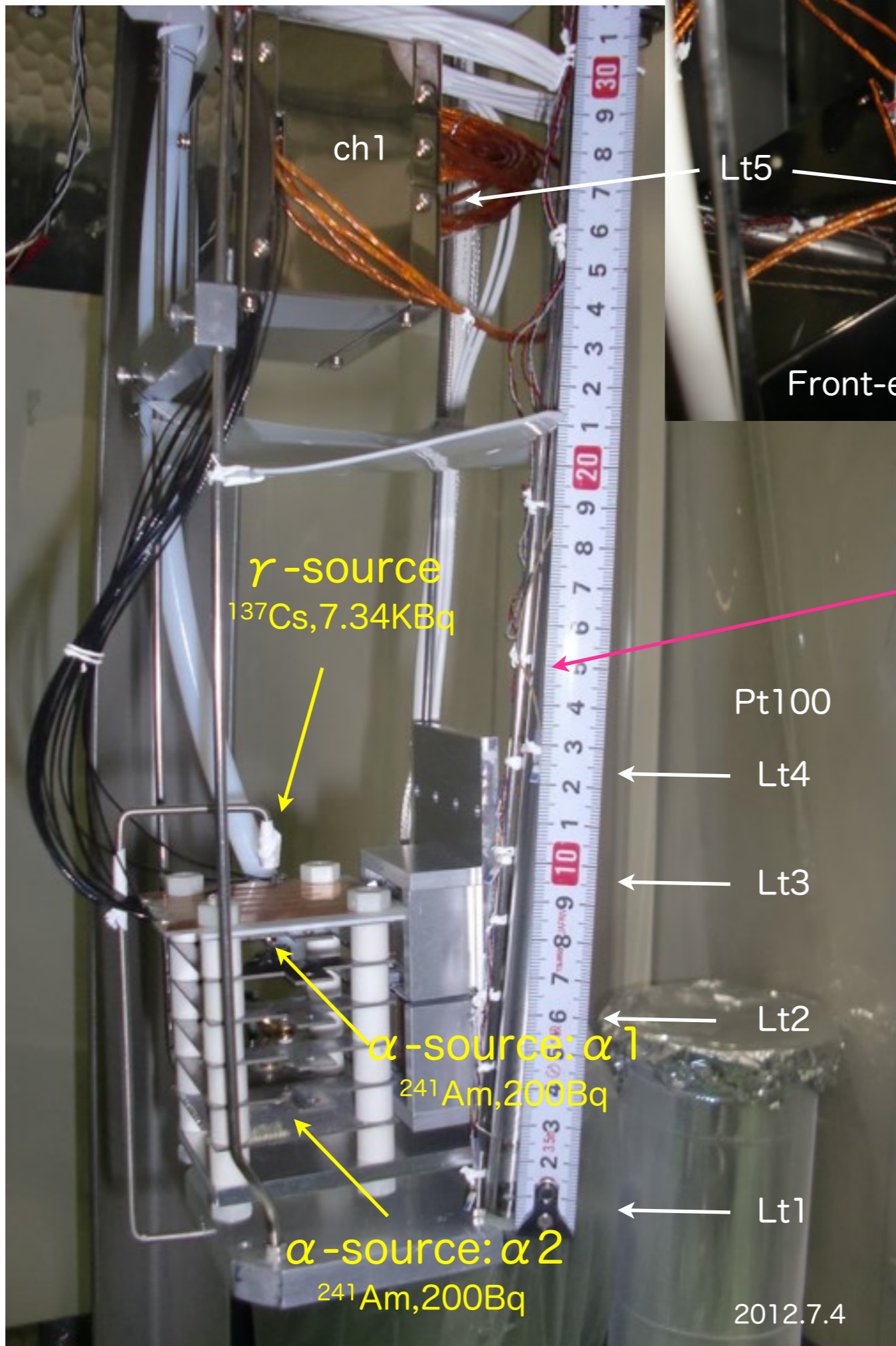
LXeTPC : Liquefaction / purification

since June 2008

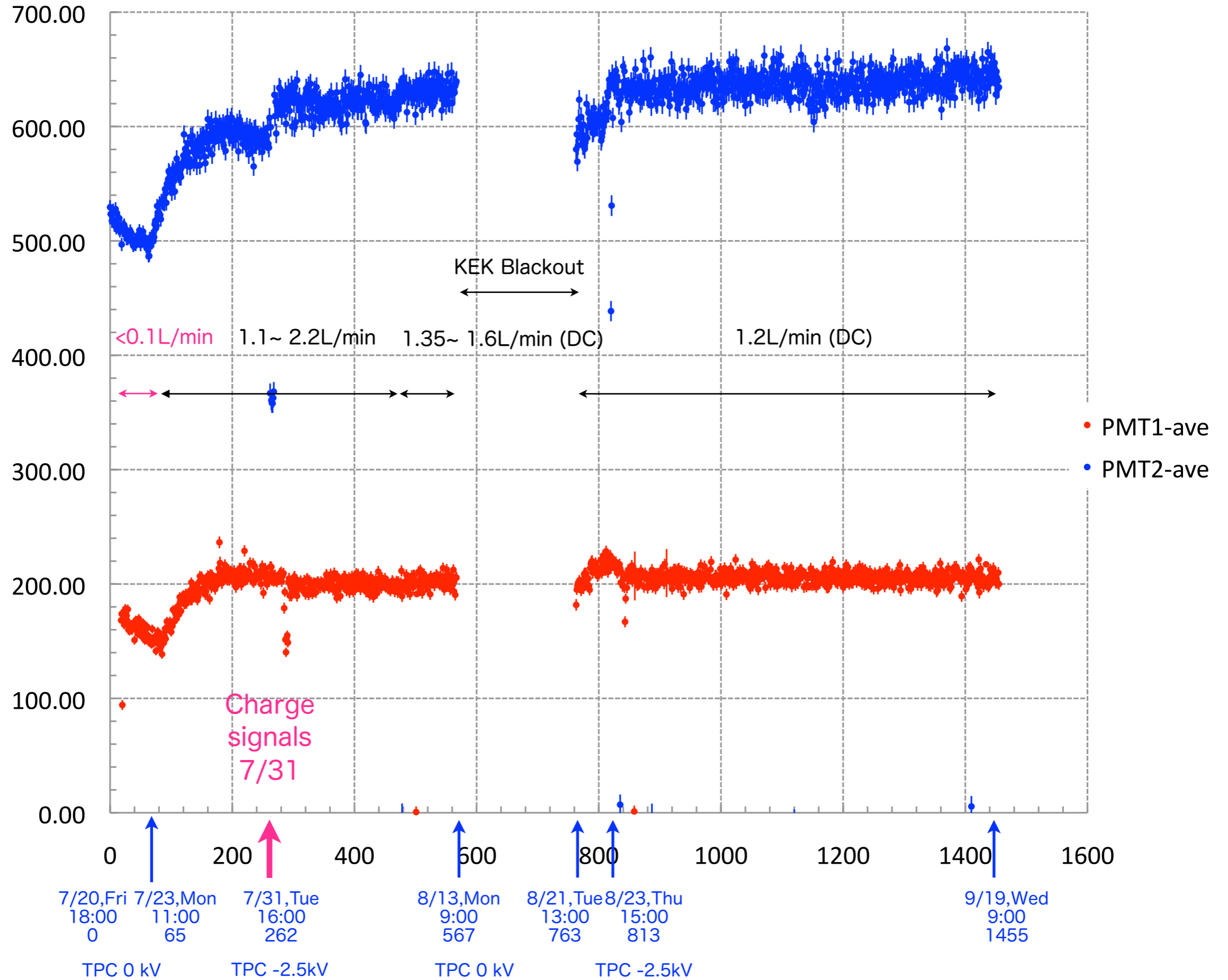
Circulation by an oil-free diaphragm pump (Enomoto co.)



148mm ϕ x 426mm (new, since 2010), 2.6L, H 15cm



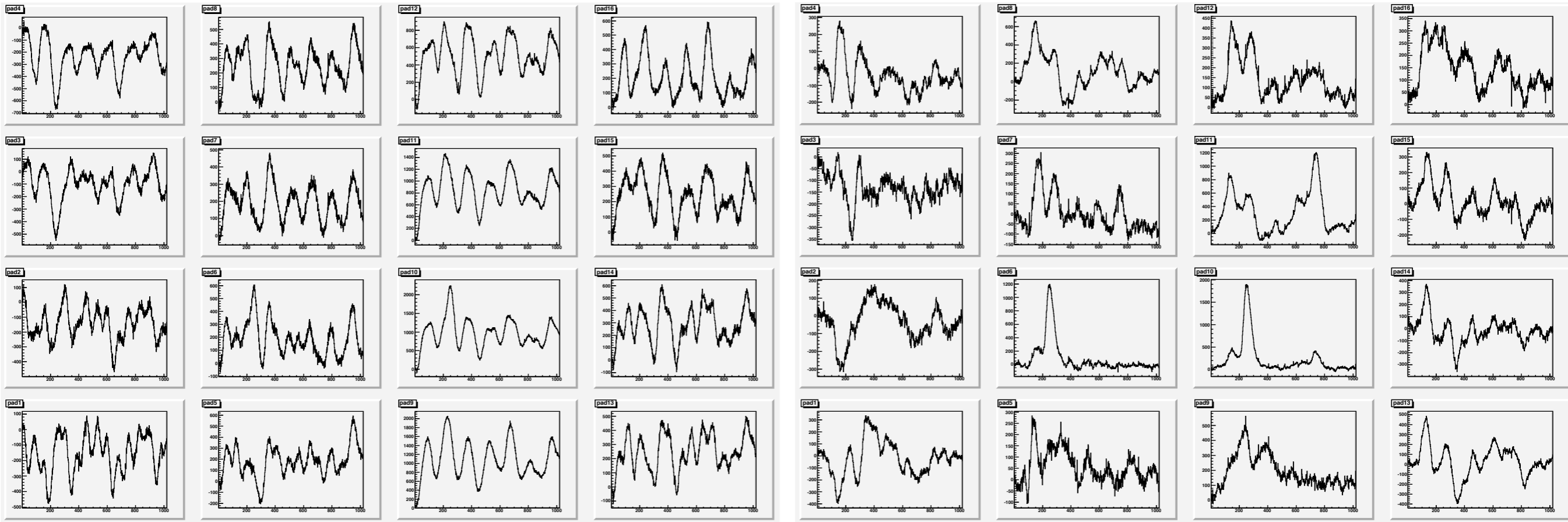
Scintillation lights in Liquid Xe, 7/20-9/19, 2012



Charge signals of 16 pads from 3,000 events

First Observation
31 July 2012

Noise reduced
9 August 2012

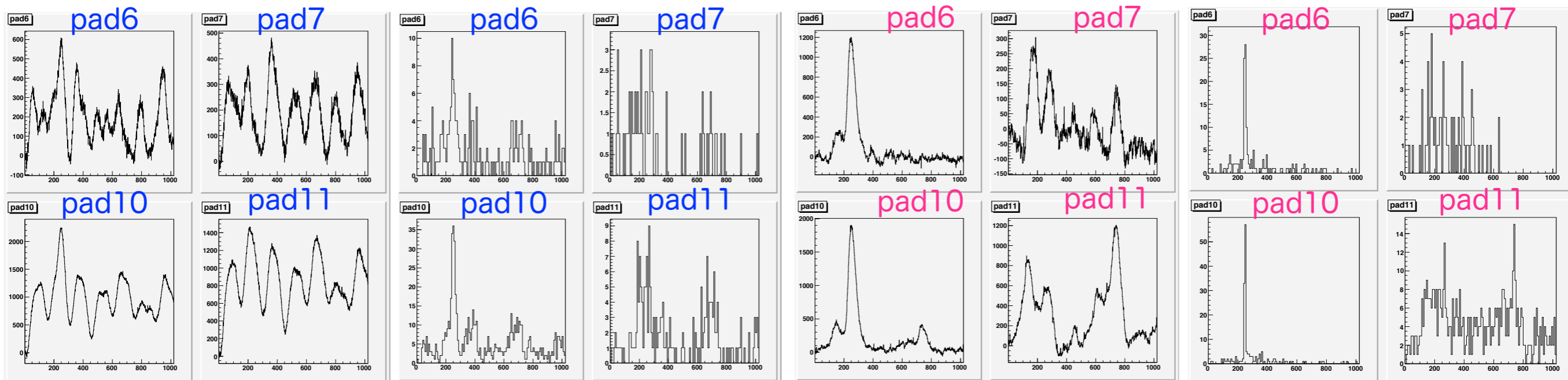


amplitude (FADC)

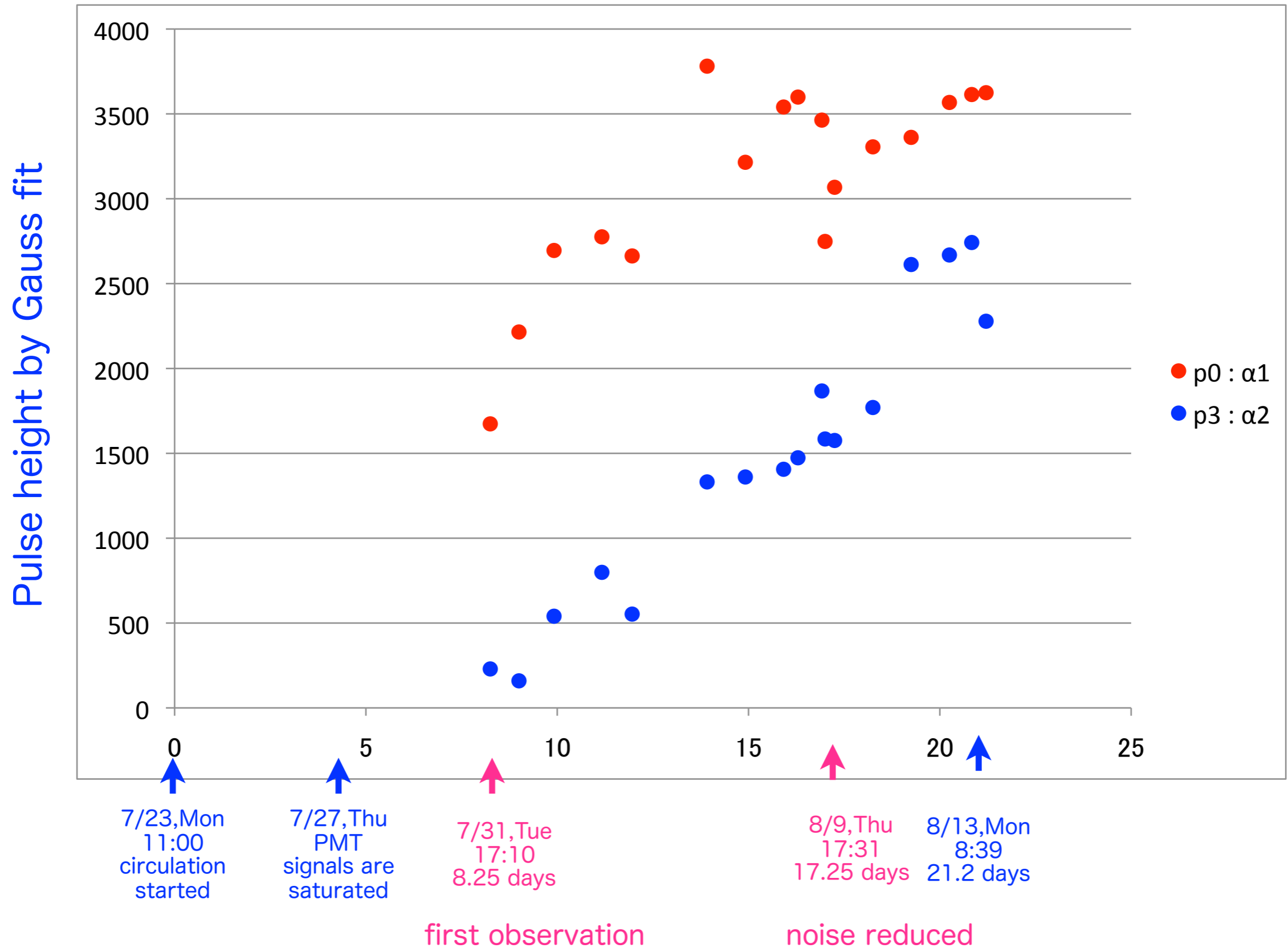
time (Gauss fit)

amplitude (FADC)

time (Gauss fit)

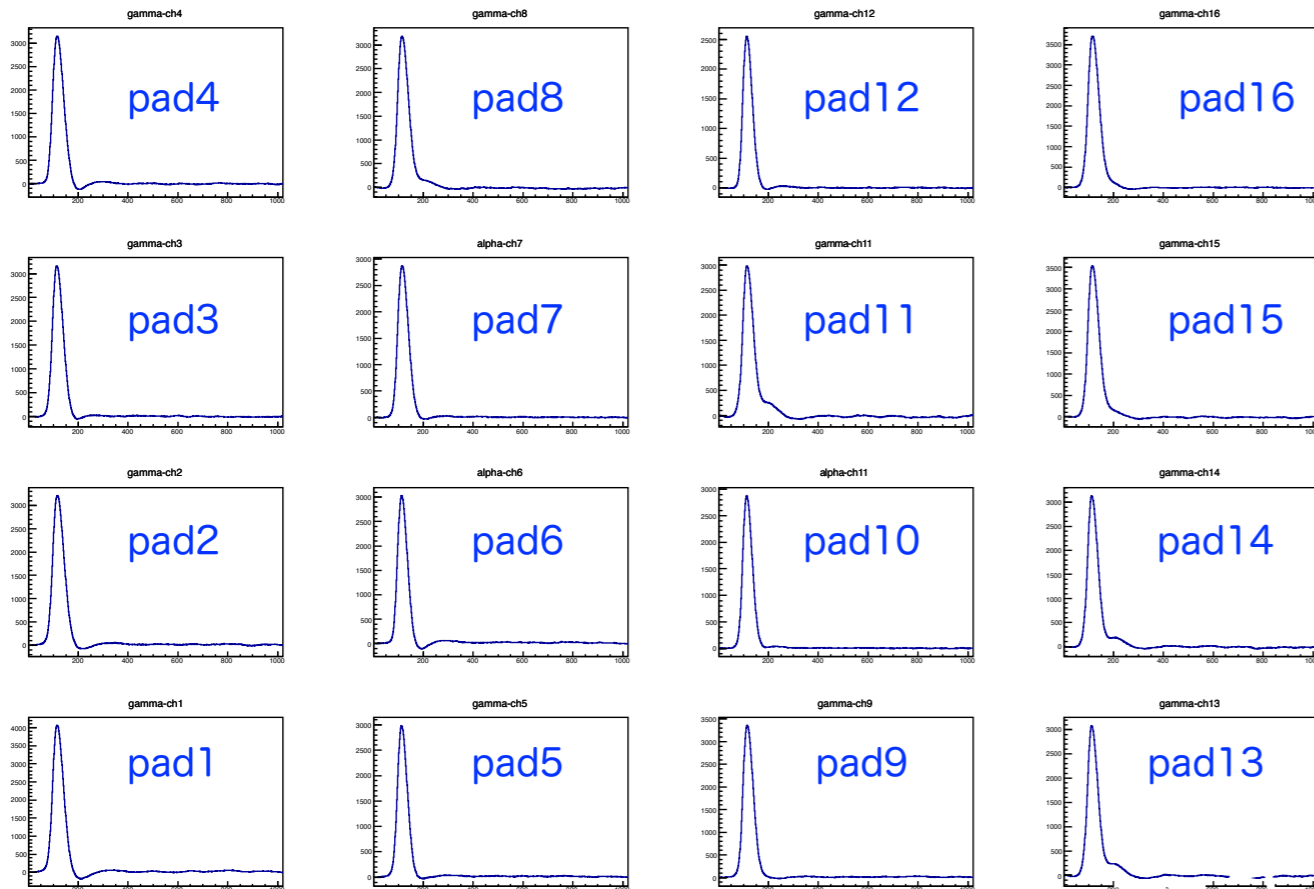


Charge signals in Liquid Xe, 7/23-8/13, 2012



Performances of test pulse run

2012.8.23 18:35



Test pulse : 50Hz, 0.025V w/ 31dB, 0.7mV, $C_i=2\text{pF}$, i.e. injected charge = 1.4fC;

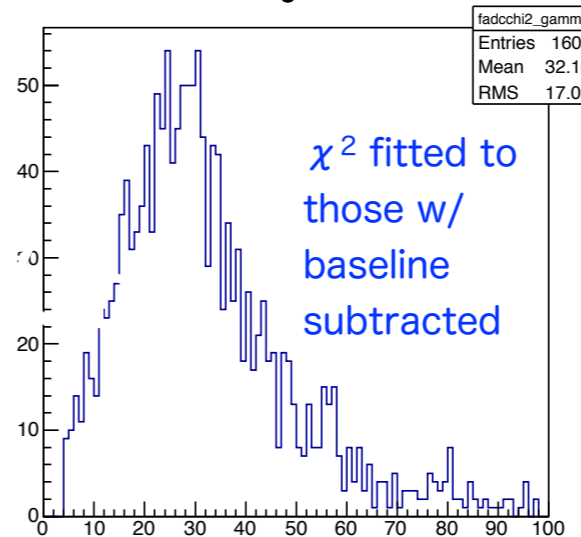
Preamp gain = 10mV/fC w/ $C_{fb}=0.1\text{pF}$ -> 14mV, but output impedance=100Ω instead of 50Ω@the scope, so $14/2=7\text{mV}$ expected ;

Observed : 5mV@preamp, 240mV@shaper-amp

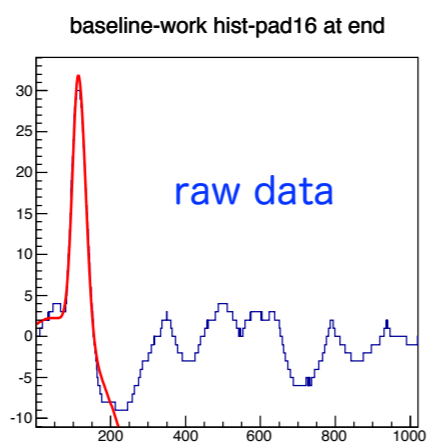
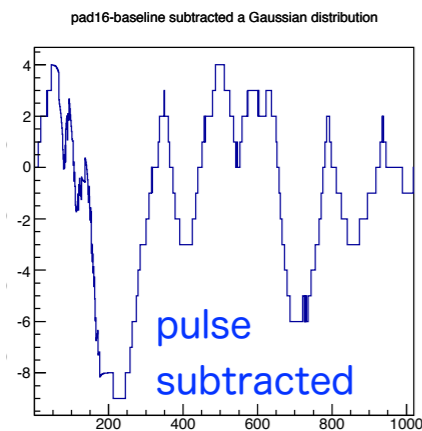
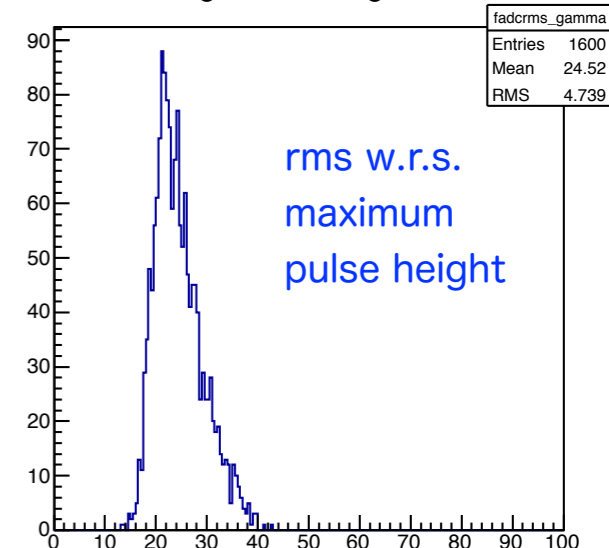
FADC20MHz : $240/7.8=31$ counts expected

So, $240\text{mV}/1.4\text{fC} = 171\text{mV/fC}$

Chi2:gamma

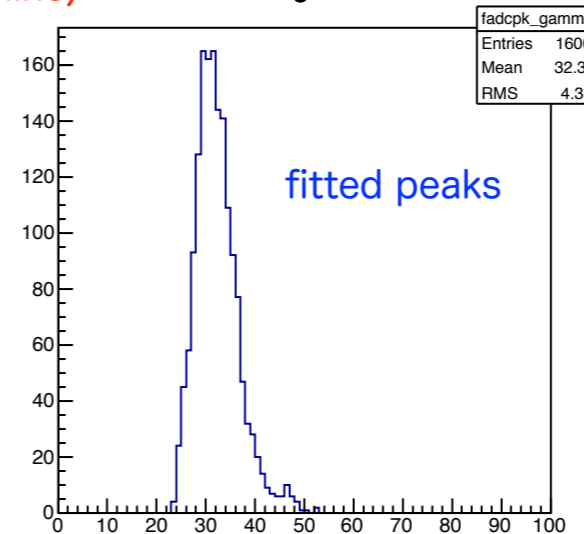


gamma charges

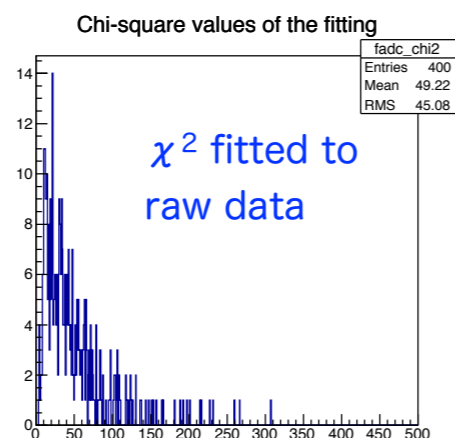
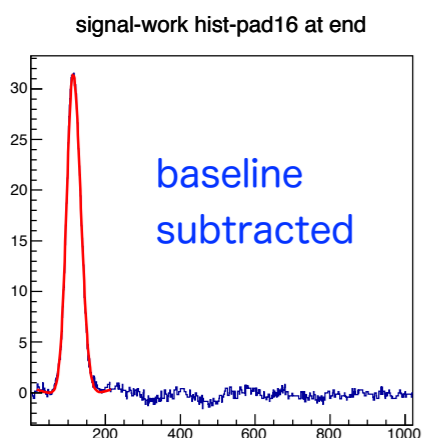
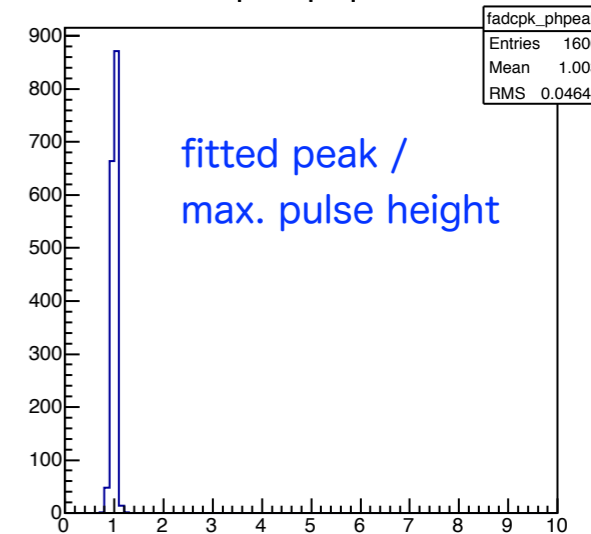


pulses are fitted with dual-Gaussian and 2nd order polynomial (baseline)

Peak:gamma

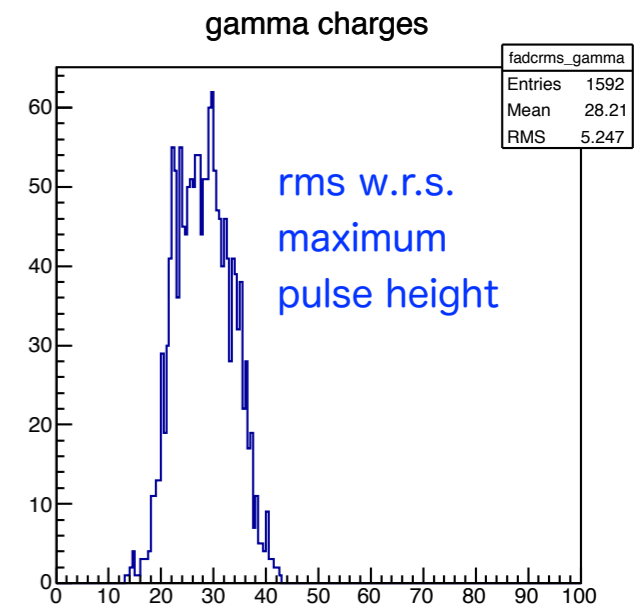
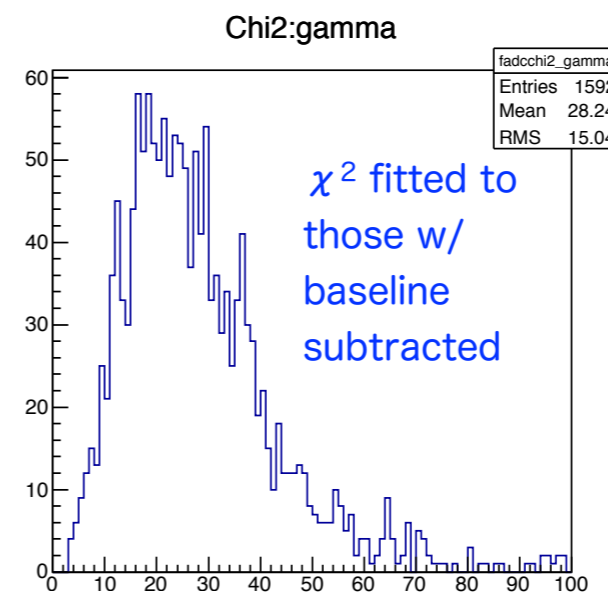
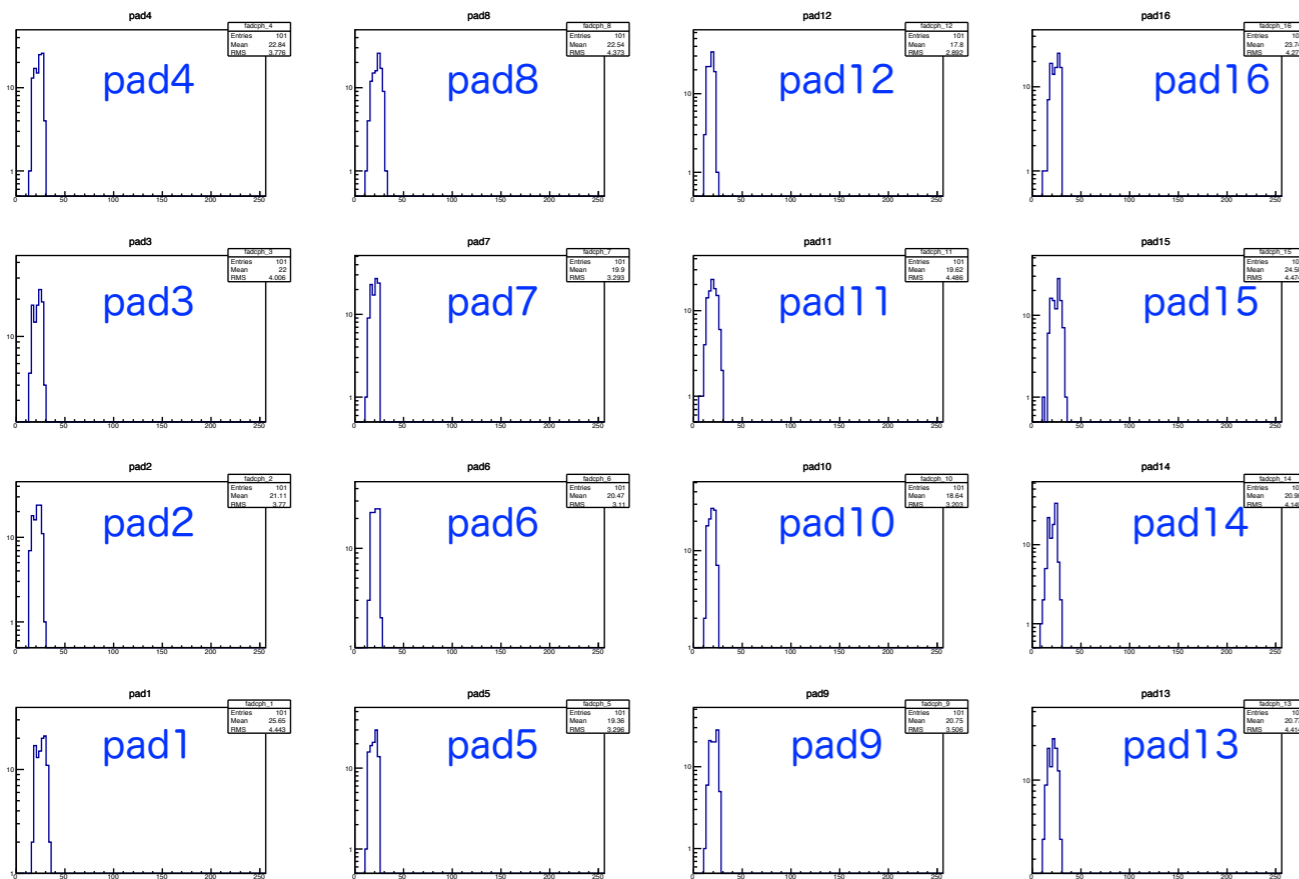


fit-peak/ph-peak

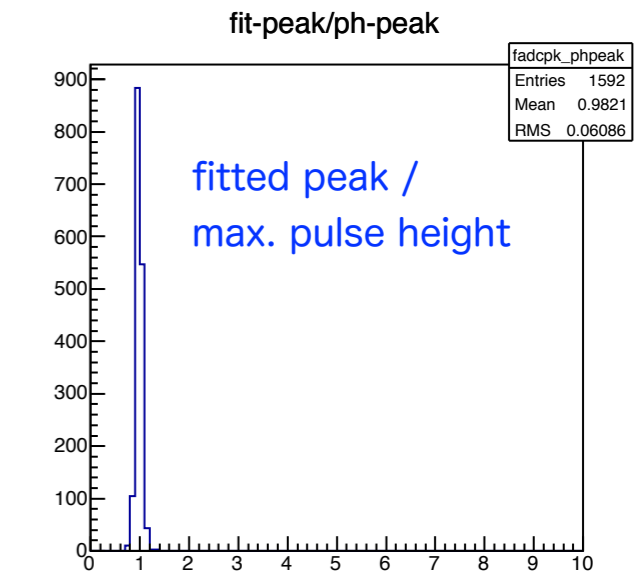
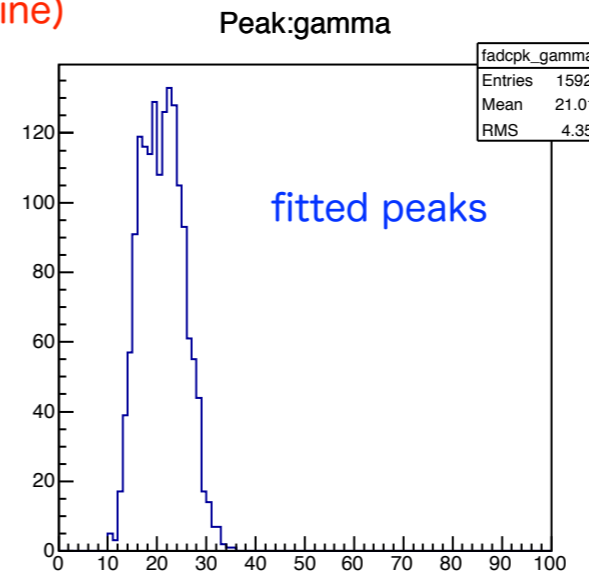
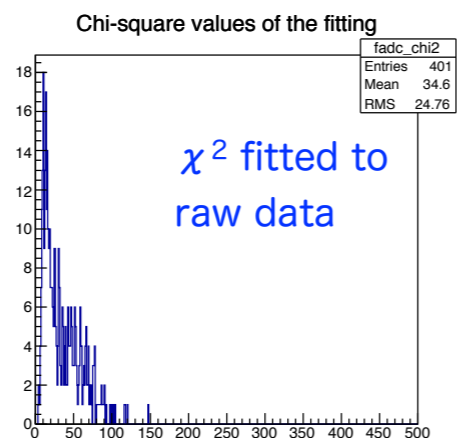
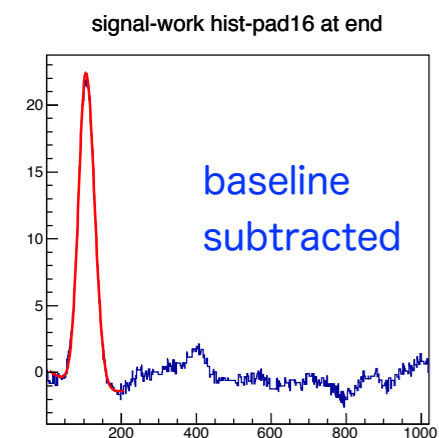
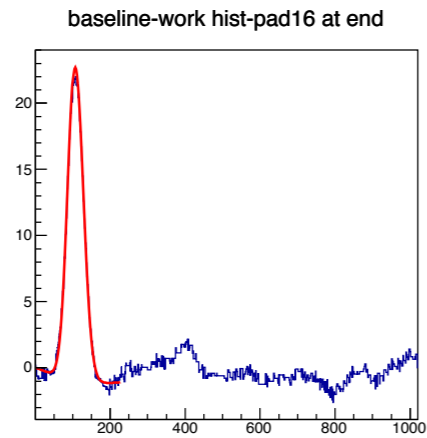
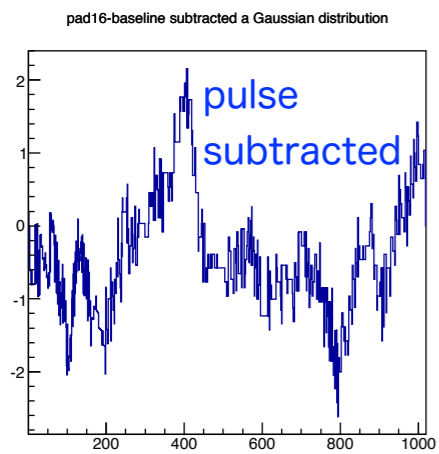


Performances of test pulse run

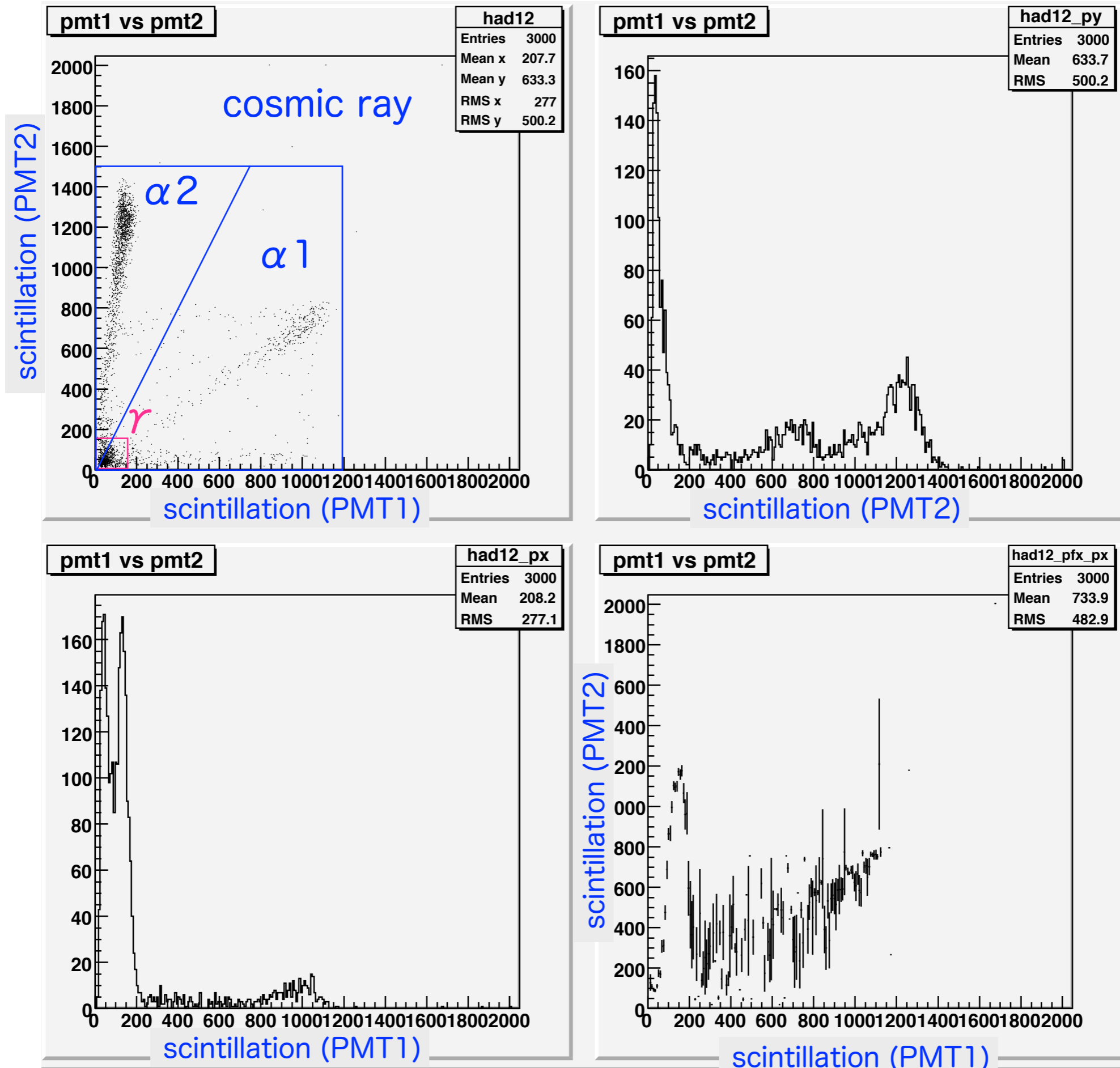
2013.5.1 18:37



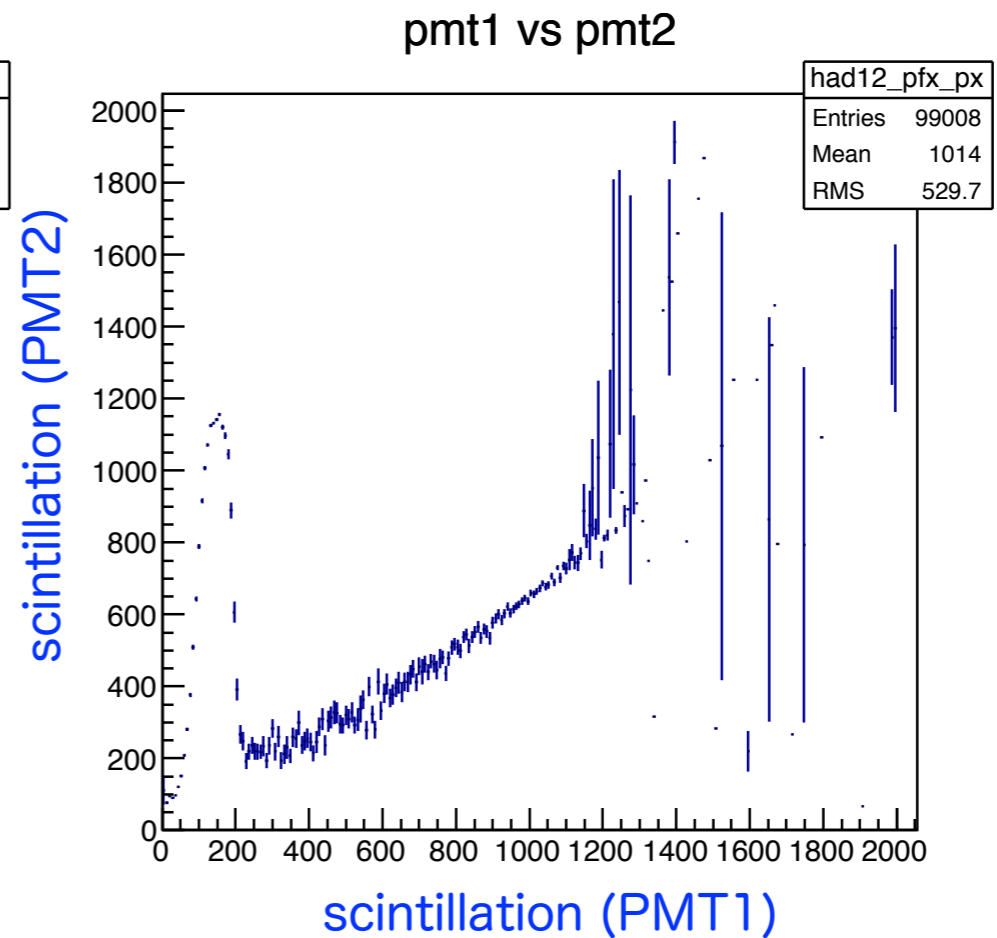
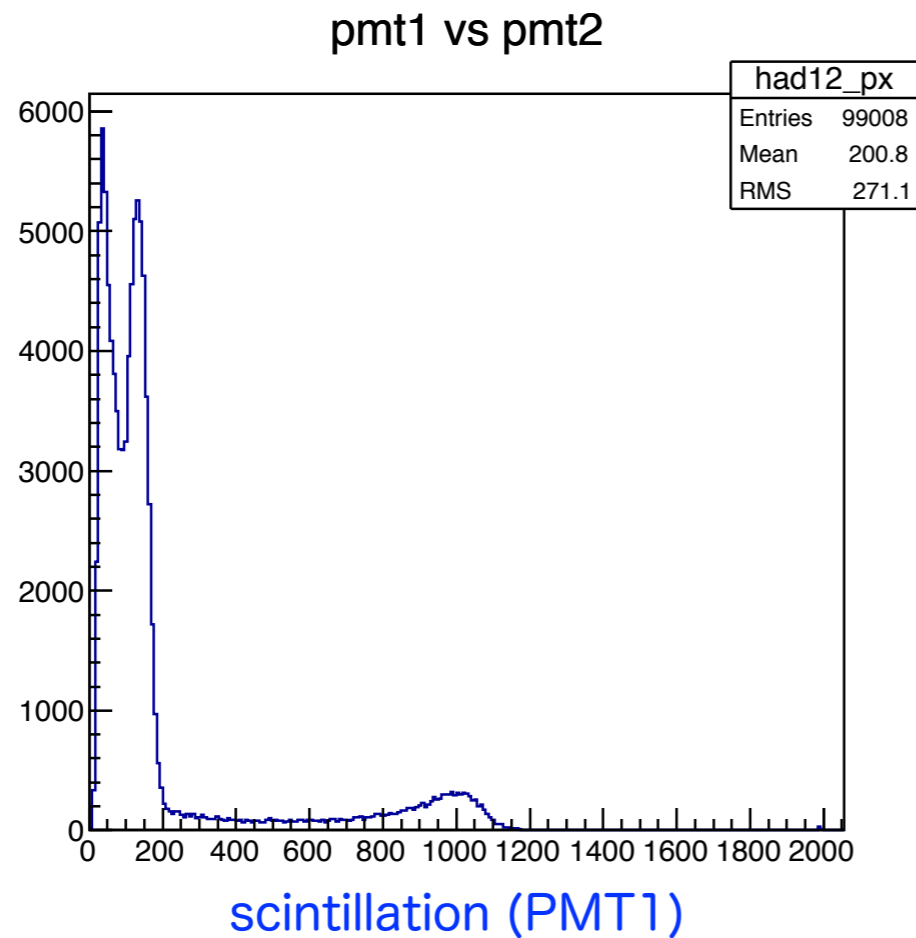
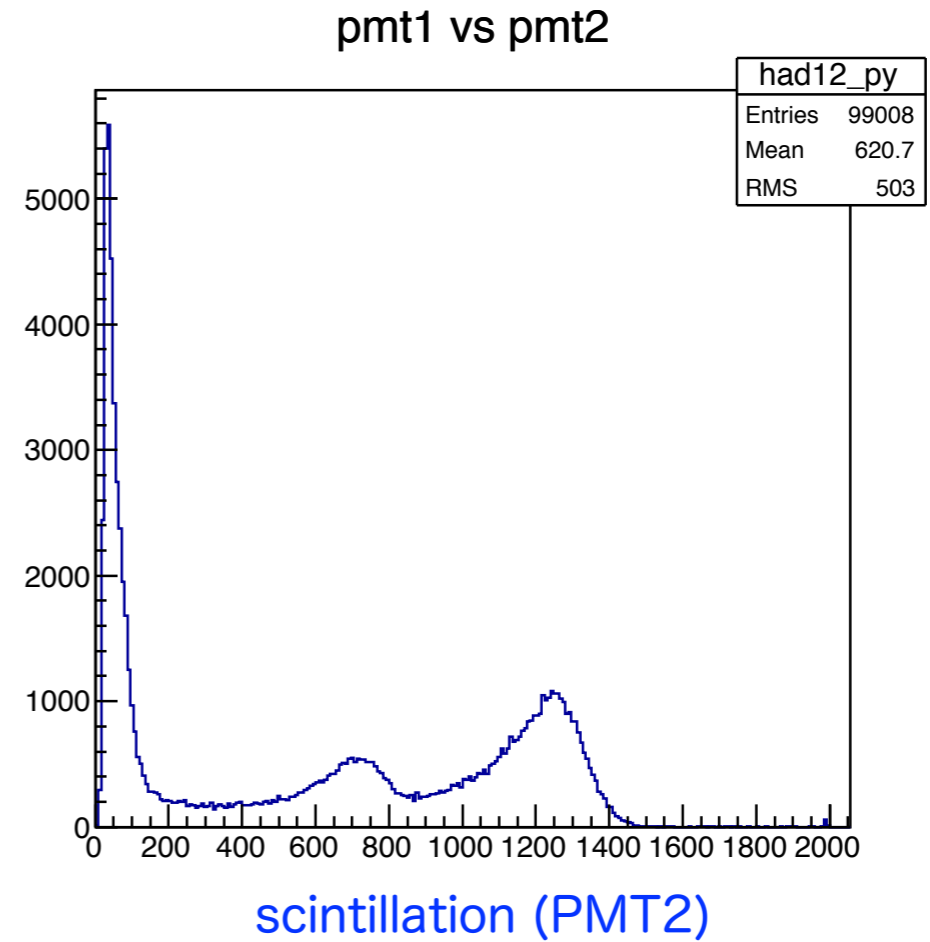
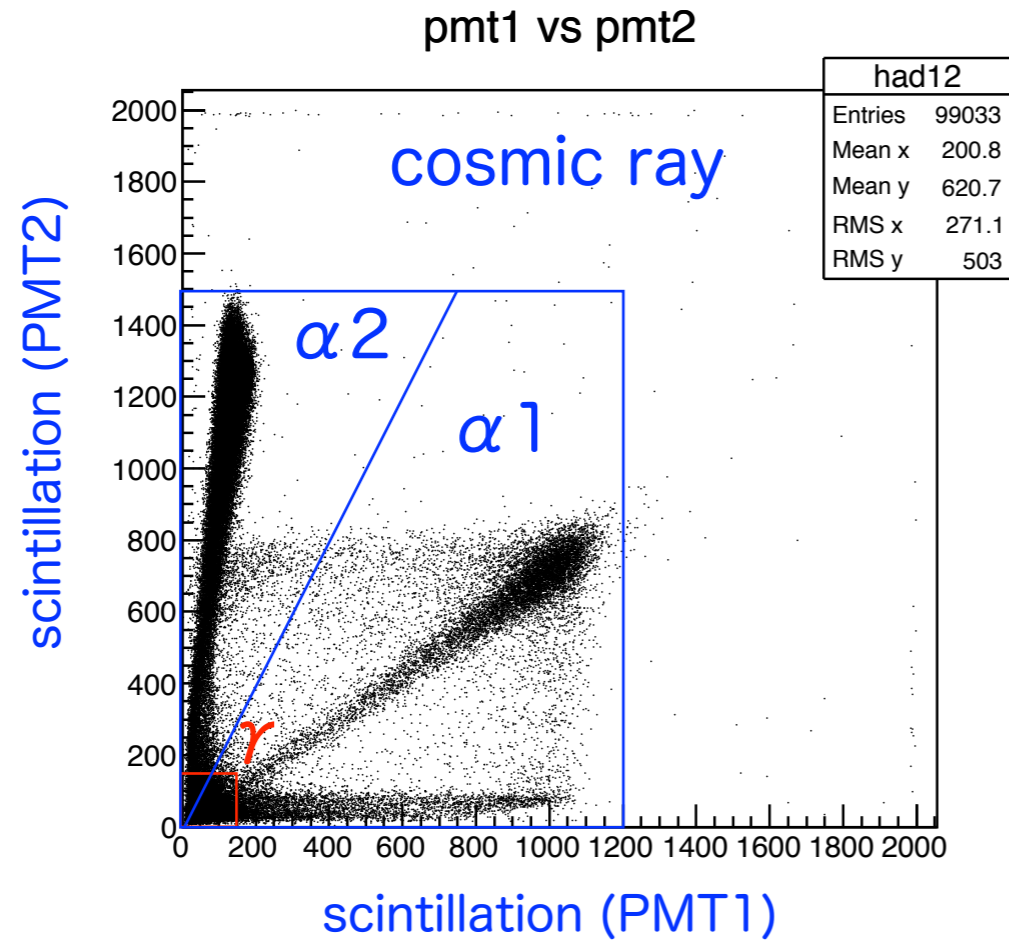
pulses are fitted with dual-Gaussian and 2nd order polynomial (baseline)



Event classifications by scintillation lights

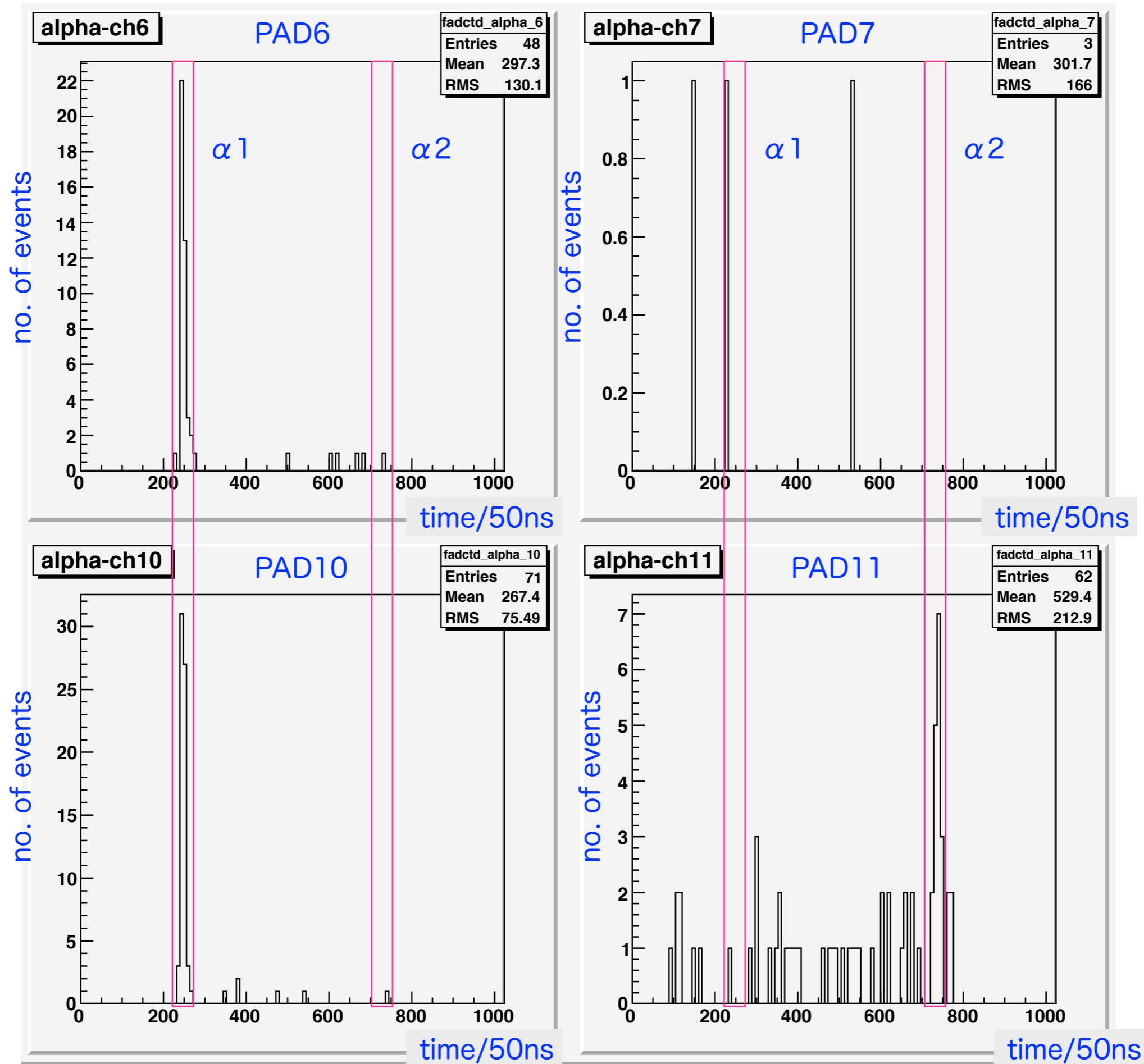


Event classifications by scintillation lights

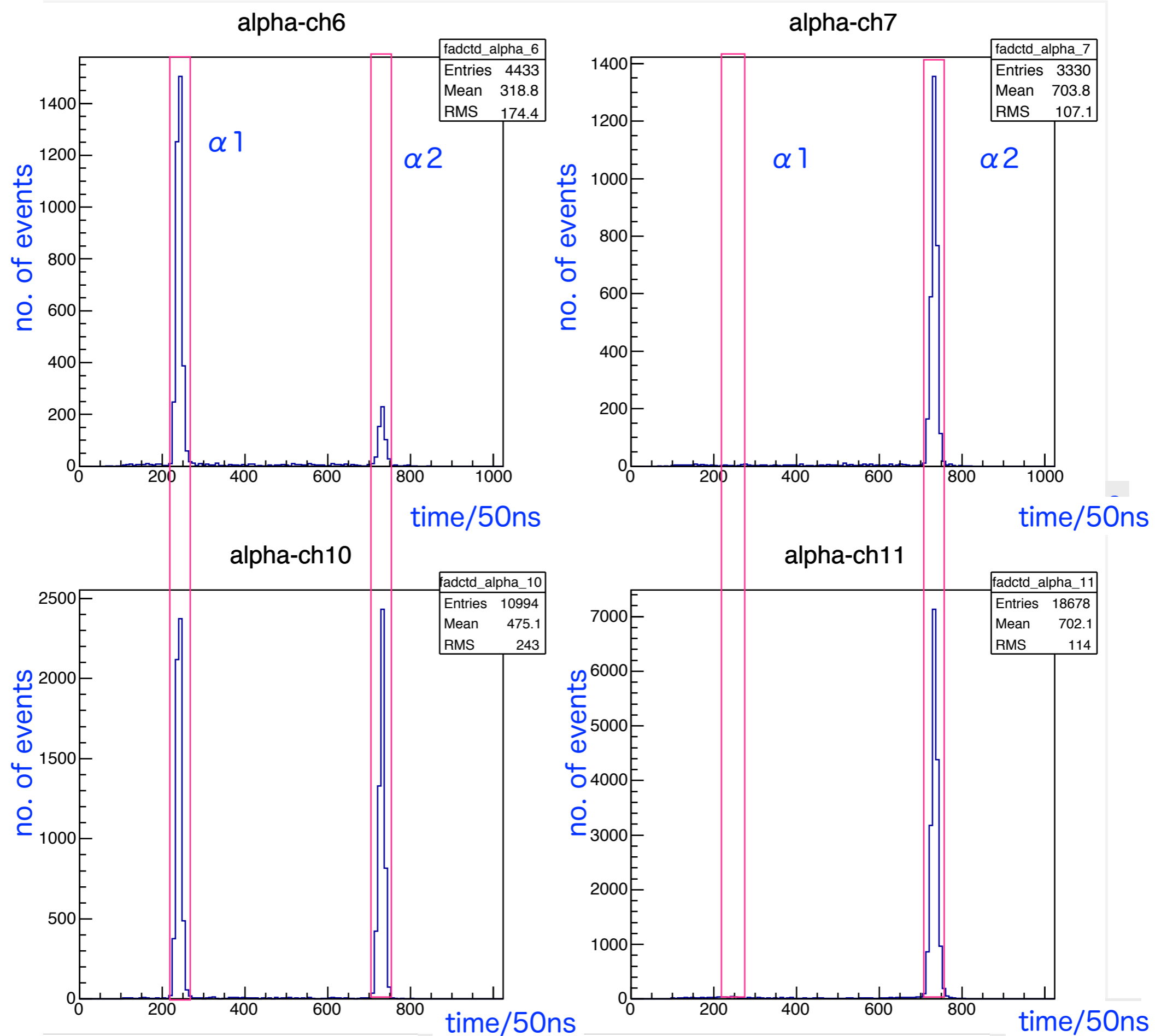


2012.12.10-
2013.1.19

Fitted peak charges

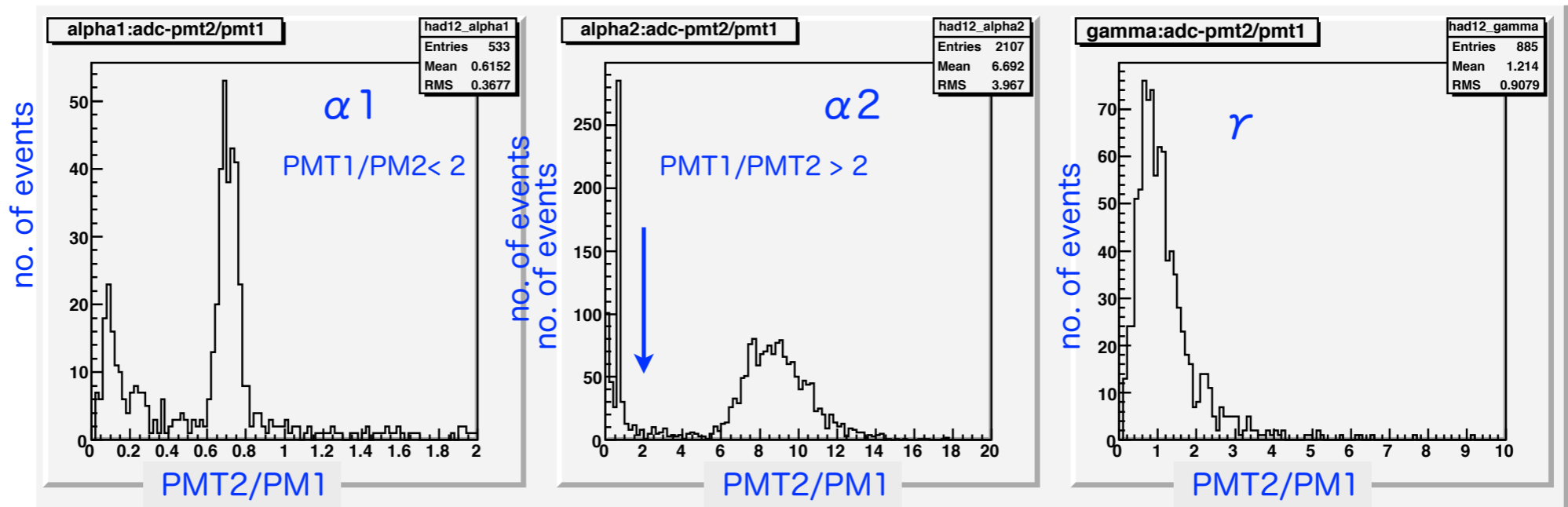


Fitted peak charges

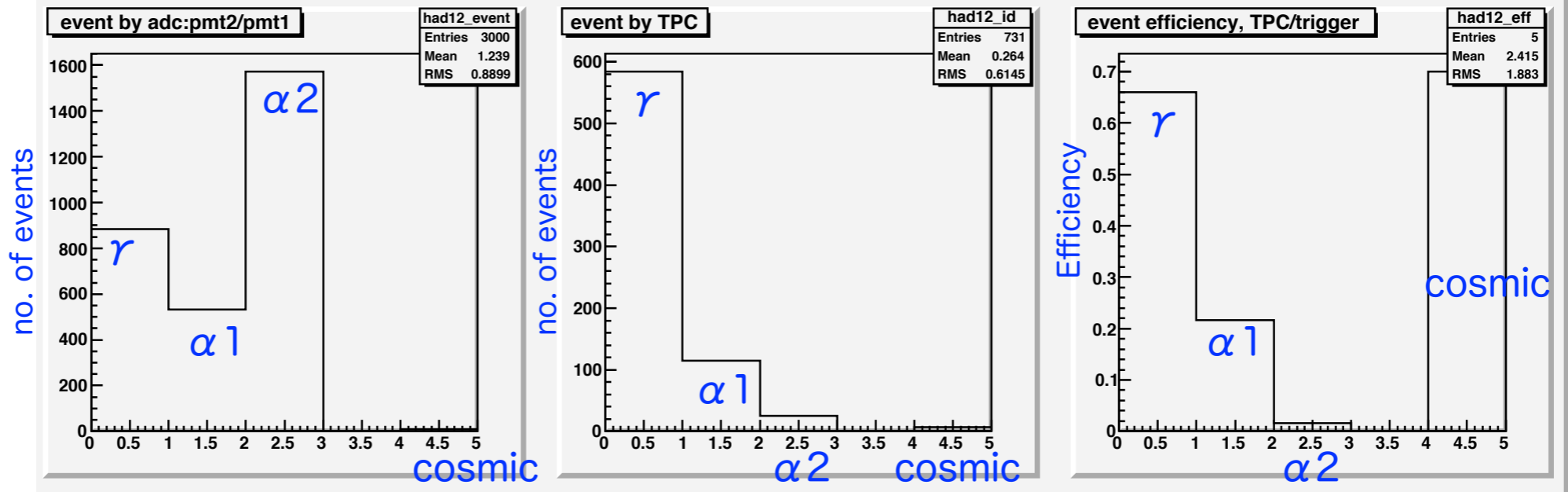


2012.12.10-
2013.1.19

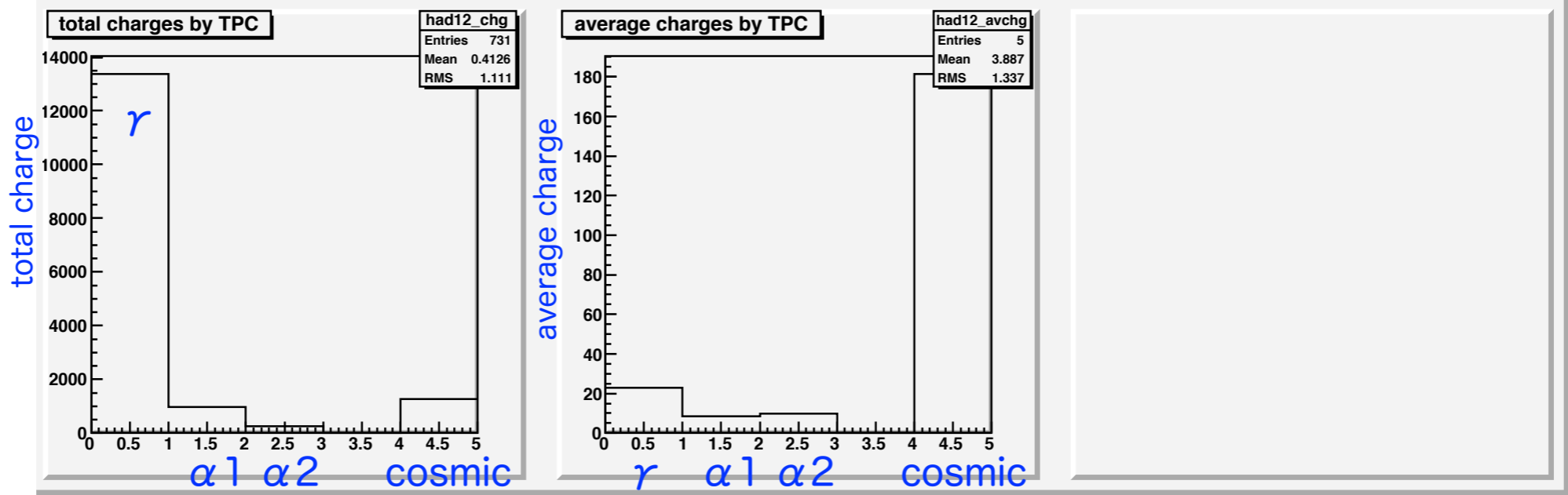
scintillation ratio :
PMT2/PMT1



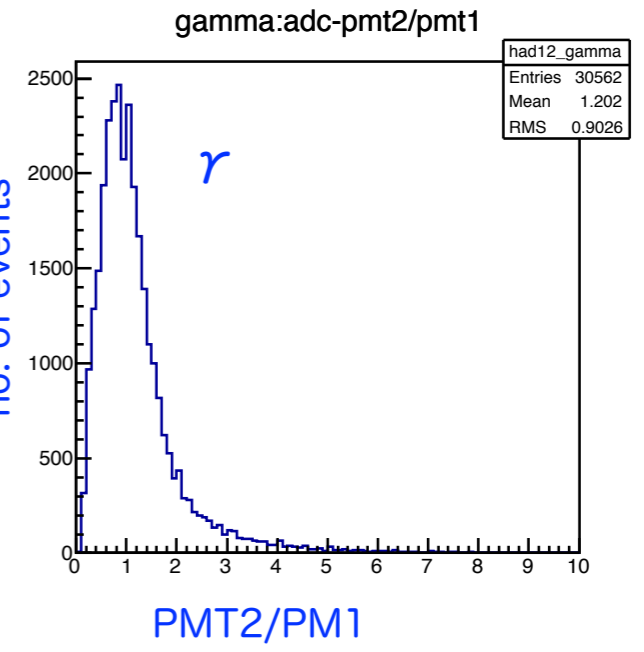
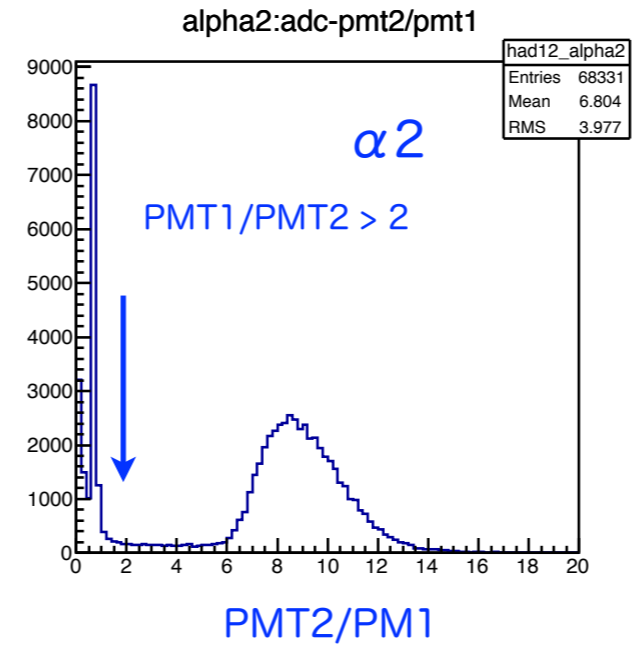
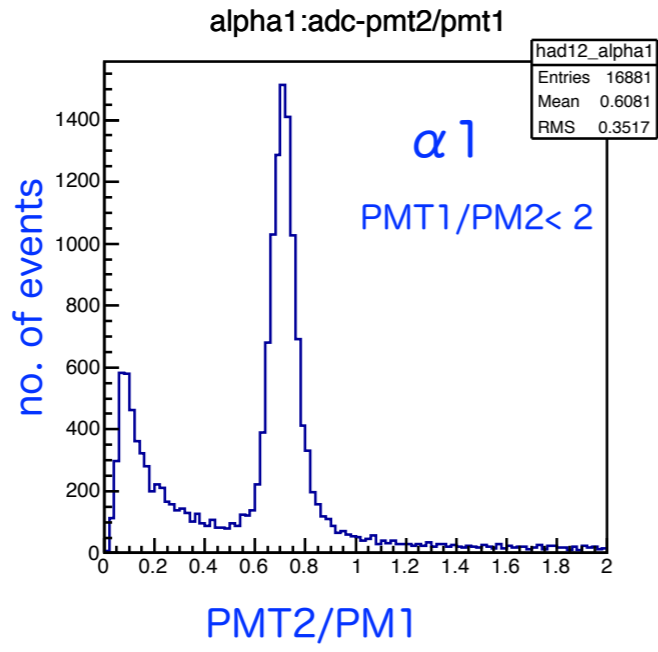
Statistics :
triggered,
identified,
efficiency



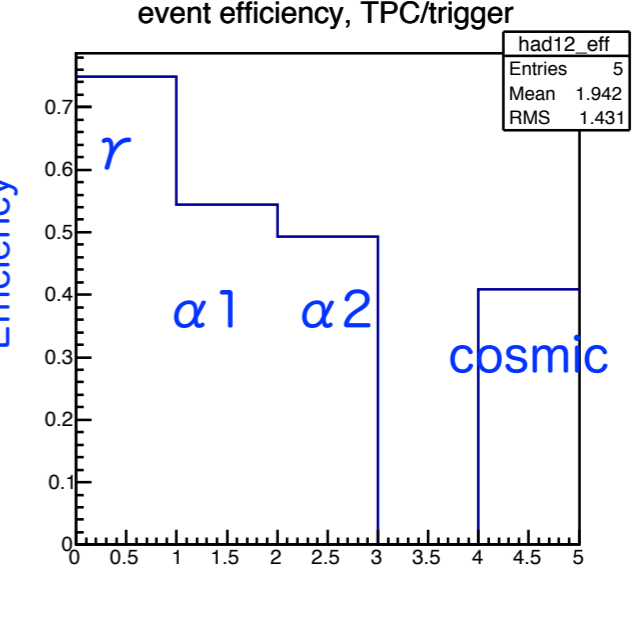
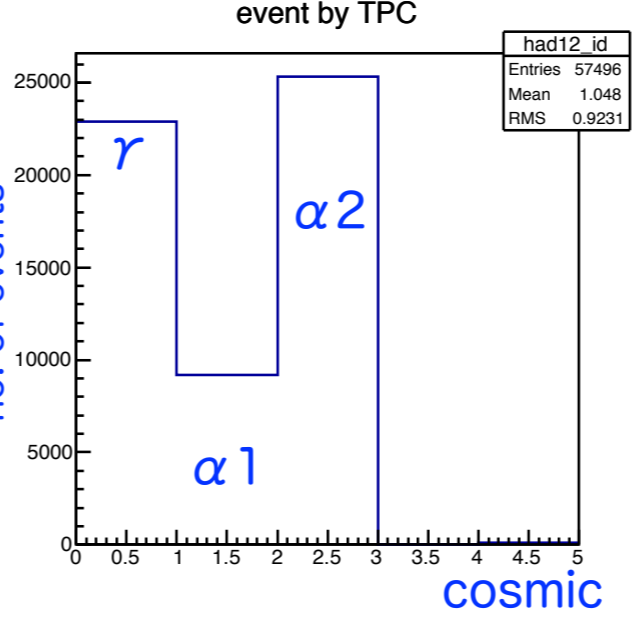
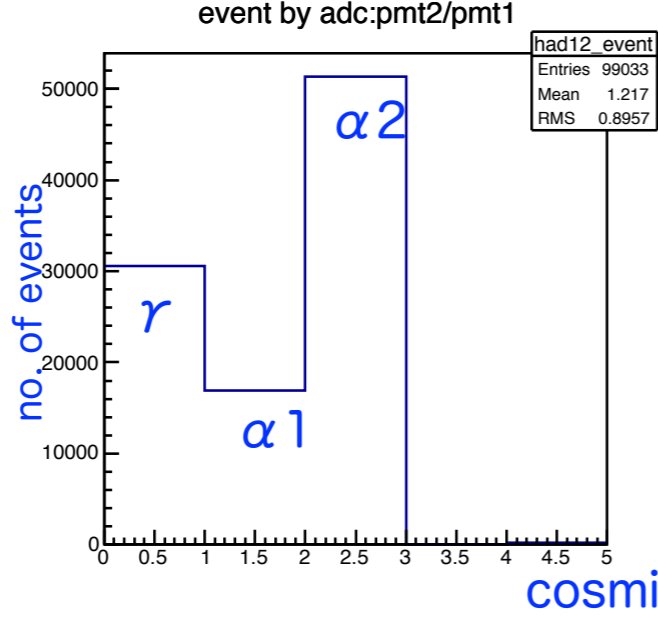
Charges :
pulse height
peak fitted,
averages



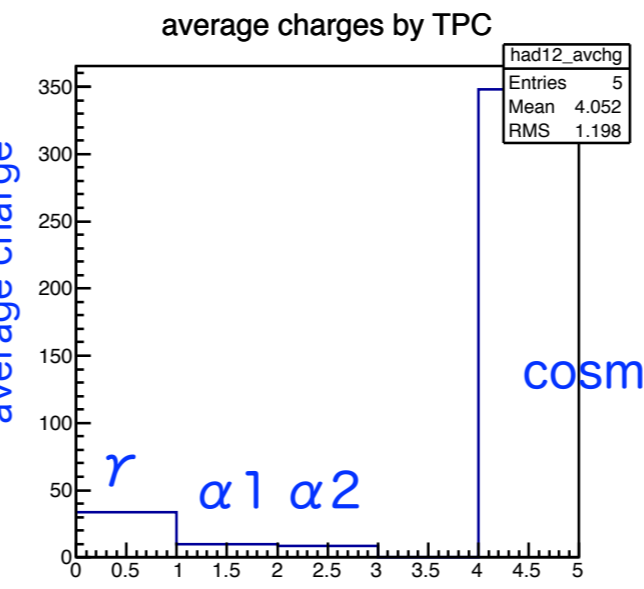
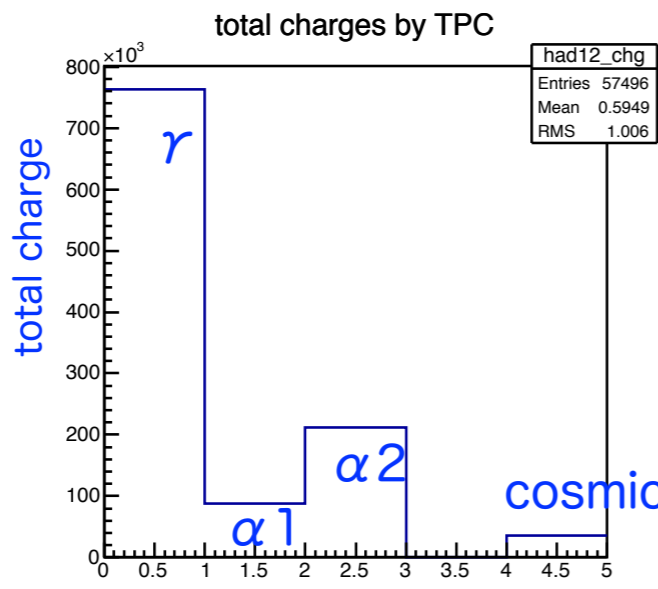
scintillation ratio :
PMT2/PMT1



Statistics :
triggered,
identified,
efficiency

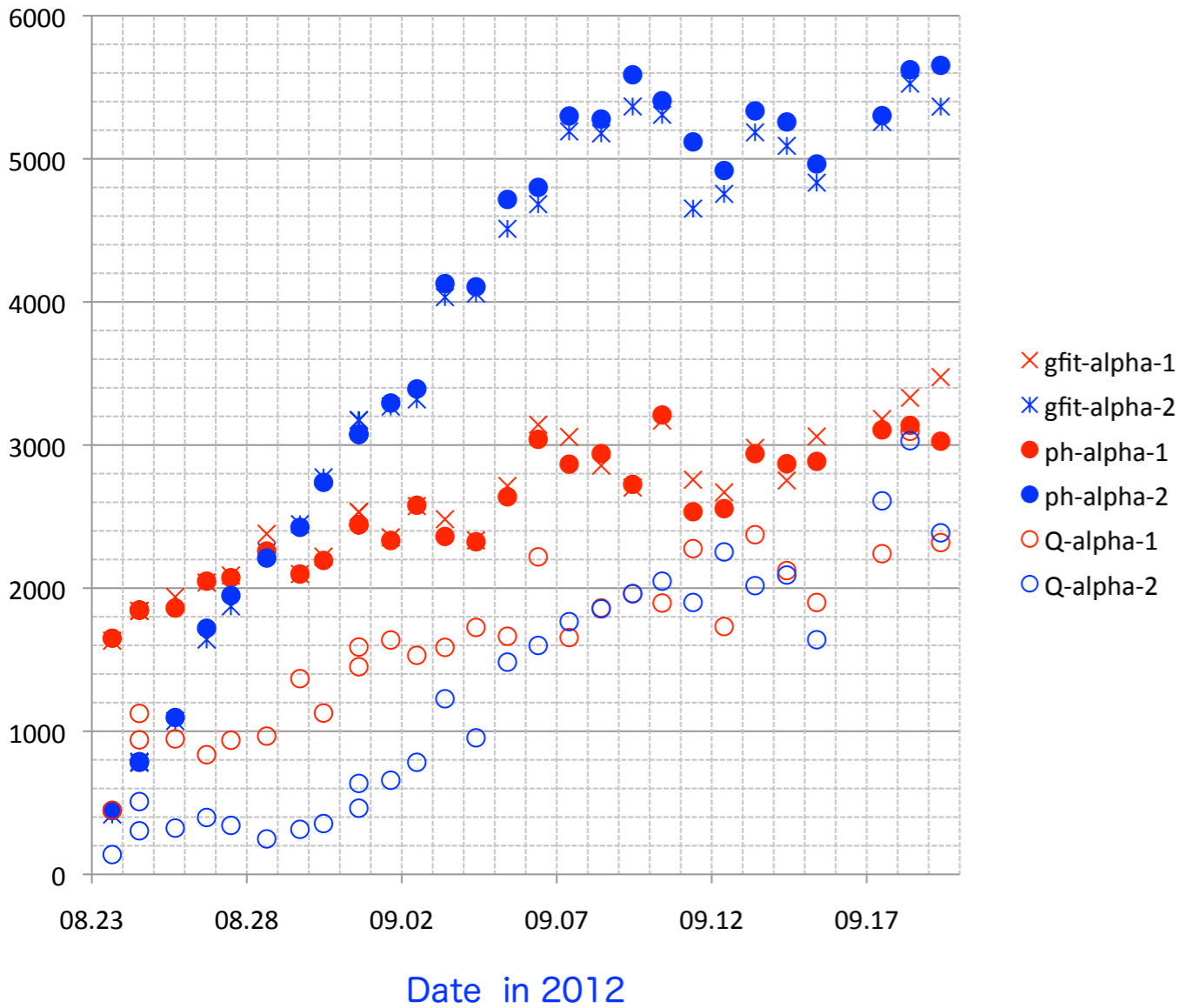


Charges :
pulse height
peak fitted,
averages

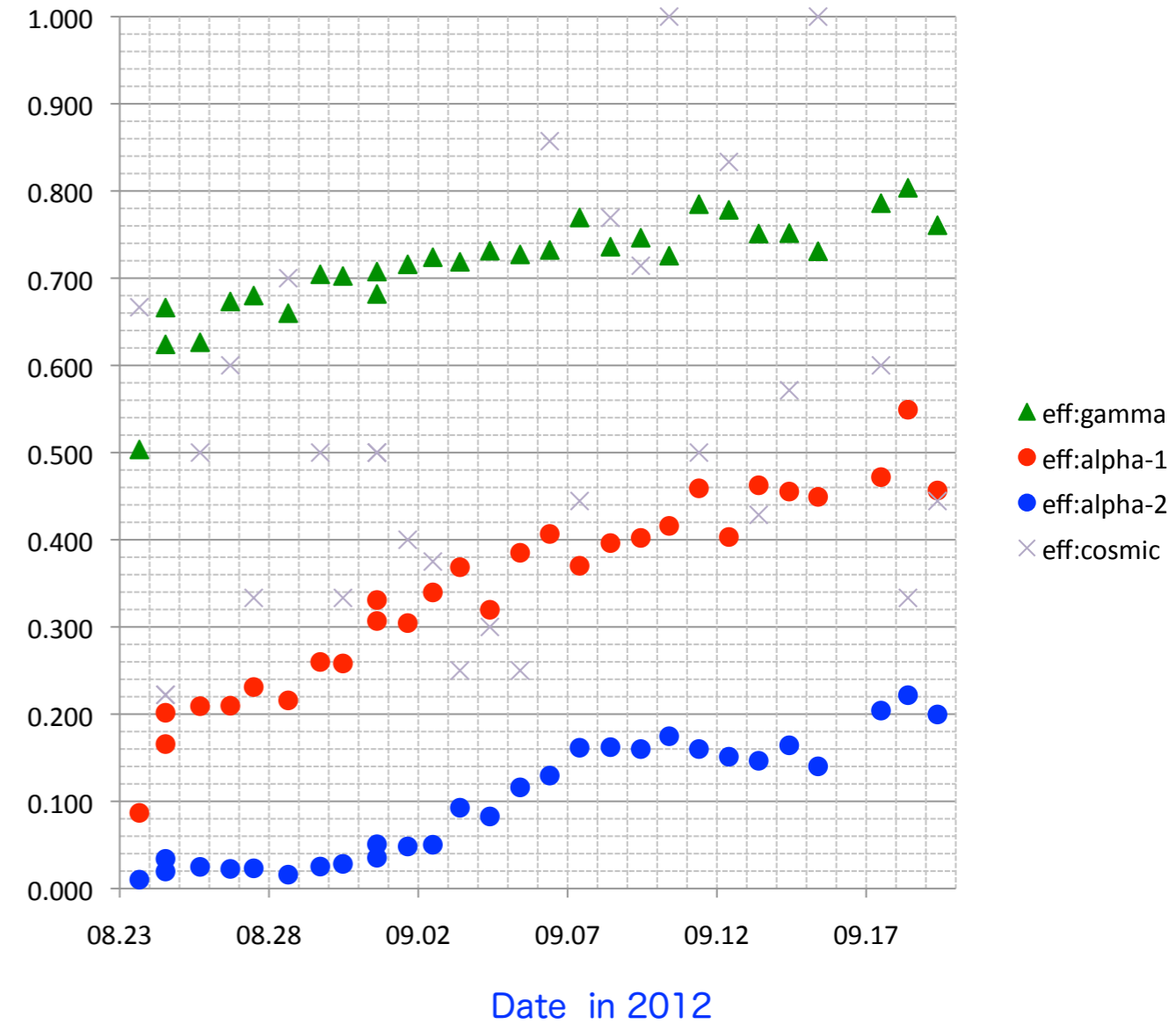


2012.12.10-
2013.1.19

Growth of charge from α sources



Efficiency of charge from α, γ sources and cosmic rays



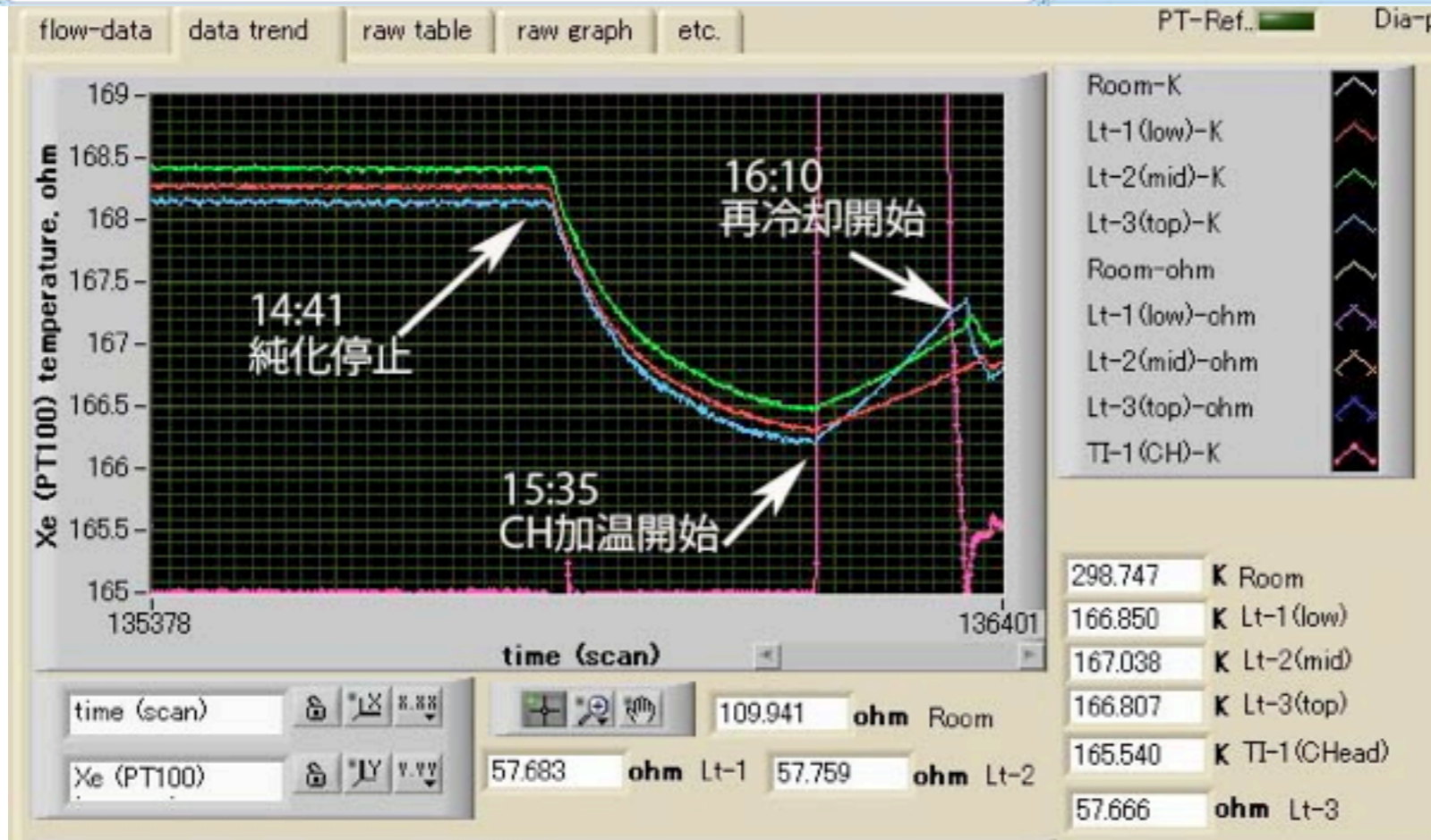
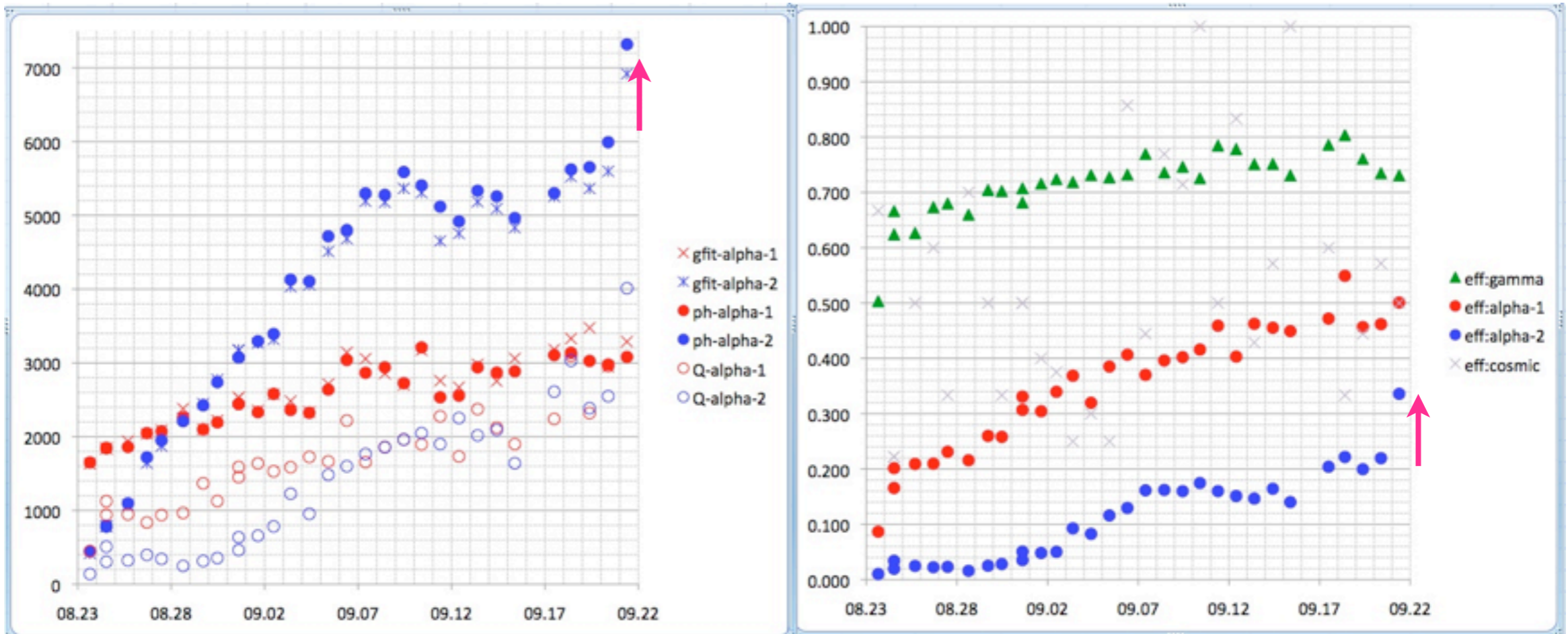
gfit-alpha-1,2 : Gaussian fit w/o baseline subtraction

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

efficiency=charge signals / signals identified
by PMTs

コールドヘッド (CH) 一時加温, 2012.9.20 14:41-16:10



純化流量1.3L/minで
ヒーターパワーが加温
前3Wから5Wへ向上

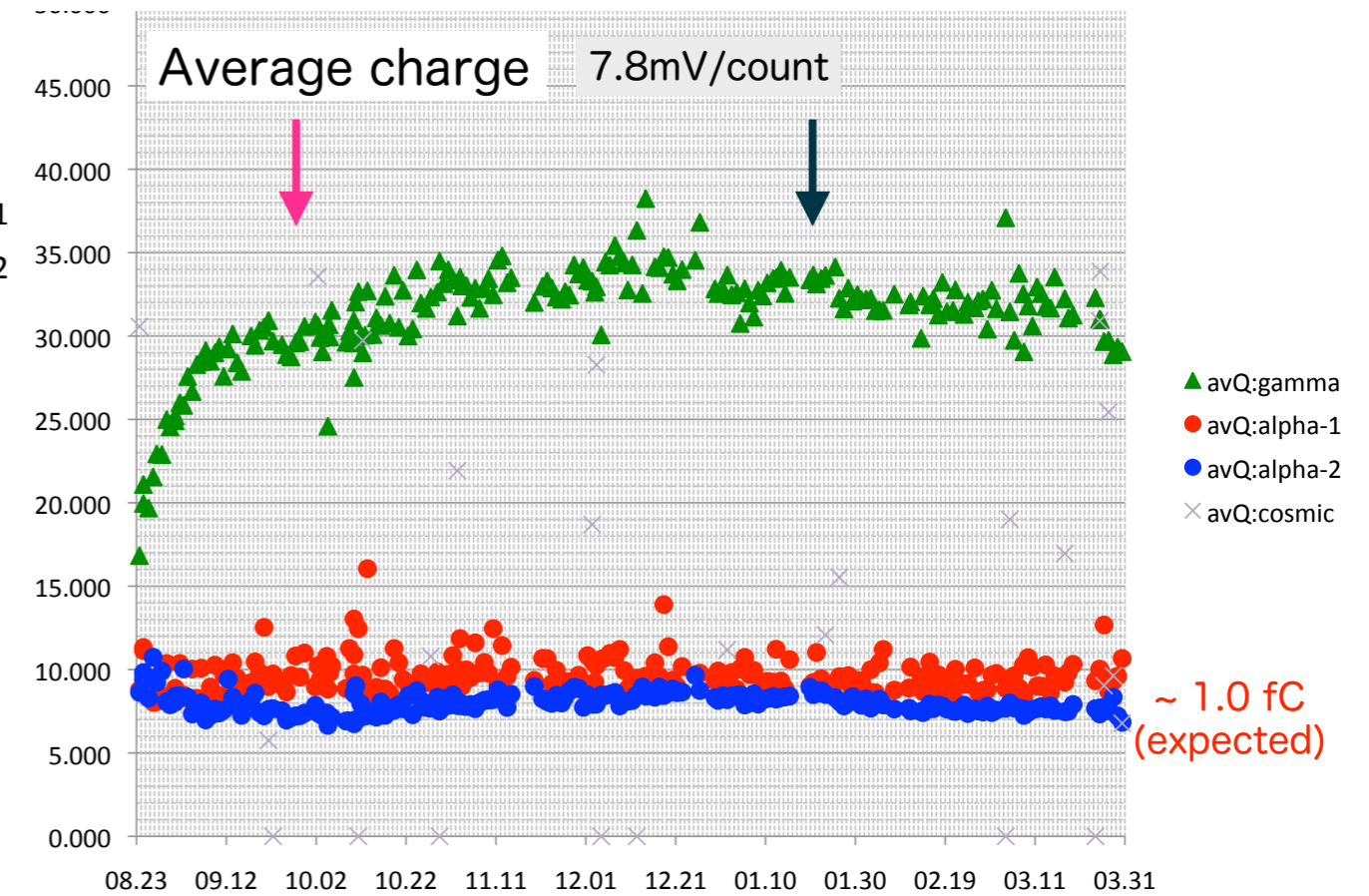
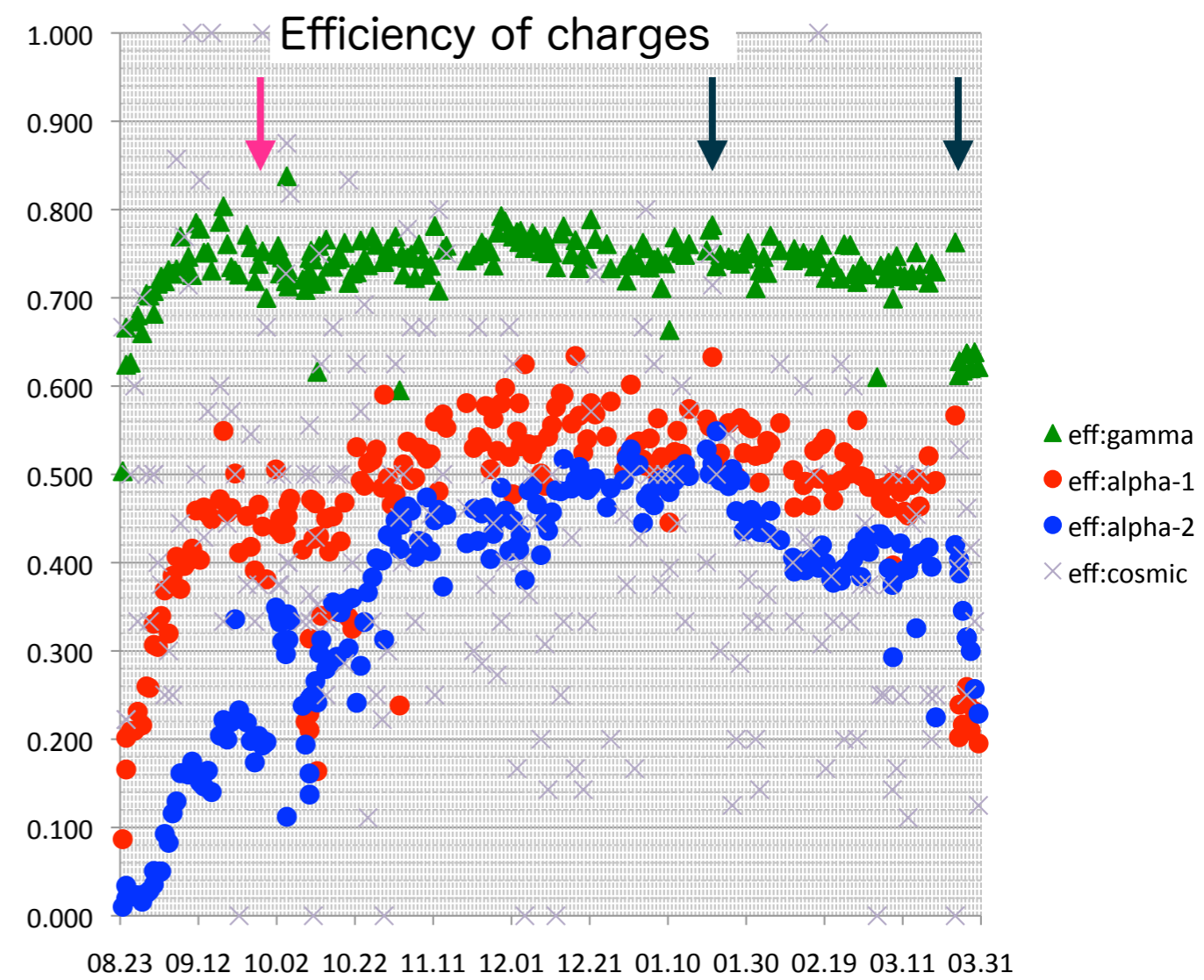
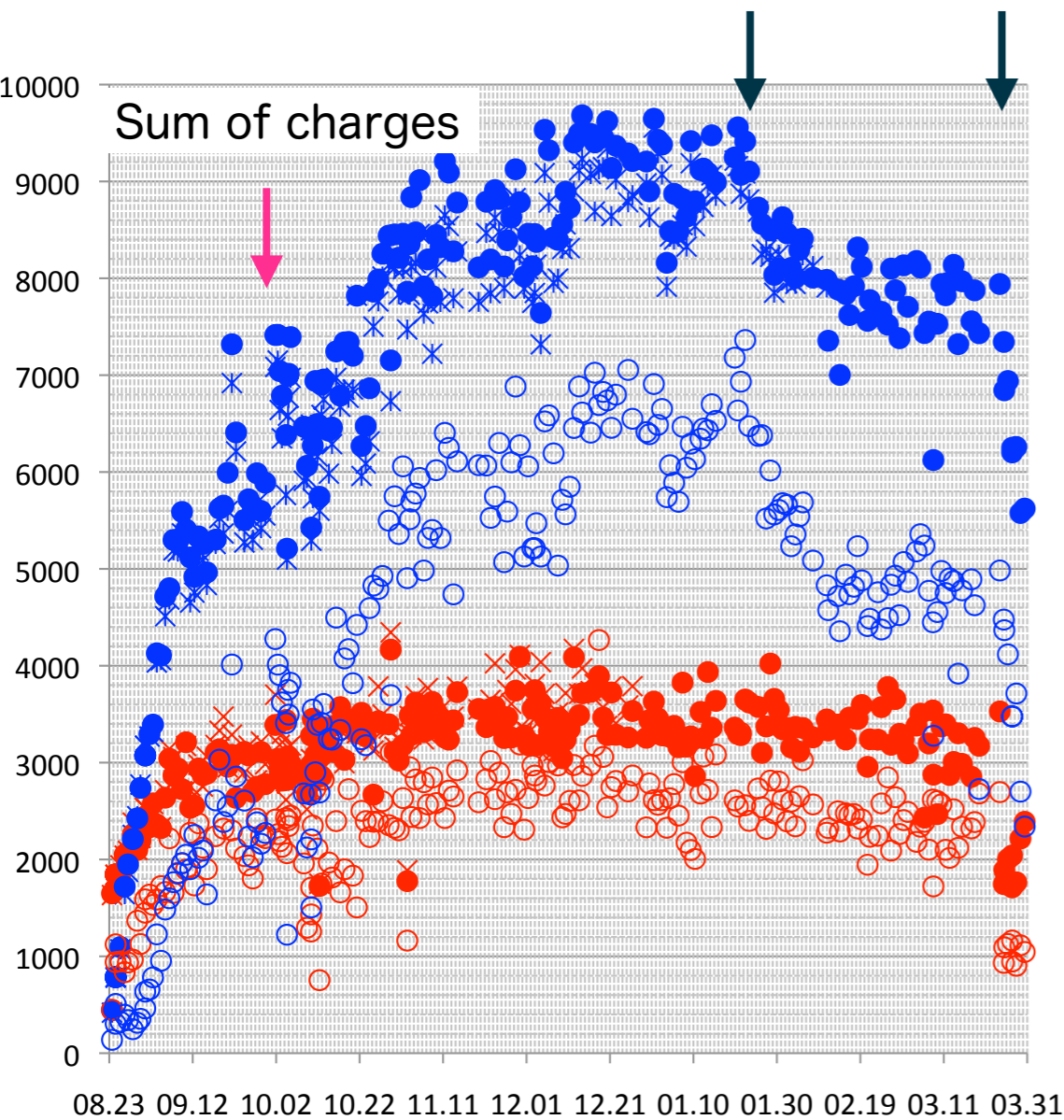
TPC charge signals

23 August 2012 to 31 March 2013

10/1よりCH加温/日(土日除く)を開始

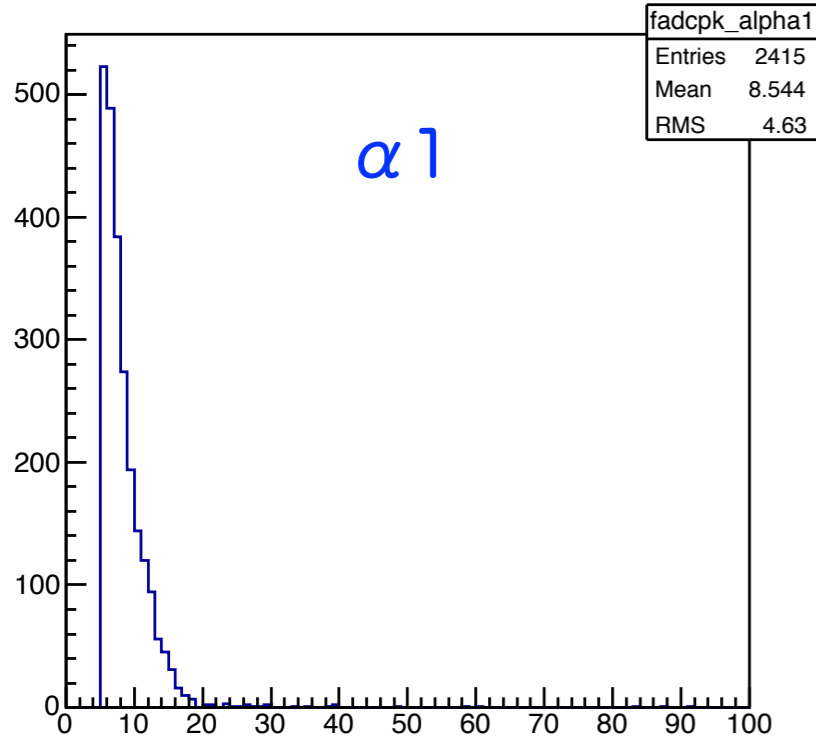
1/20よりCH加温/日を停止

3/25よりガス循環停止

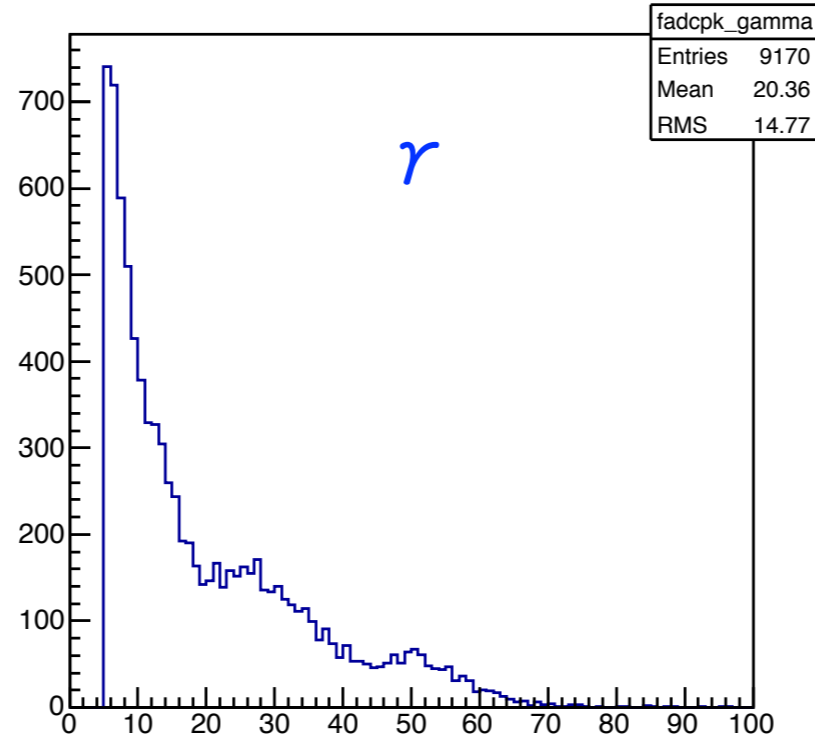


Charges/pad (peak of D-Gaussian fit) of $\alpha 1$, $\alpha 2$ and γ , 2012.12.20-12.31 (8 days)

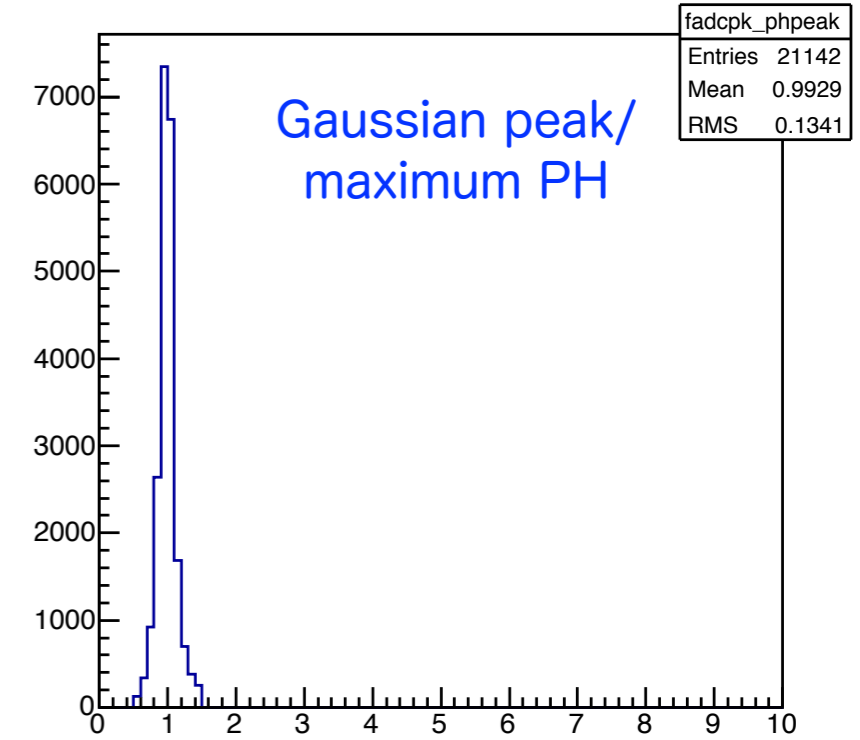
Peak:alpha1



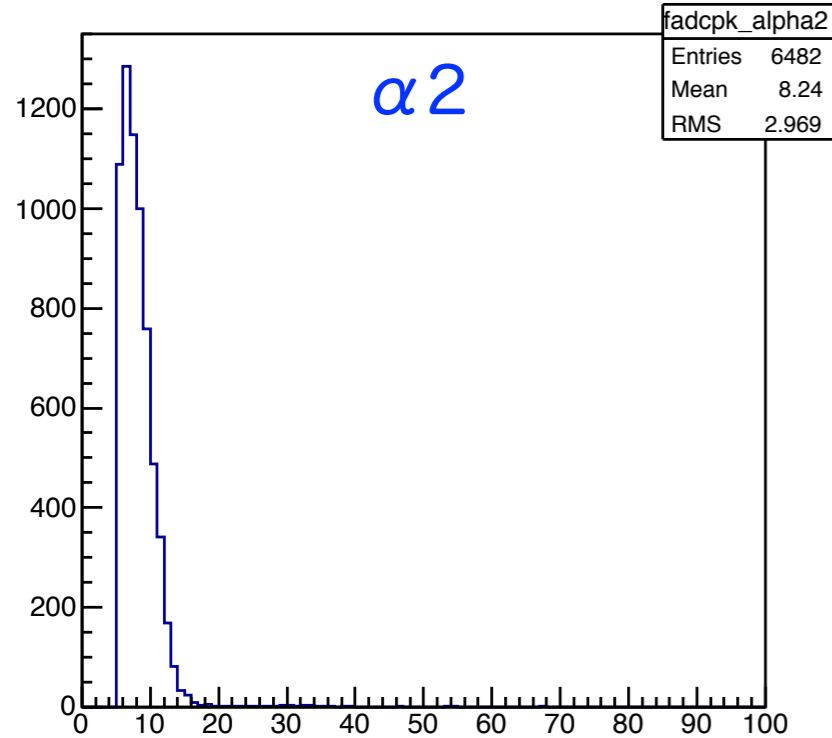
Peak:gamma



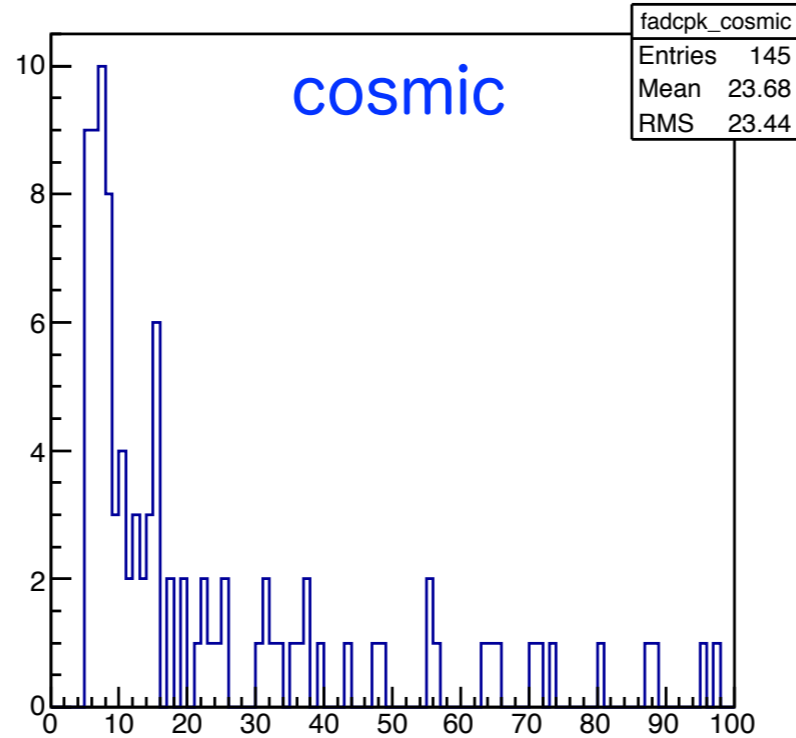
fit-peak/ph-peak



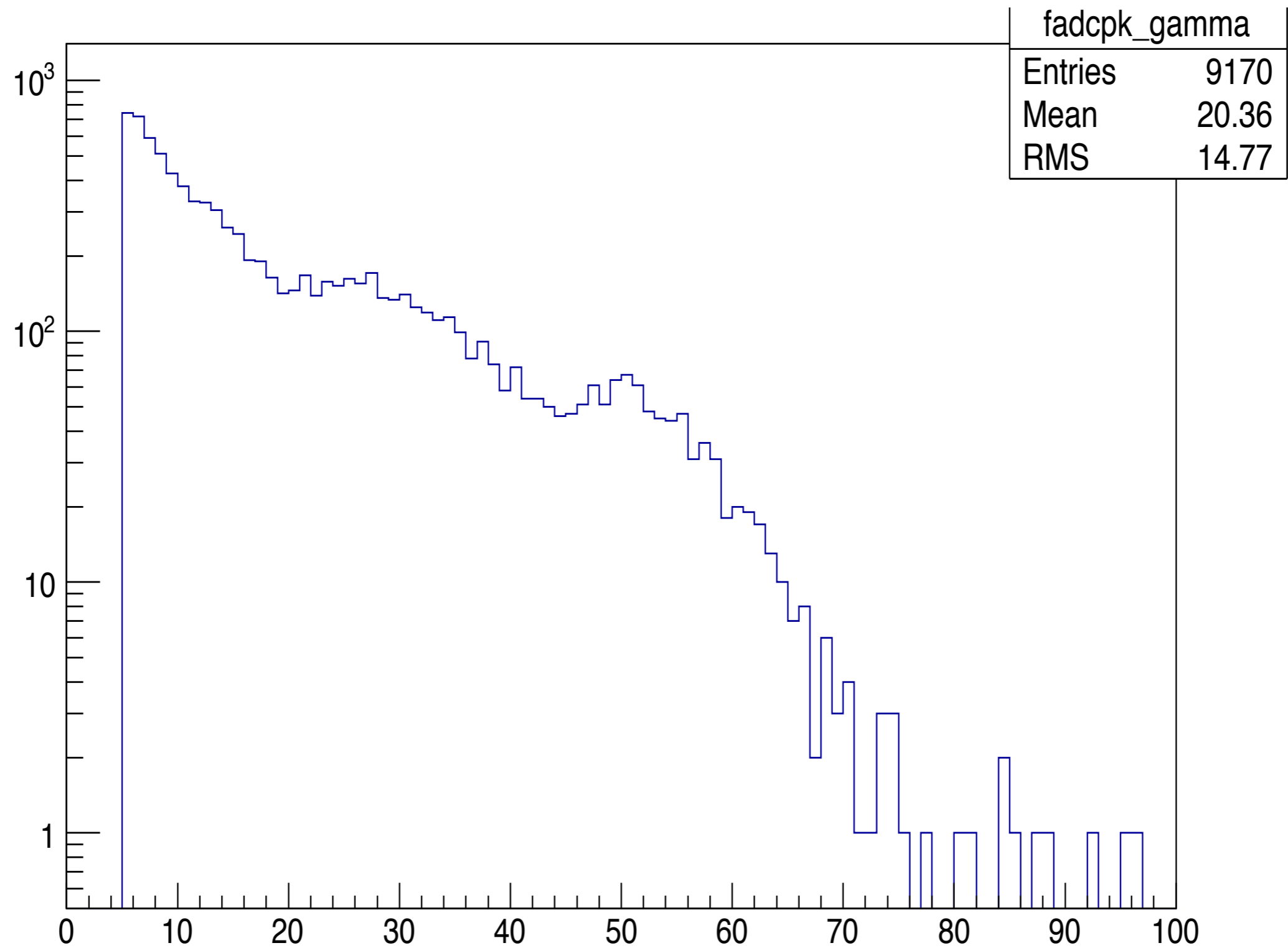
Peak:alpha2



Peak:cosmic



Charges/pad (peak of D-Gaussian fit) of γ , 2012.12.20-12.31 (8 days)



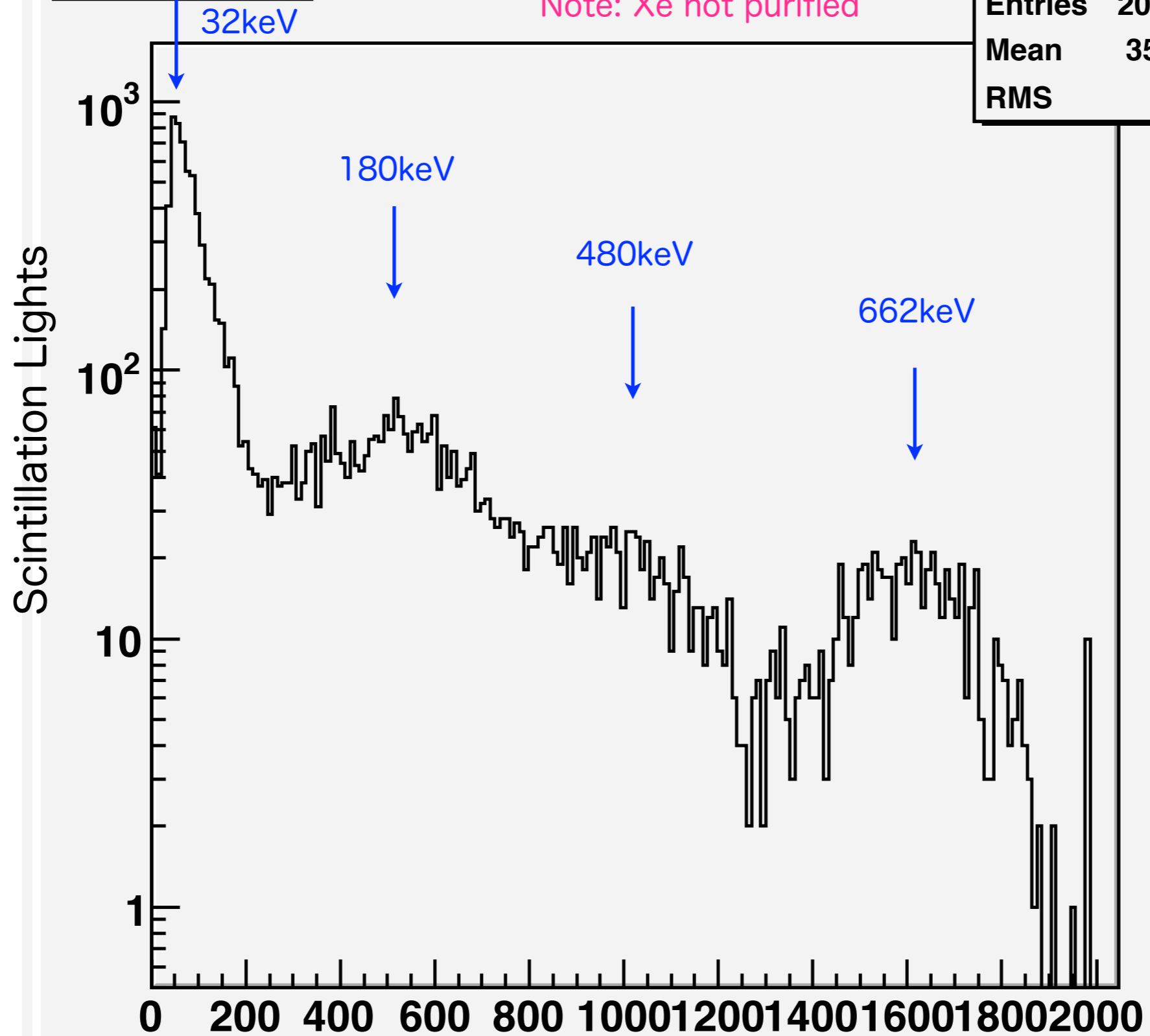
adc-pmt1

had1

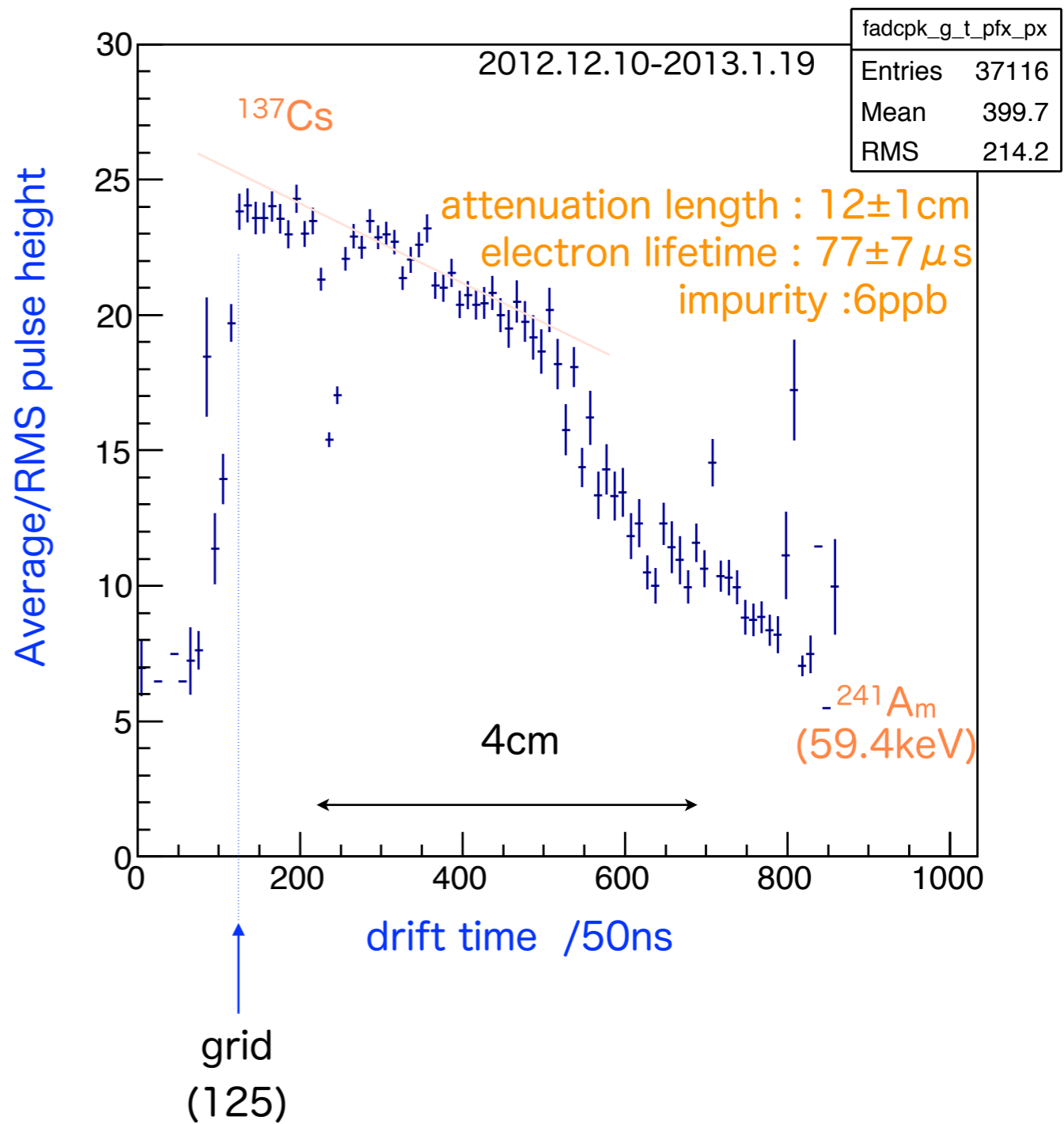
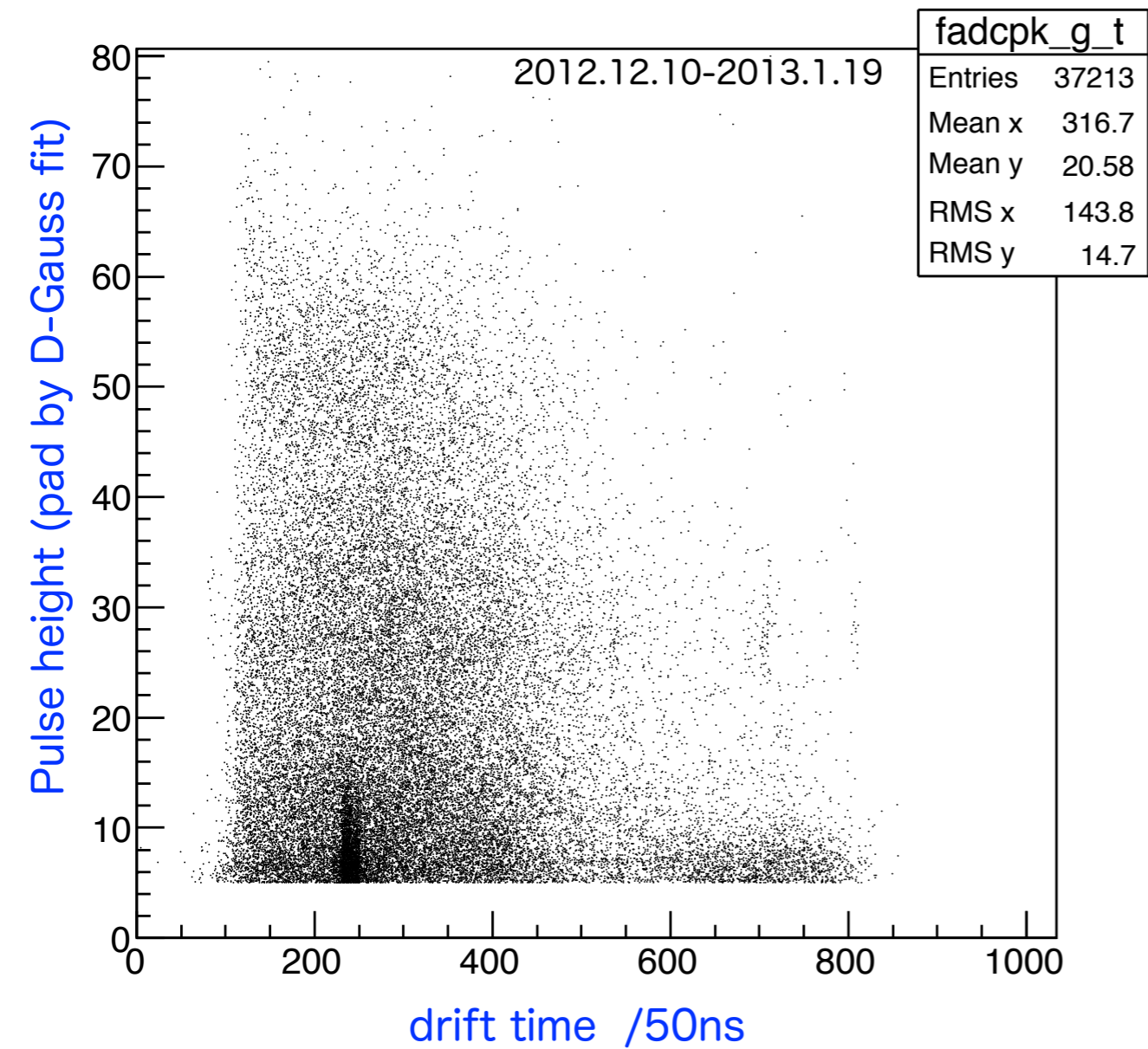
EDIT2013
2013.3.19

Note: Xe not purified

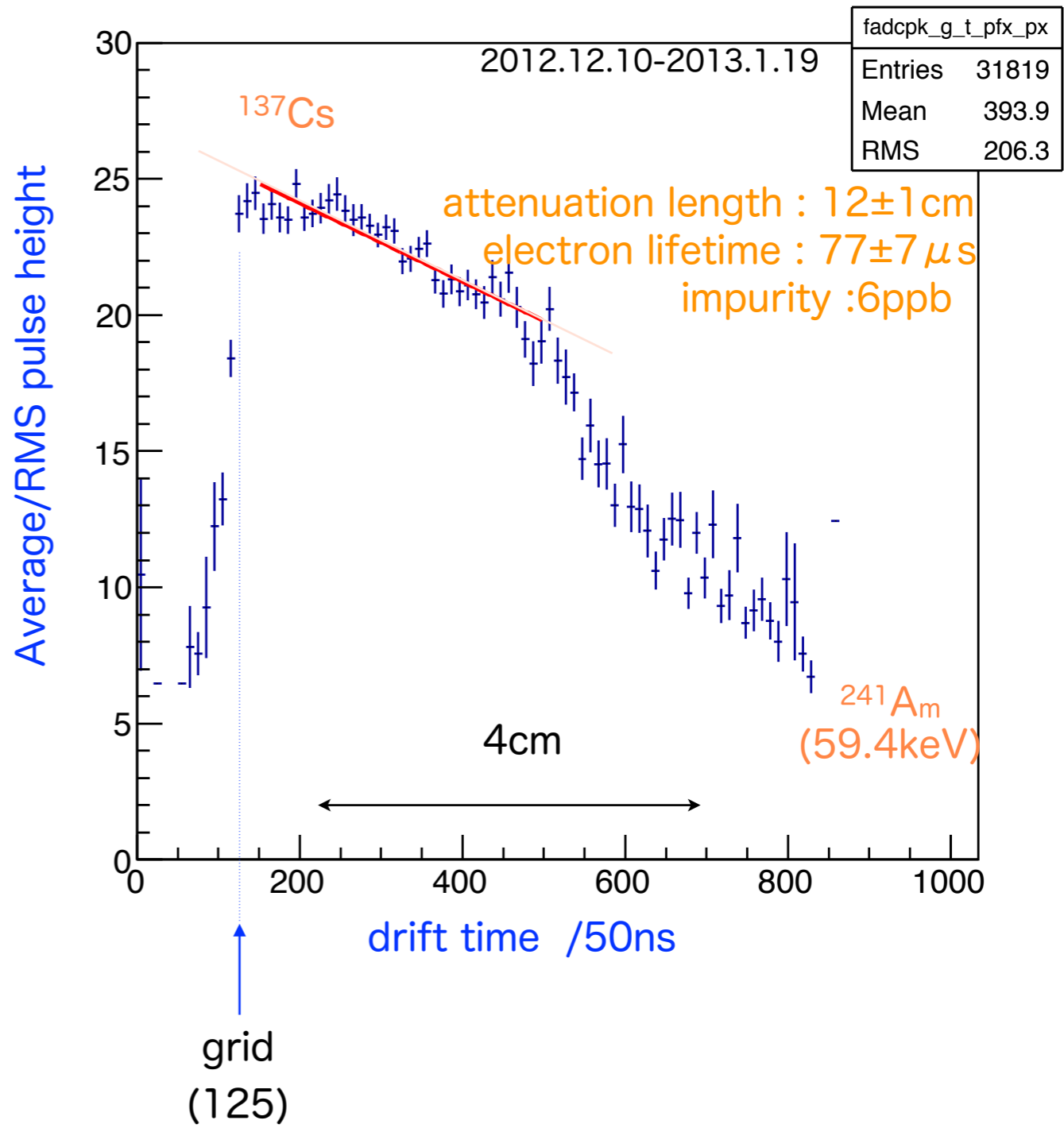
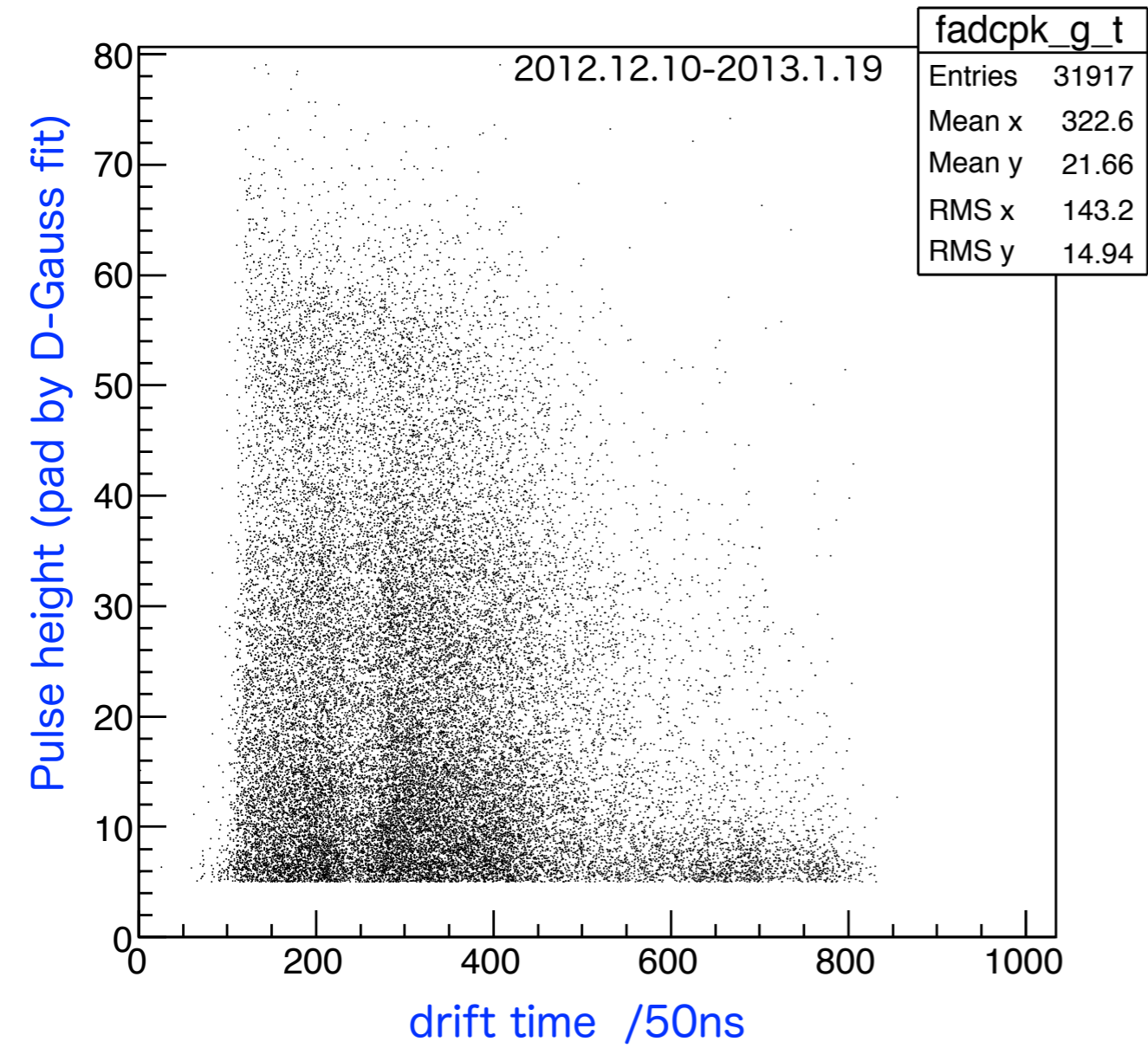
Entries	20000
Mean	357.3
RMS	437



¹³⁷Cs in Liq.Xe by 2249W ADC with 800nsec gate, PMT HV=750V, ph=400mV, 191526

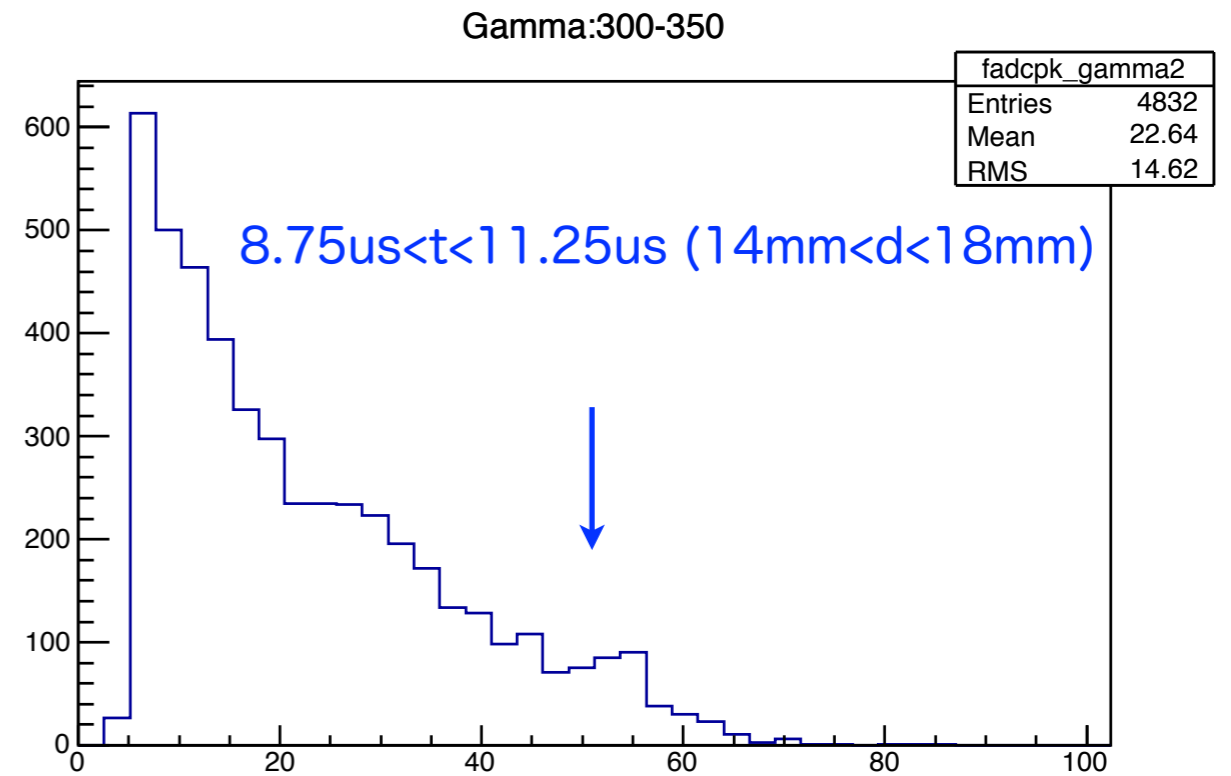
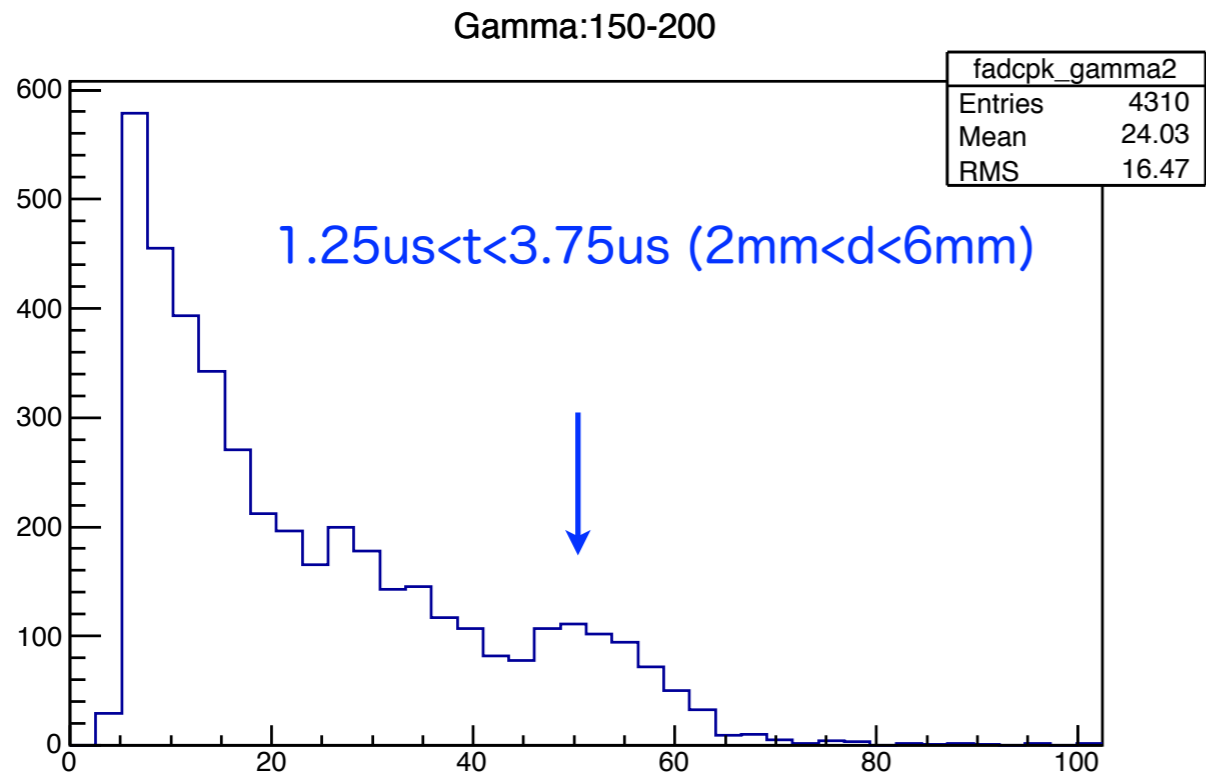
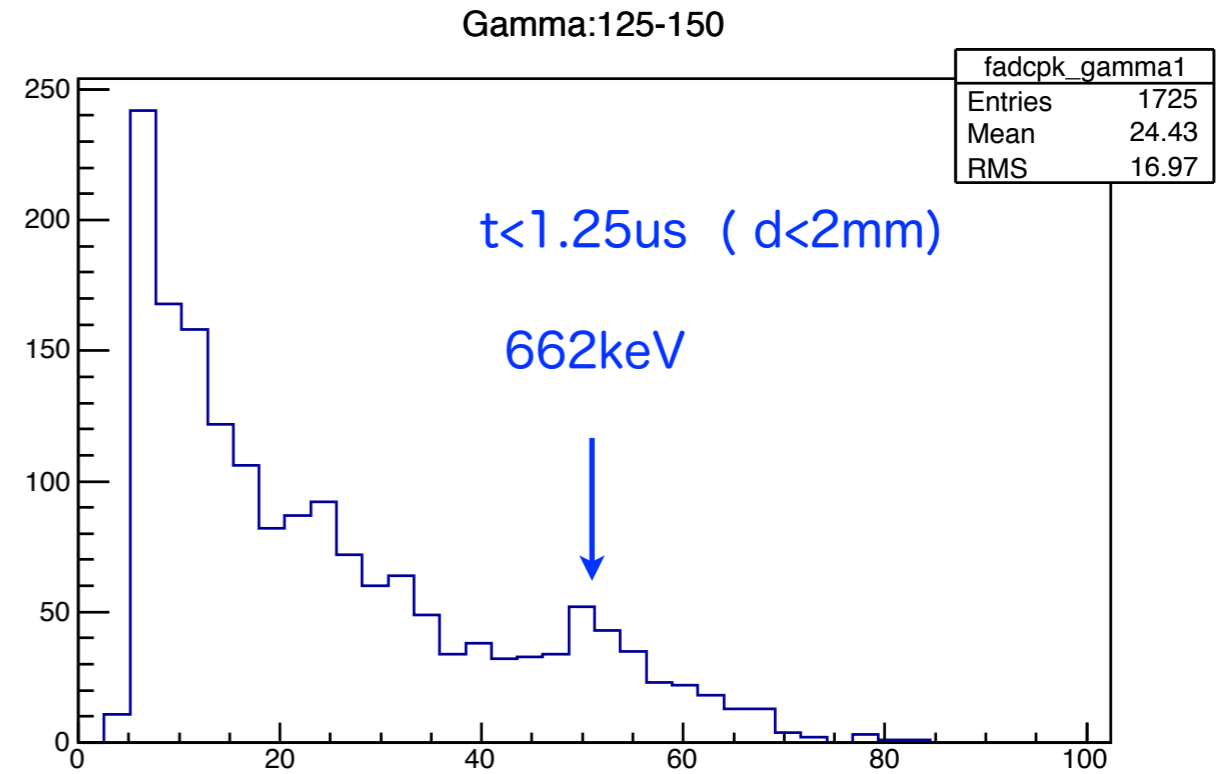
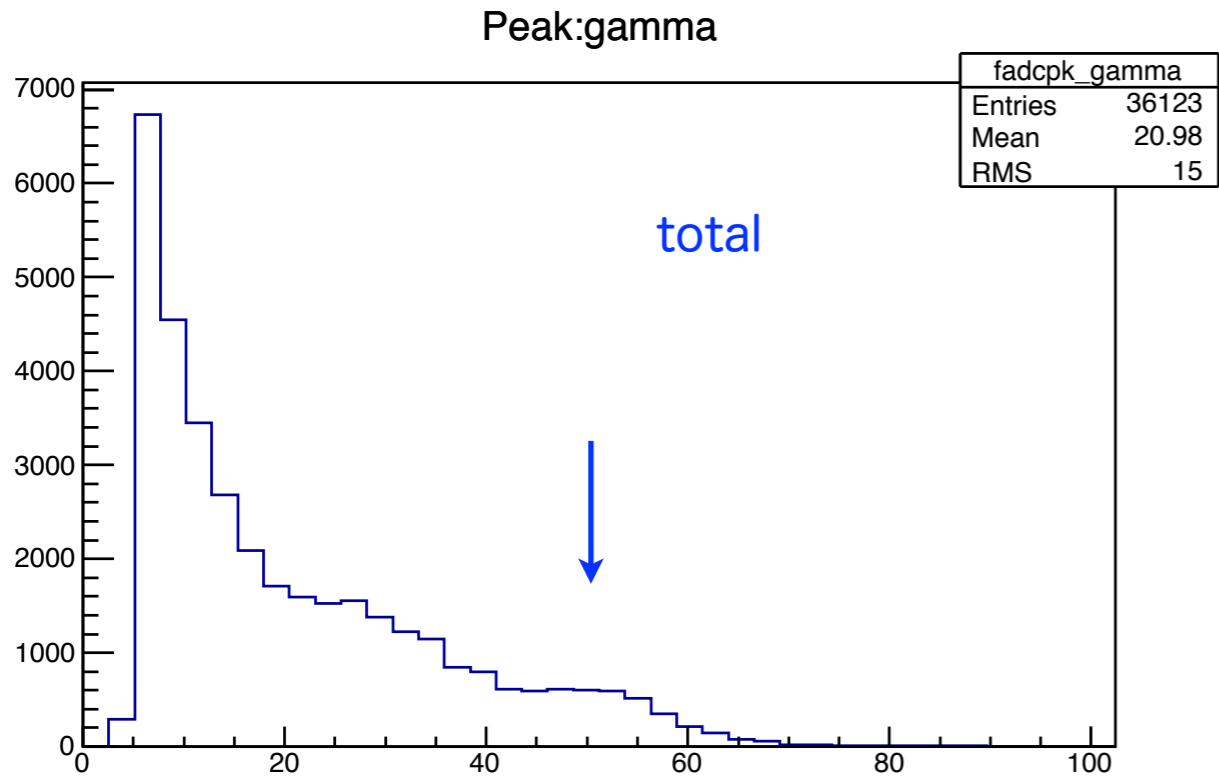


note : the anode plane at 125

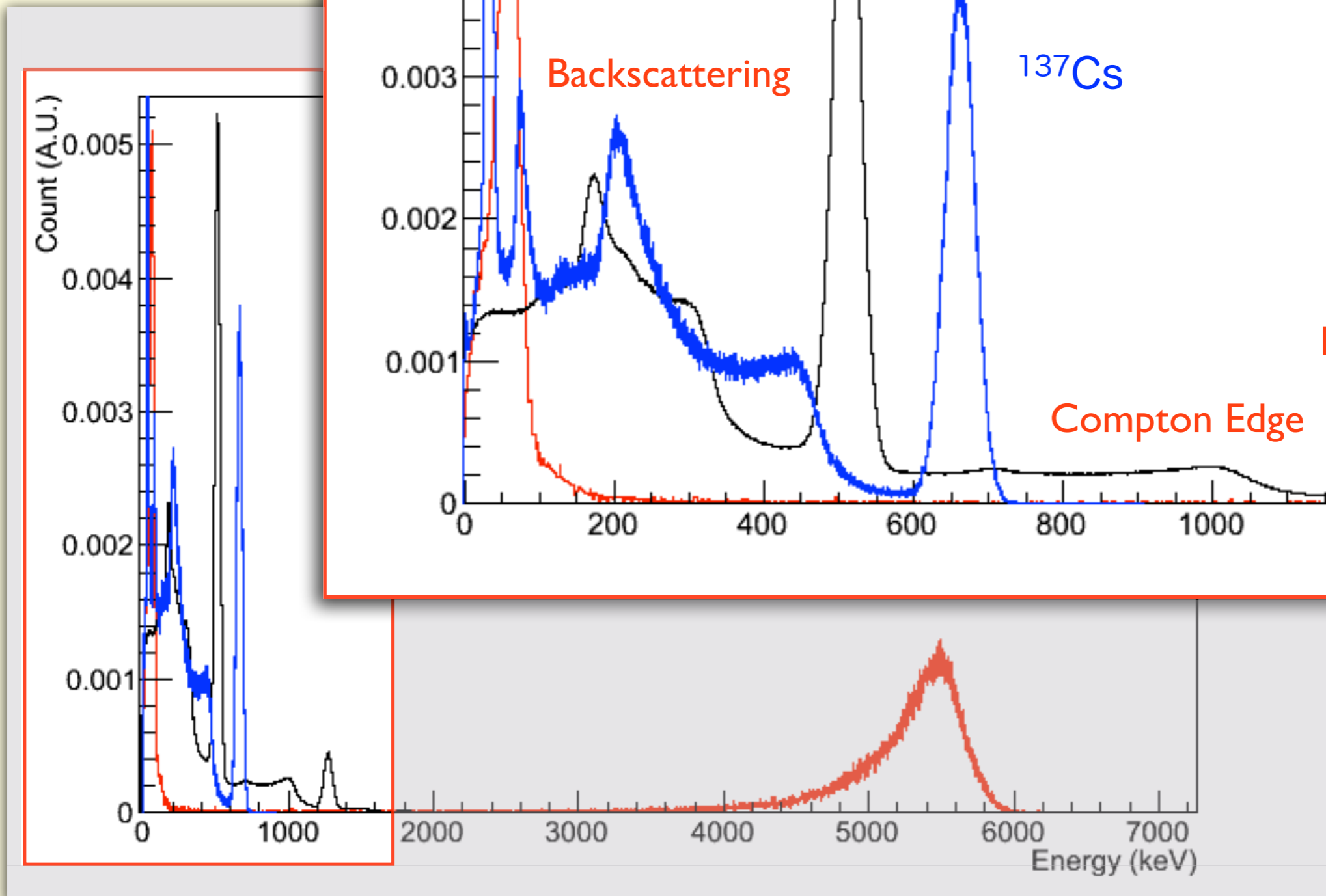
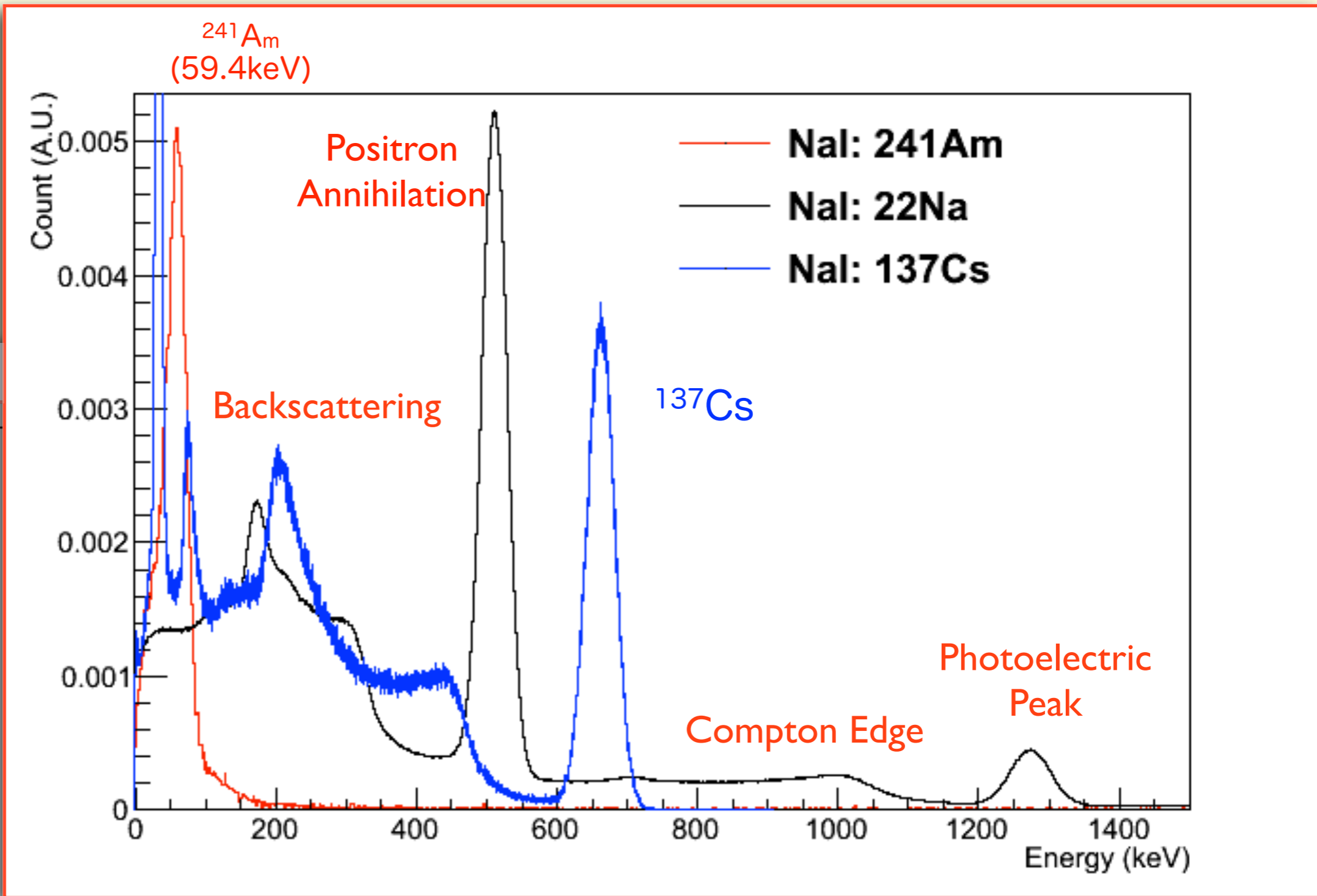


note : the anode plane at 125

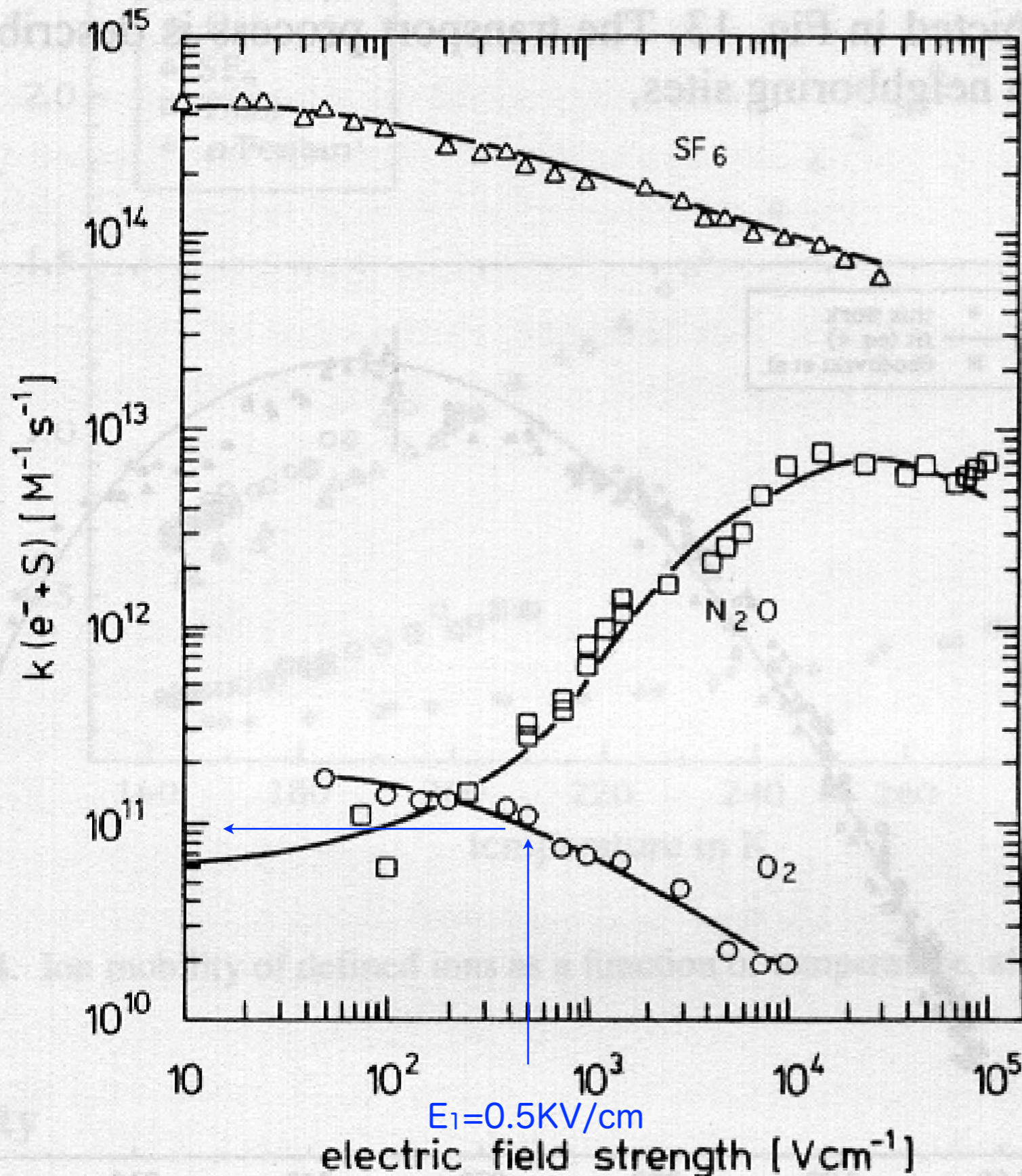
Charges/pad (peak of D-Gaussian fit) of γ , 2012.12.10-2-13.1.19



γ Spectra by the second team, EDIT2013, 2013.3.19



Attachment rate constant k and Purity



O_2 equivalent

$$k(\text{O}_2) = 4.5(10) \times 10^{10} \text{ L/mol/s}$$

at $E = 2(0.5) \text{ kV/cm}$

1.0 L/mol of liquid Xe :

$$1000 \times 3.06 / 131.3 = 23 \text{ mol}$$

$$k(\text{O}_2) = 1,035(2,300) \text{ ppb/s}$$

electron lifetime time τ :

$$\tau = 1/k$$

$$\tau = 966(435) \mu\text{s/ppb}$$

attenuation length λ :

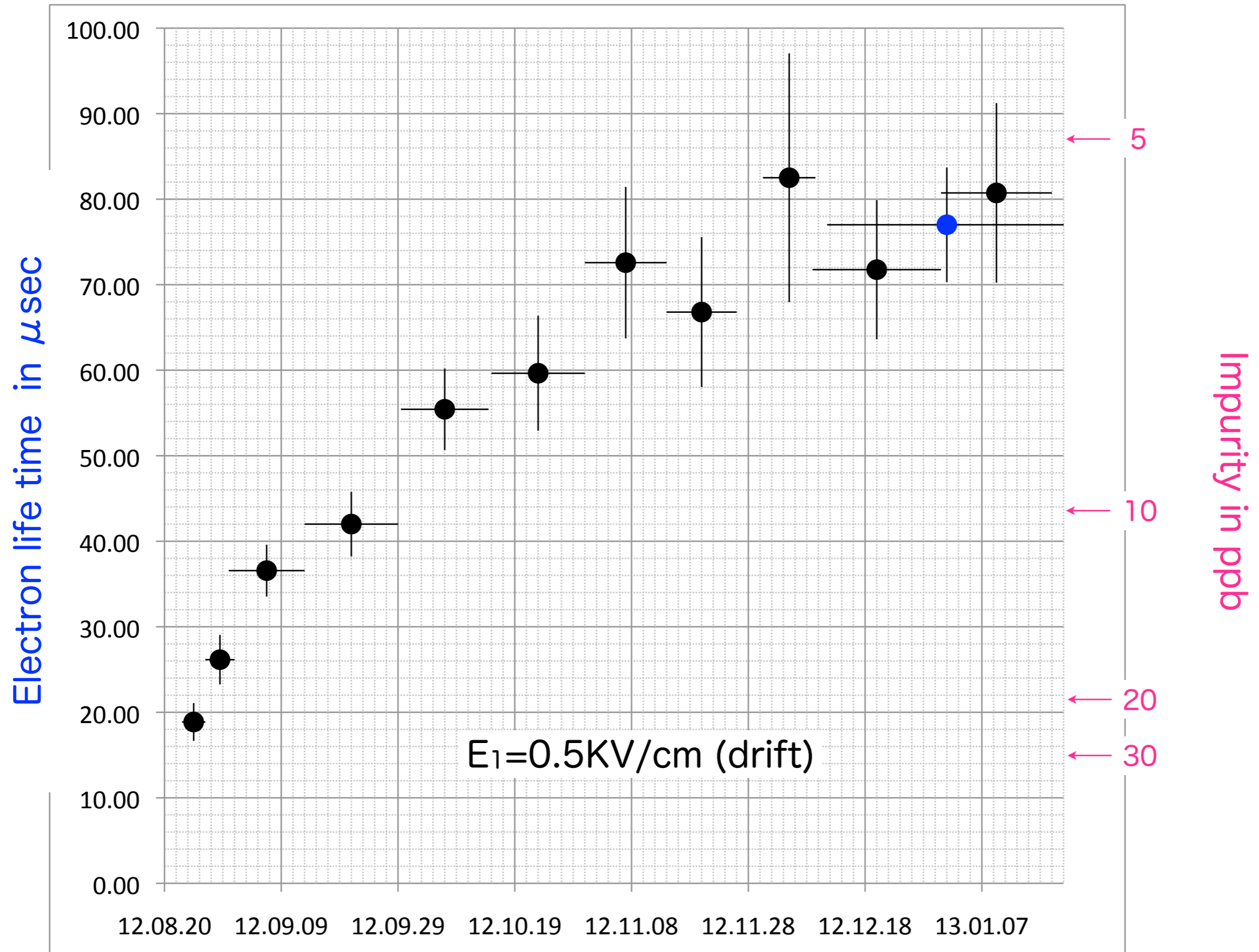
$$\lambda = v_d \times \tau$$

$$\lambda = 2.1(0.7) \text{ m/ppb}$$

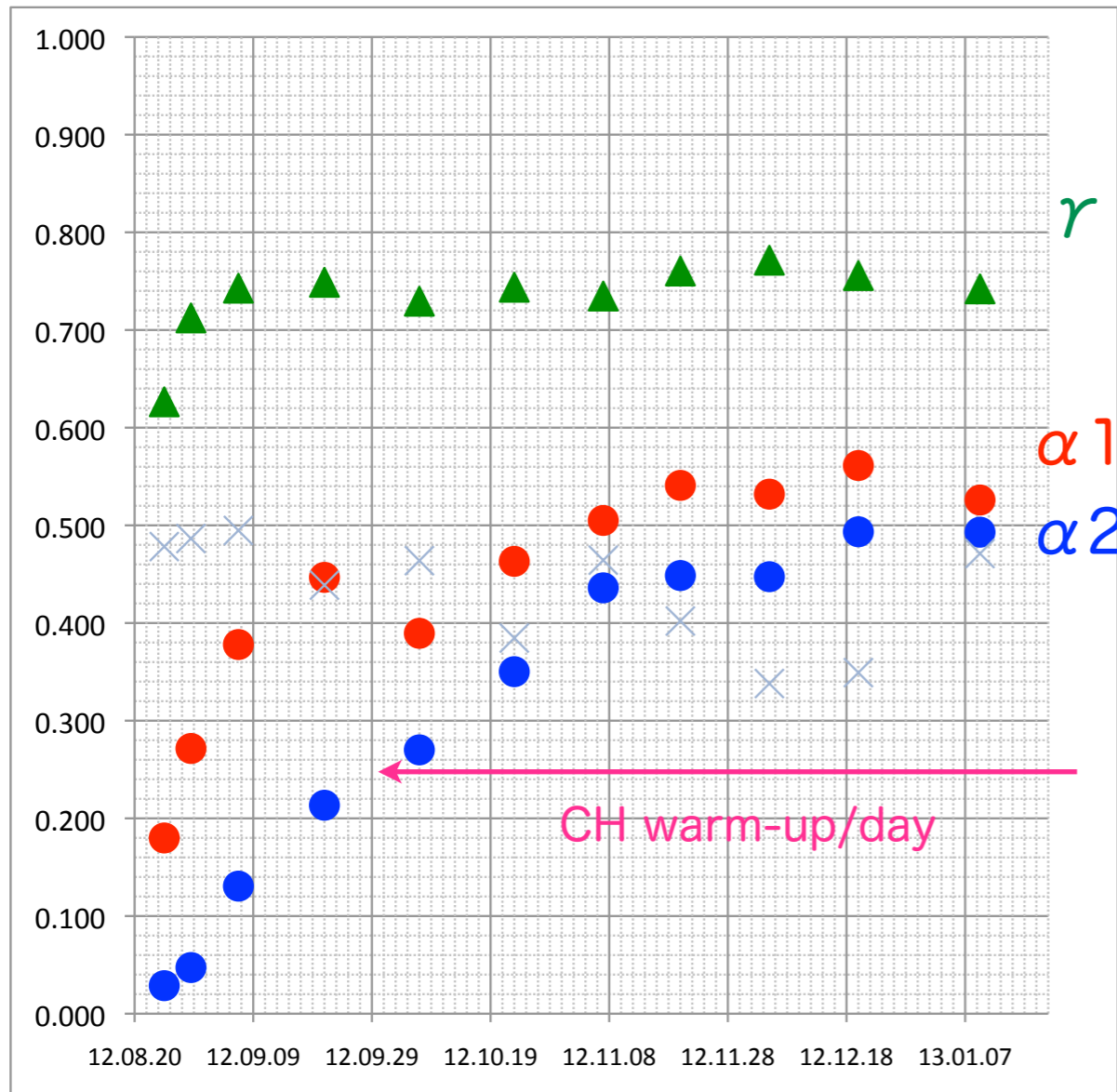
$$v_d = 2.2(1.6) \text{ mm}/\mu\text{s}$$

Electron life time and impurity in Liquid Xe

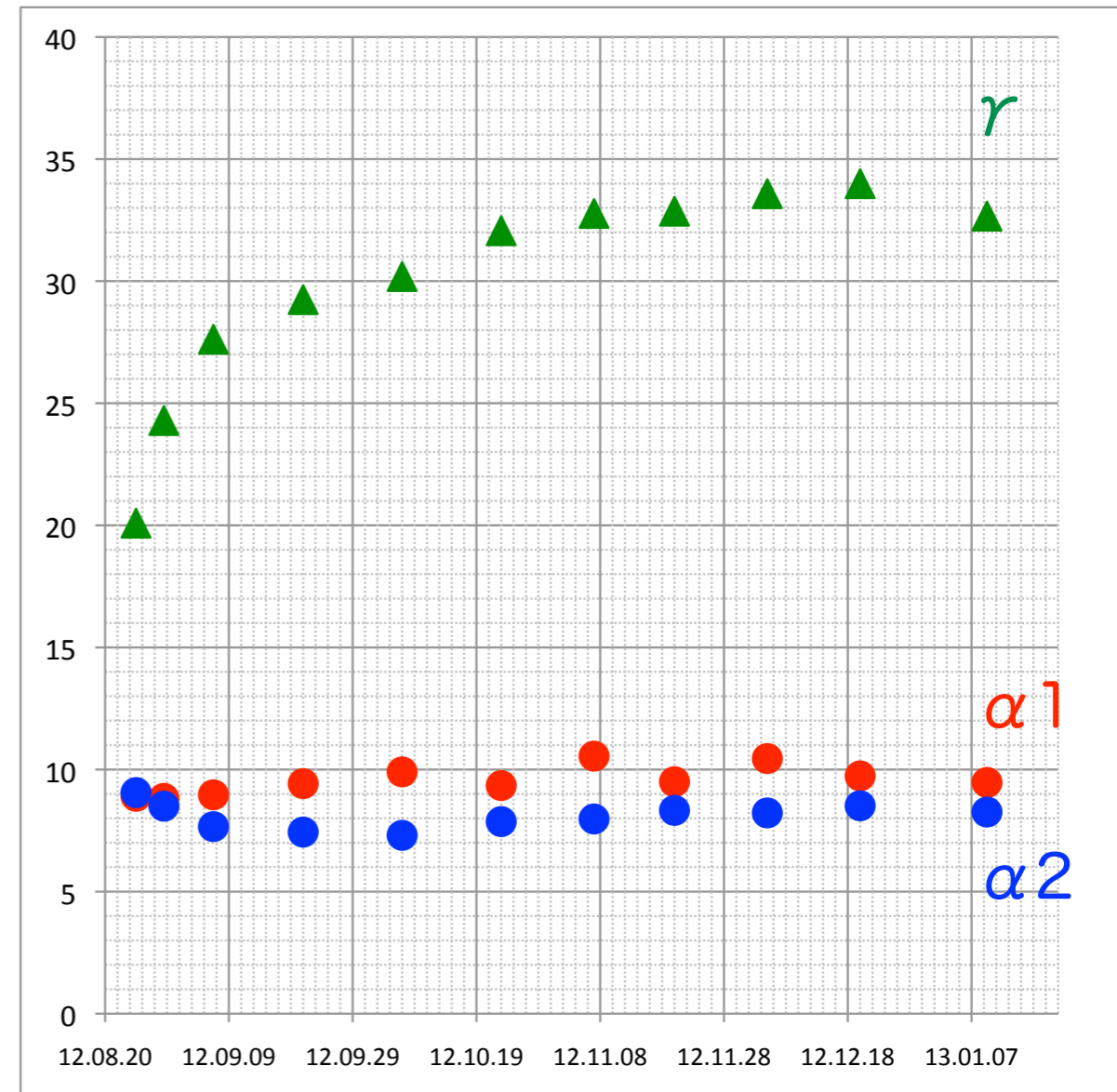
2012.8.23-2013.1.19



Efficiency of charges



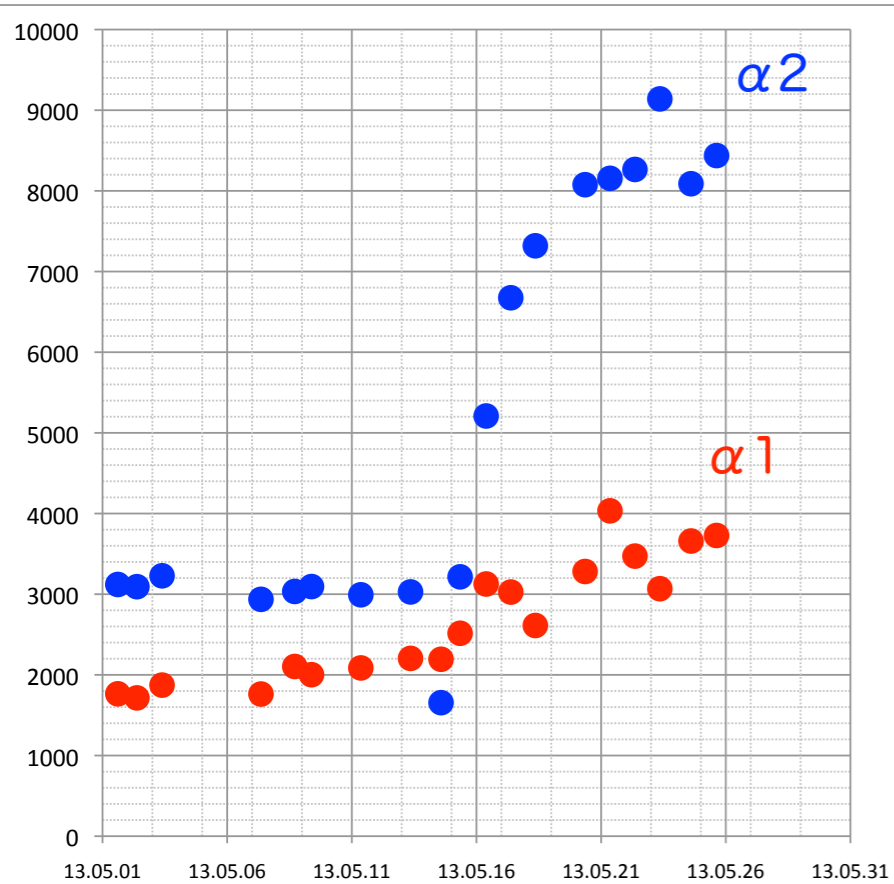
Average charge



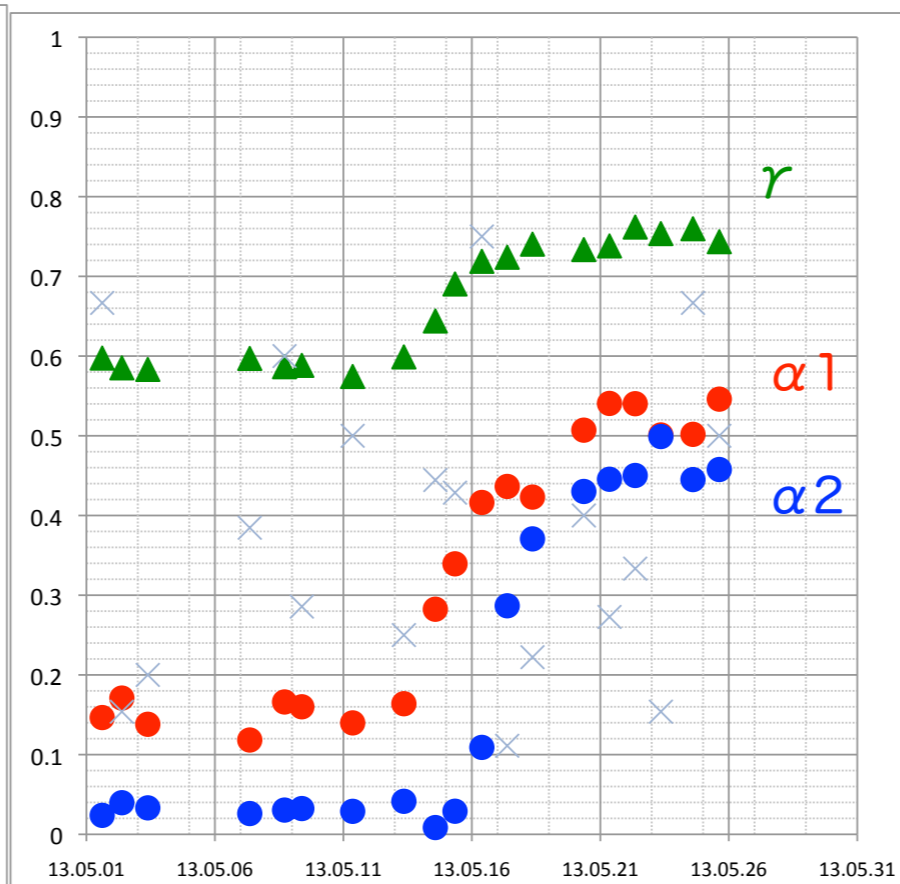
Recovery of signal charges

Circulation started at 8:55am, 14 May, 2013.

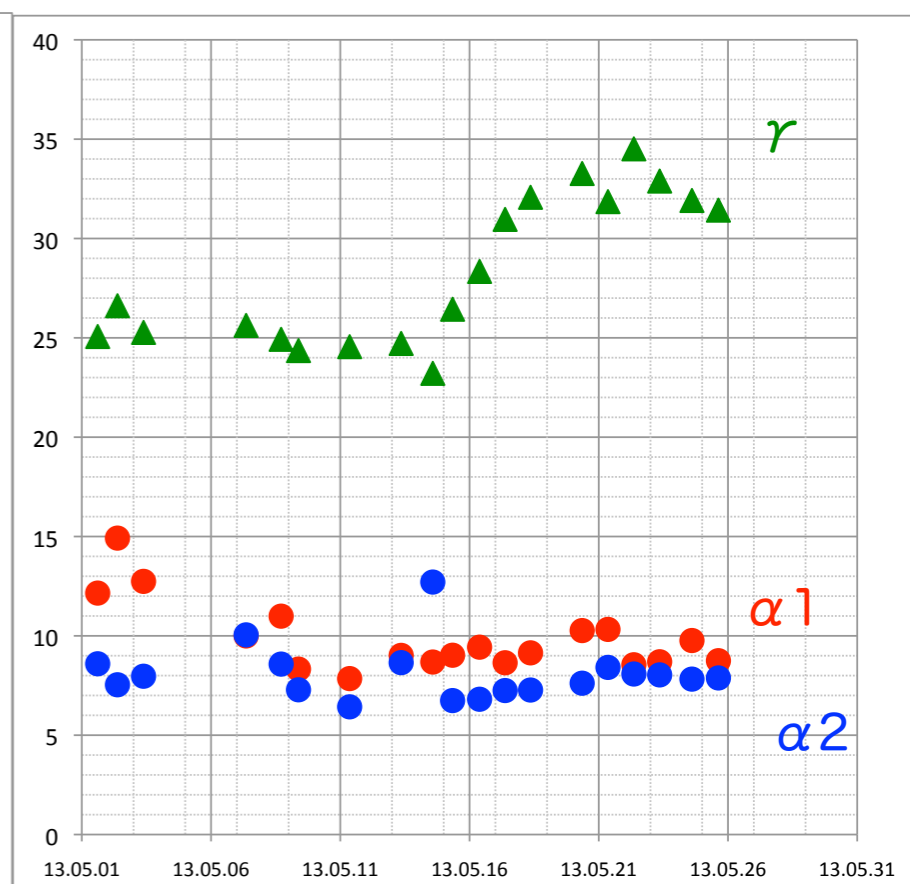
total sum of charges



efficiency

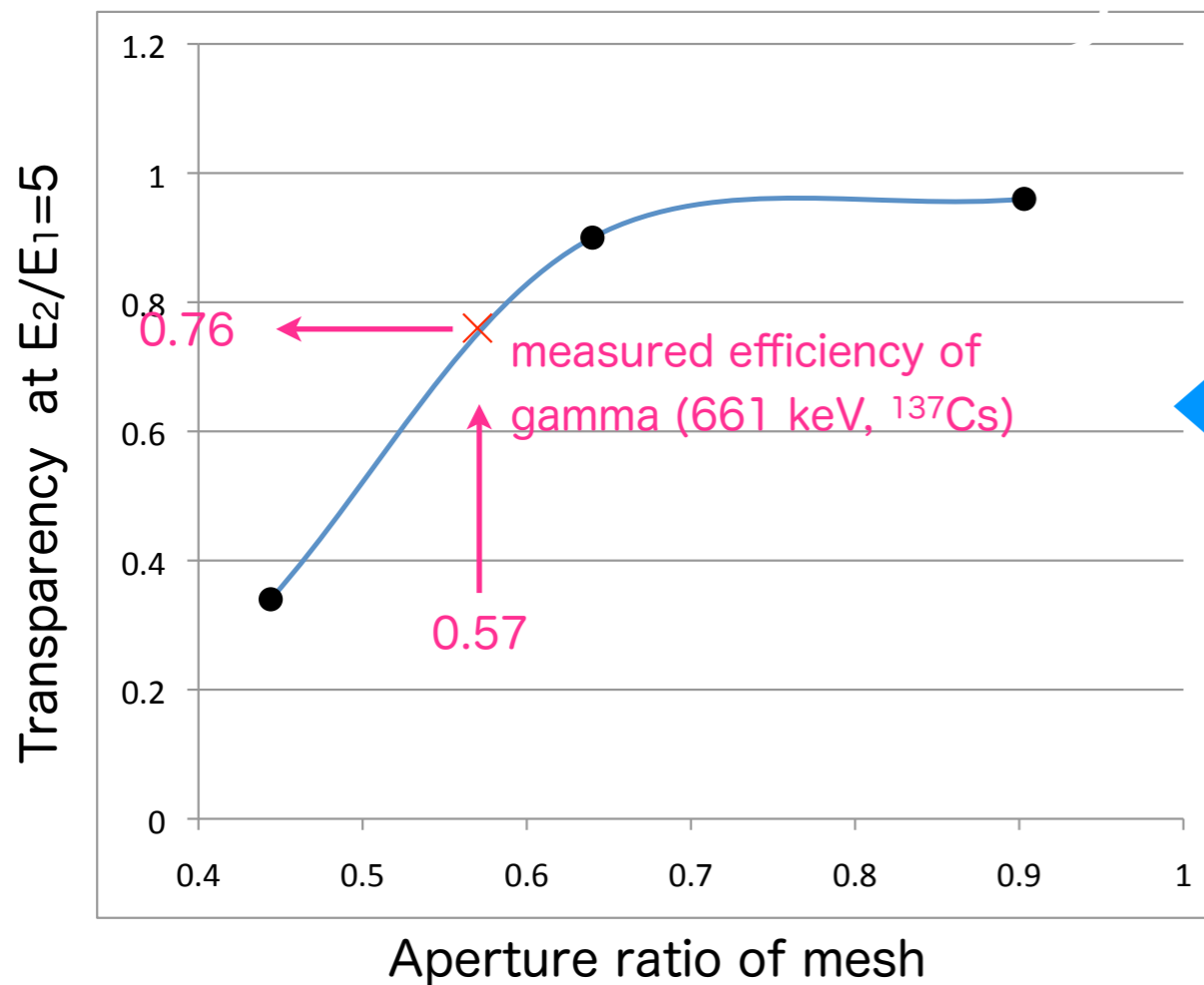
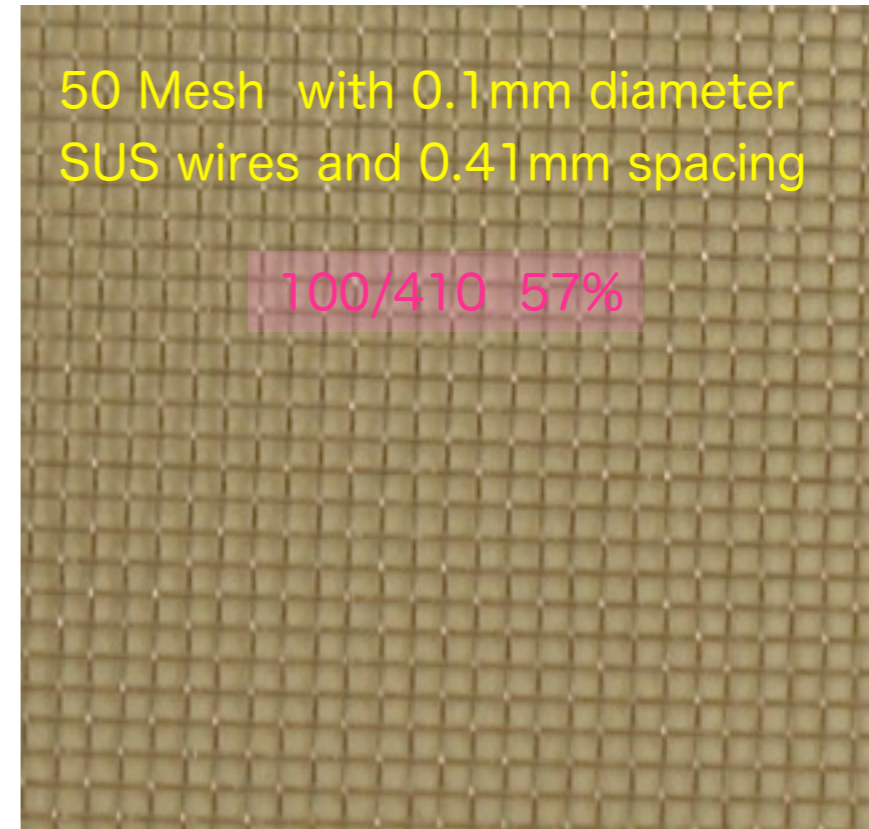


average charge/pad

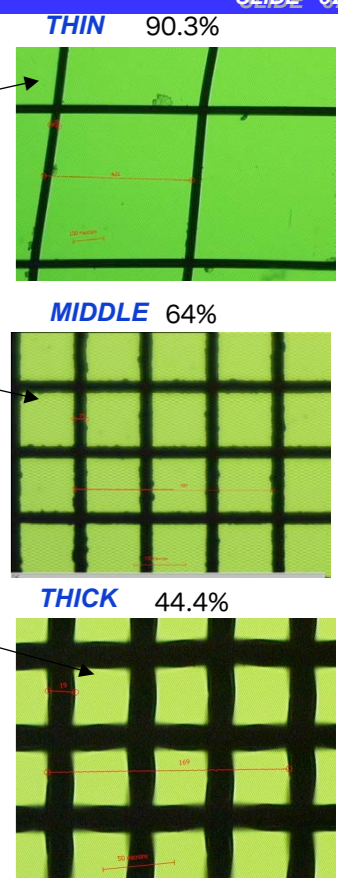
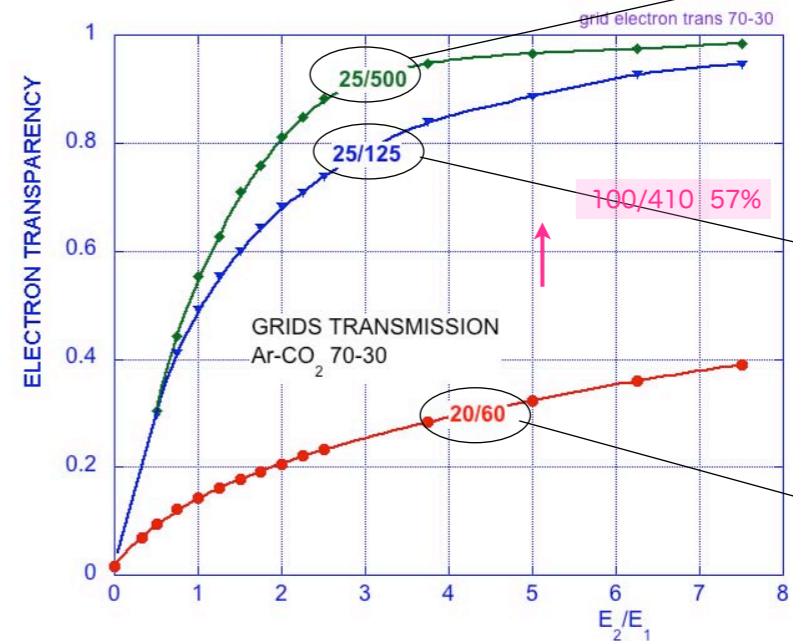


Estimation of the grid transparency

Our mesh for the grid

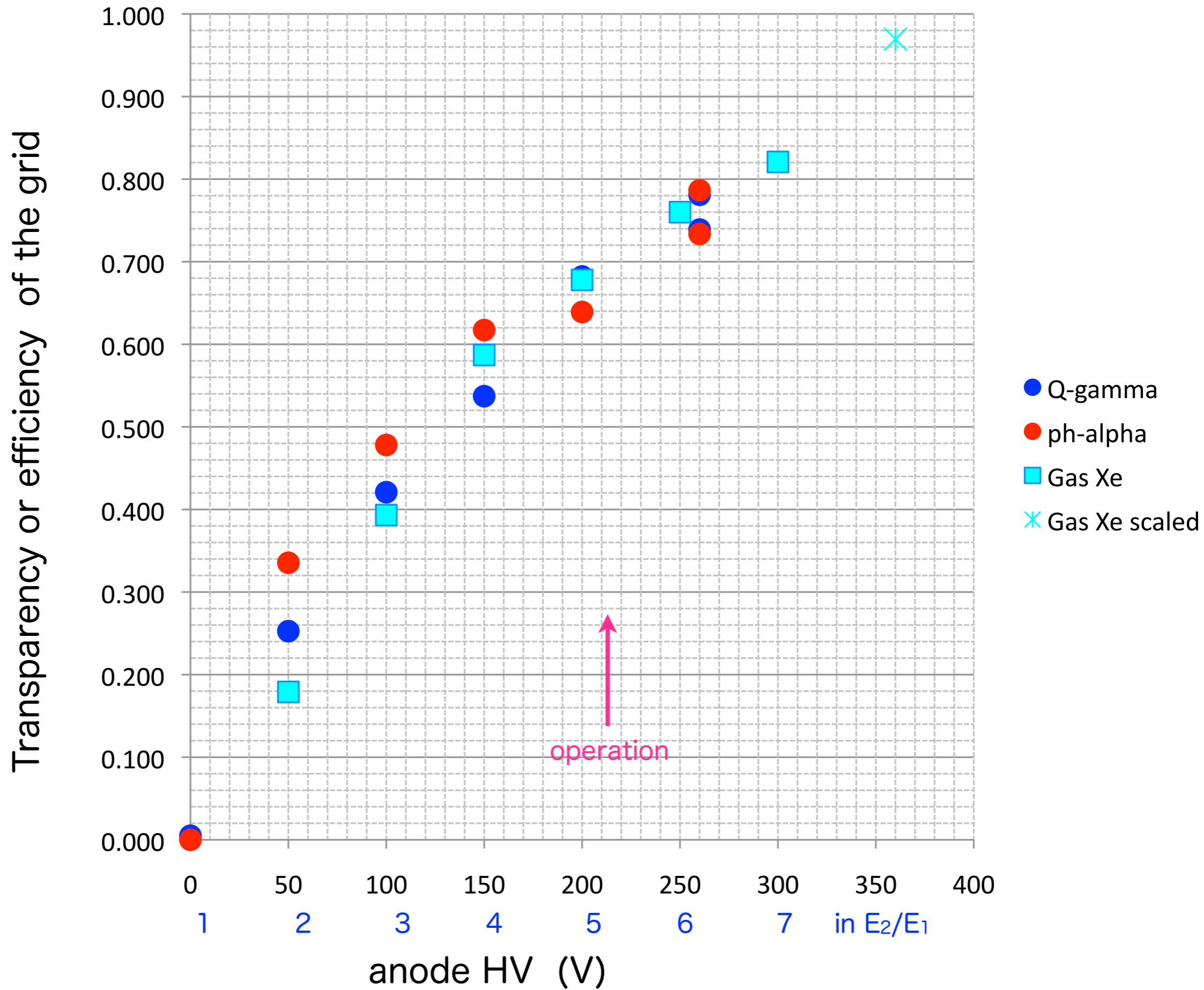


MESH TRANSPARENCY

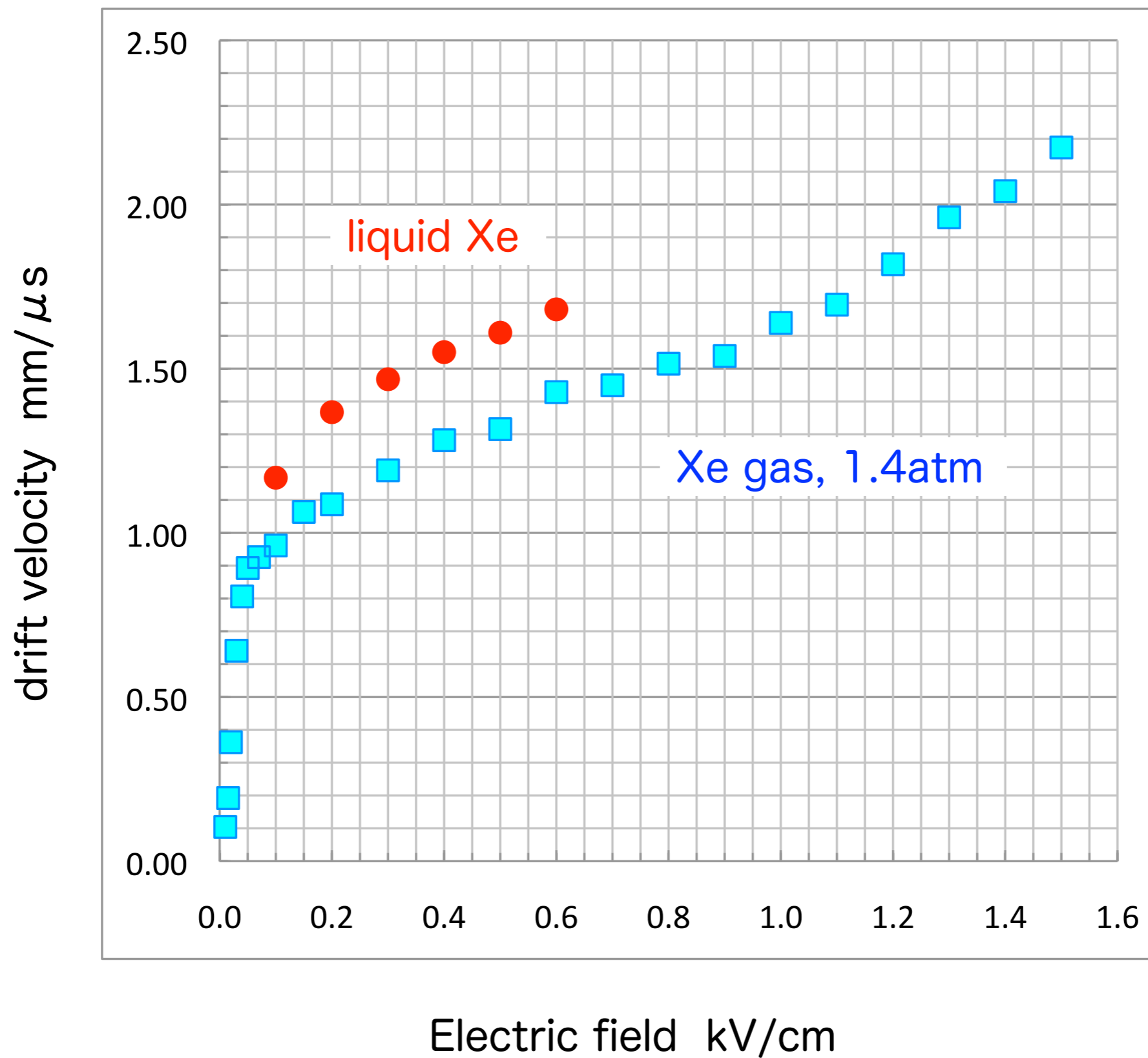


HIGH FIELD RATIO REQUIRED FOR GOOD TRANSMISSION!

P. Everaerts et al, IEEE Nucl. Sci. Symp. (San Diego, Oct. 2006)



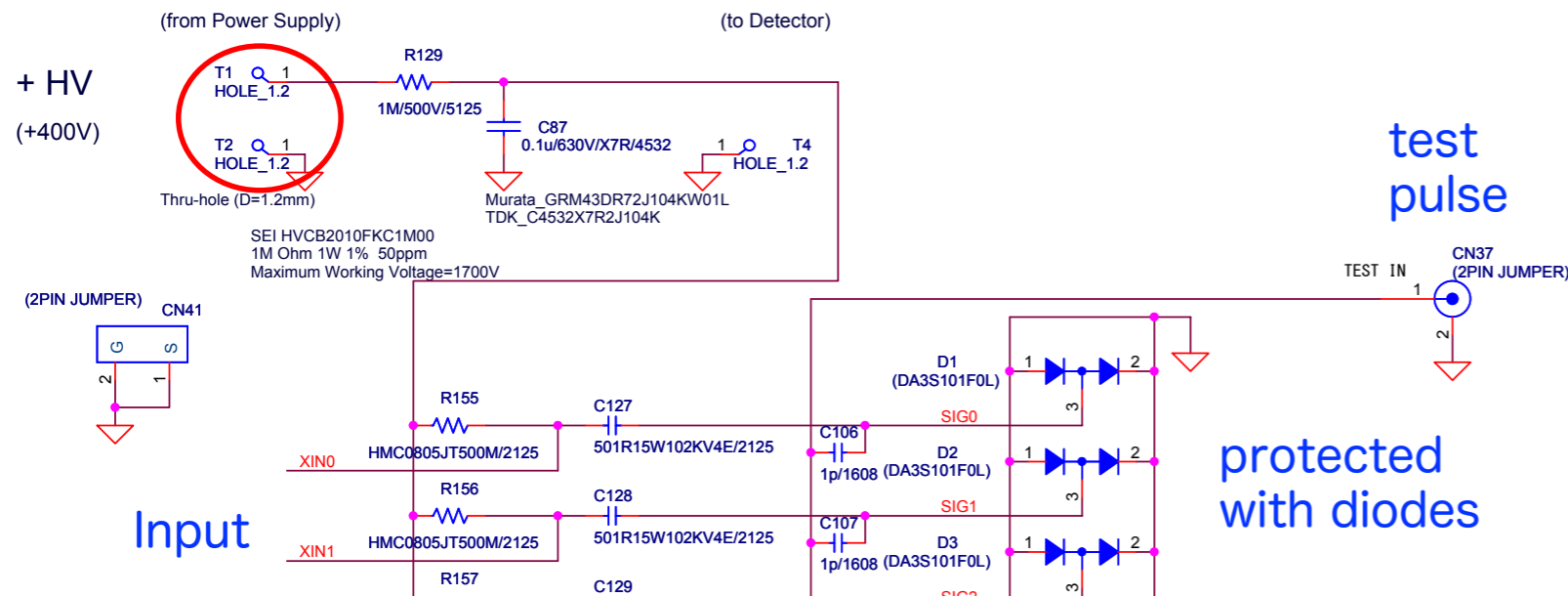
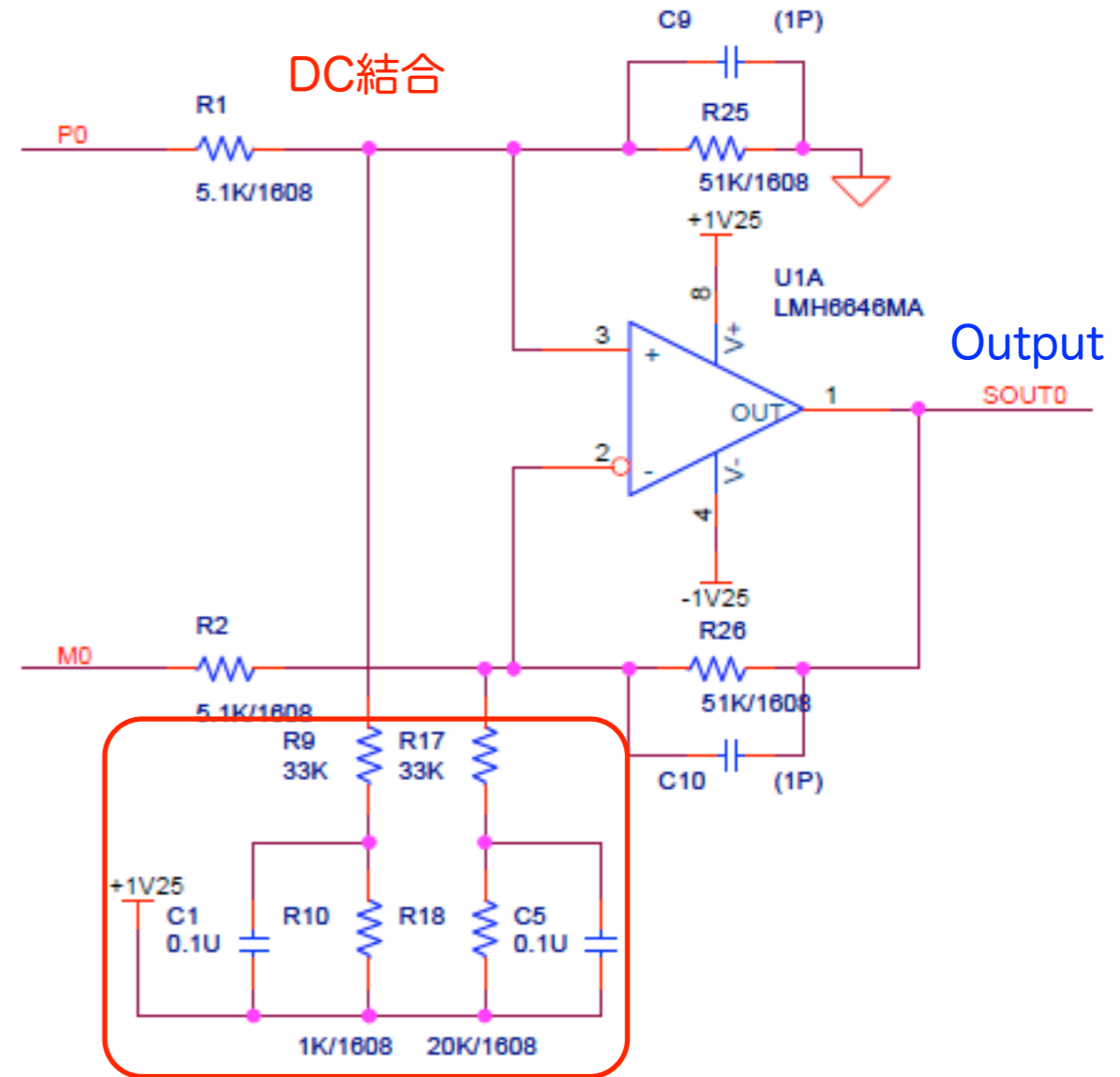
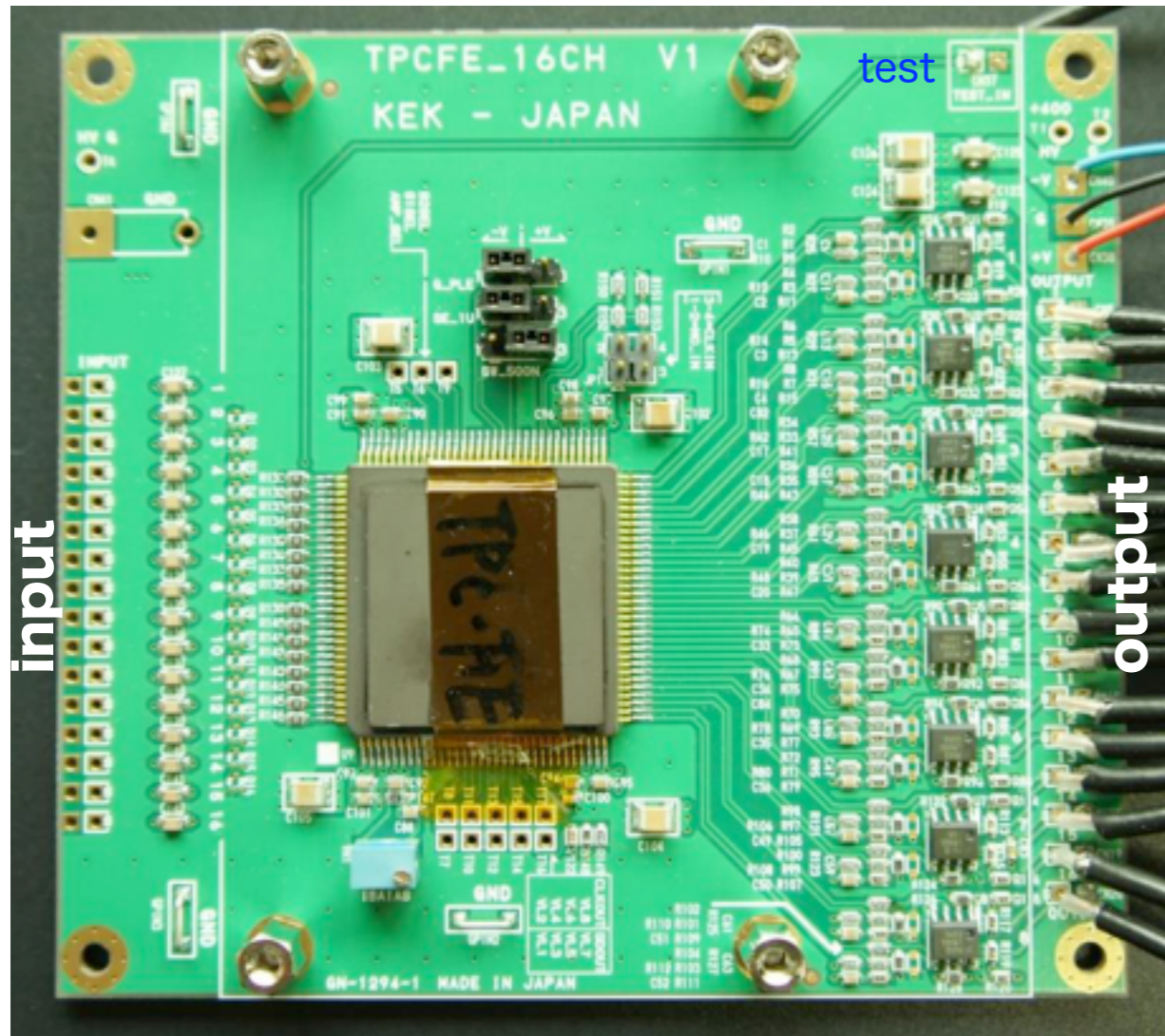
Drift velocity in Liquid Xe



Mother board of TPCFE (16ch), version -1, for test, Jan-Mar 2013

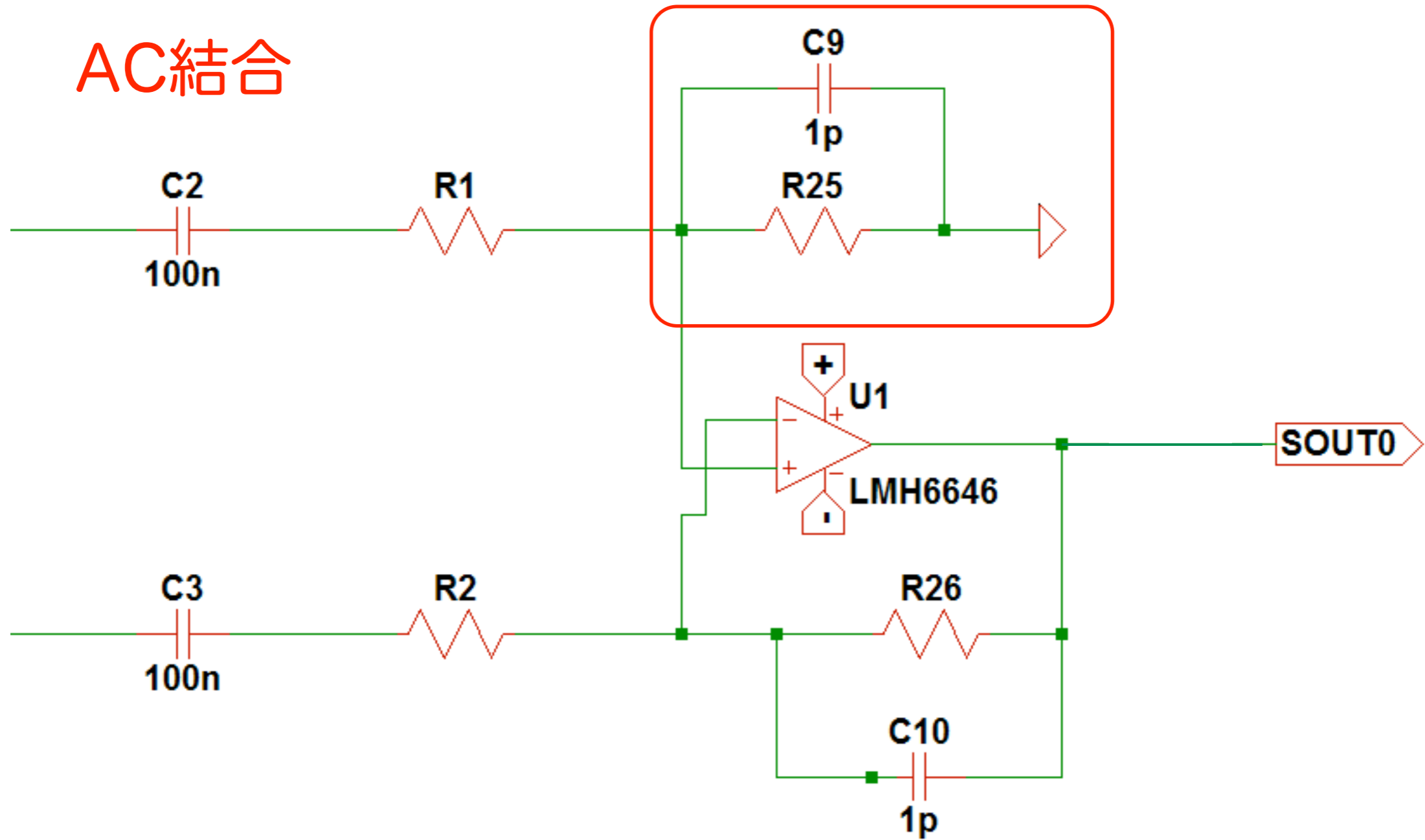
studied by Yuya Iwazaki, Yokohama National University

GN-1294-1(FR4), based on Takagi's M thesis



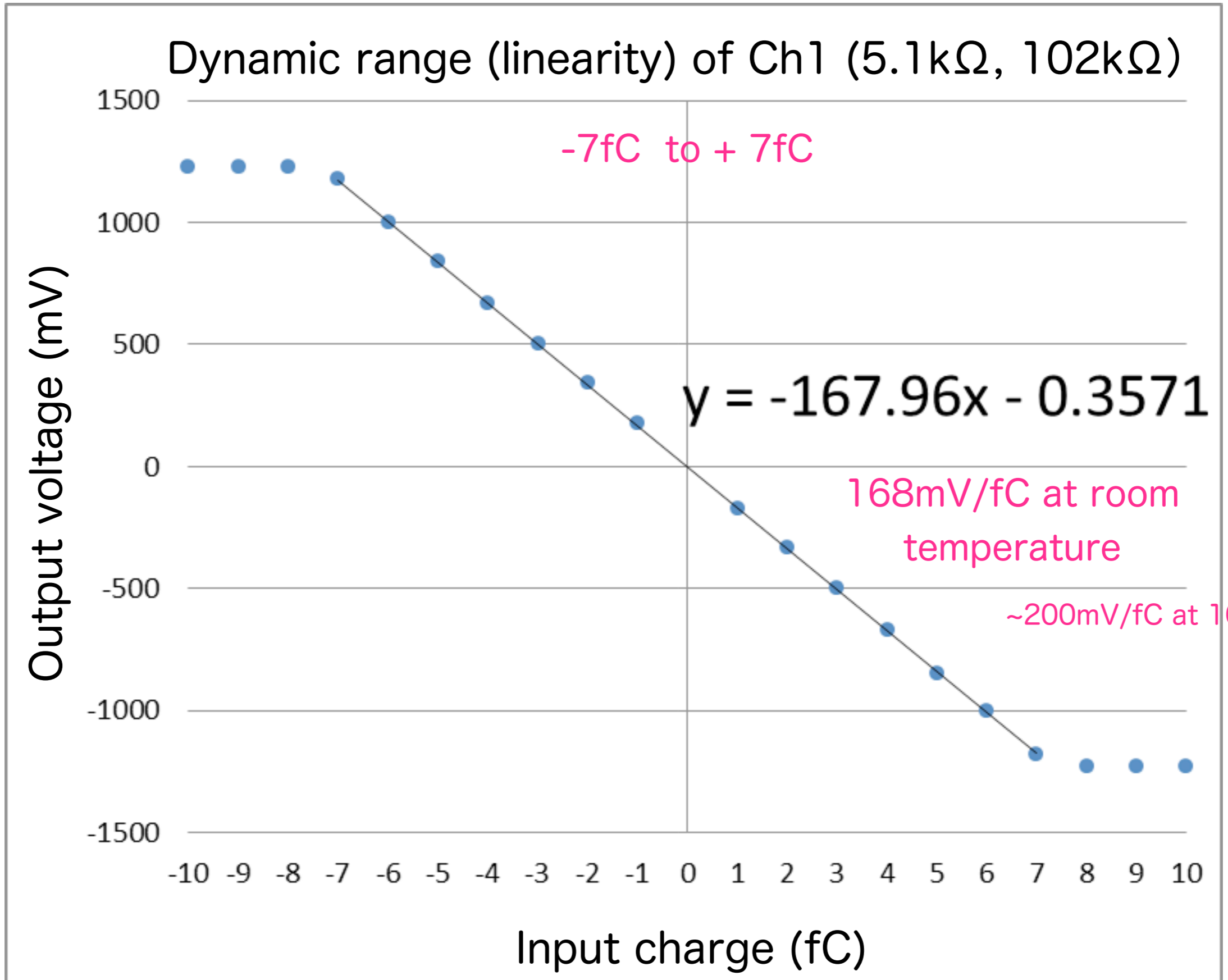
AC結合

DCリターン



$R1=R2=5.1k\Omega$: $R25=R26=100k\Omega$ Gain=19.6 → GN-1294-2(LTCC)

GN-1294-2(LTCC)



Summary

1. Preamp : Al 16 ch OK (2012.July - 2013 May)
2. Purification : gas circulation at $1.3 \ell / \text{min}$ for about three months
8/23-9/9 (17days) smooth increase of charge signals followed with saturation
10/-12/10 (71days) increase with CH warm-up/day followed with saturation
3. Impurity estimated by γ spectrum of ^{137}Cs (662keV, Compton edge)
after 2nd saturation : life time= $77 \pm 7 \mu\text{s}$, attenuation $L.=12 \pm 1 \text{cm}$, 6ppb
4. Grid transparency as a function of E_2
good agreement with the expectation from the micro-megas results
transparency= 0.76 at $E_2/E_1=5.2$, mesh aperture= 0.57
5. Drift velocity as a function of E_1
 $1.6 \text{mm}/\mu\text{sec}$ at $E_1=0.5 \text{kV}/\text{cm}$ ($1.3 \text{mm}/\mu\text{sec}$ in Xe gas at 1.4atm)
6. Preparation of TPCFE09 (ASIC) in the chamber
 $168 \text{mV}/\text{fC}$, $-7 \text{fC} < Q_{\text{in}} < +7 \text{fC}$ at room temperature by simulation and test bunch
 $0.2 \text{V}/\text{fC}$ expected at 165K (peaking time = $1 \mu\text{sec}$)

TPCX : Plan in 2013

- (1) Noise reduction by isolation of He compressor
as much as possible
- (2) Readout of 16ch with TPCFE09
radiation sources: ^{22}Na above the anode, $\alpha 2$ @cathode
- (3) Increase of gas circulation by adding a PTR
- (4) In addition, heat exchanger with vacuum
insulation will be used

つくば国際戦略総合特区

産学官マッチング・デイ2013

—つくばの科学技術との出会い—

主催 つくばグローバル・イノベーション推進機構

協力 筑波大学、高エネルギー加速器研究機構、防災科学技術研究所、農業・食品産業技術総合研究機構、国立環境研究所

後援 茨城県、つくば市

●つくばを中心とする地域が、総合特別区域法に基づく「国際戦略総合特区」に指定され、大学・独法研究機関等の枠を超えたイノベーションの仕組みを目指しています。

●今回の「産学官マッチング・デイ」では、つくばの大学・研究機関の技術シーズを創造し、産業界からの幅広い目でもみたマッチングの仕組みを進めます。

開催日

平成25年
6月25日(火)

開場時間13:00~16:30

開催場所

つくば国際会議場
大会議室101

〒305-0032 茨城県つくば市竹園2丁目20-3
【つくばエクスプレスつくば駅より徒歩10分】
【駐車場あり(有料)】

参加申込方法

●事前に下記WEBサイトにアクセスし、フォームよりお申込みください。
(当日参加も受け付けます)。

<http://www.tsukuba-sogotokku.jp/matchingday2013/>

●出展者の技術シーズ概要を、WEBサイトで公開しています。事前に閲覧していただくことをお勧めします。質問等、事前にいただければ、スムーズに対応できます。

<http://iblc.co.jp/tsukuba/contents/> (上記のWEBサイトからもアクセス可能です)

出展技術シーズ一覧

●出展者の技術シーズ概要を、WEBサイトで公開しています <http://iblc.co.jp/tsukuba/contents/>

1	生体親和性レドックス機能を有する高分子ナノ粒子	長崎 幸夫 教授	筑波大学
2	大腸内視鏡検査における癌検出を支援する鉄イオンセンサーの技術開発	金子 剛 講師	筑波大学
3	健康長寿に働く長寿遺伝子活性化物質の探索と開発	坂本 和一 准教授	筑波大学
4	ナノ/マイクロサイズに制御された高効率物質内包りポソームの製造技術の開発	市川 創作 教授	筑波大学
5	リチウムイオン二次電池用高性能正極材料の開発	小野田 雅重 准教授	筑波大学
6	バリウム・シリサイド(BaSi2)半導体による高効率薄膜太陽電池の開発	末益 崇 教授	筑波大学
7	ガラス基板上に作成したゲルマニウム薄膜による高効率・低コスト太陽電池の開発	都甲 薫 助教	筑波大学
8	使いやすく高性能な新型ニューラルネット	森田 昌彦 教授	筑波大学
9	高精細裸眼立体ディスプレイ	掛谷 英紀 准教授	筑波大学
10	ギガヘルツ級超高速デジタル信号の波形整形技術の開発	安永 守利 教授	筑波大学
11	自由視点映像技術を用いたスポーツ中継システムの開発	北原 格 准教授	筑波大学
12	eコミュニティ・プラットフォーム	臼田 裕一郎 主任研究員 田口 仁 研究員	防災科学技術研究所
13	汎用性のあるリアルタイム浸水予測システムの開発	中根 和郎 研究参事	防災科学技術研究所
14	液体キセノン検出器を用いた次世代PETの開発	田内 利明 准教授	高エネルギー加速器研究機構
15	マイクロパターンガス検出器による中性子・X線画像装置の開発	宇野 彰二 教授	高エネルギー加速器研究機構
16	小型高輝度光子ビーム発生装置開発とその基盤技術	浦川 順治 教授	高エネルギー加速器研究機構
17	低有機物濃度排水の無加温メタン発酵処理技術	珠坪 一晃 室長	国立環境研究所
18	表面にDNAが固定された新しいナノファイバー	岩浦 里愛 主任研究員	農業・食品産業技術総合研究機構
19	糖鎖自動合成も可能にする全自動固相ライブラリー合成装置の開発	今場 司朗 主任研究員	農業・食品産業技術総合研究機構
20	高機能乳酸菌の食品分野以外への応用展開 ～老化抑制、肌改善、脱毛抑制～	木元 広実 主任研究員	農業・食品産業技術総合研究機構

出展大学・研究機関

- 筑波大学
- 高エネルギー加速器研究機構
- 防災科学技術研究所
- 農業・食品産業技術総合研究機構
- 国立環境研究所

交通アクセス

- ◆電車: つくばエクスプレスつくば駅A3出口を出る。
A3出口前 券売所の手前を右折。
階段を上り歩行者専用道路を直進、徒歩10分。
- ◆バス: 「つくばバスセンター」4番乗場「学園南循環」に乗車。「つくば国際会議場停留所」にて降車。
- ◆車: 有料駐車場があります。
(北駐車場・南駐車場160円/時、南2・3・4 220円/時)



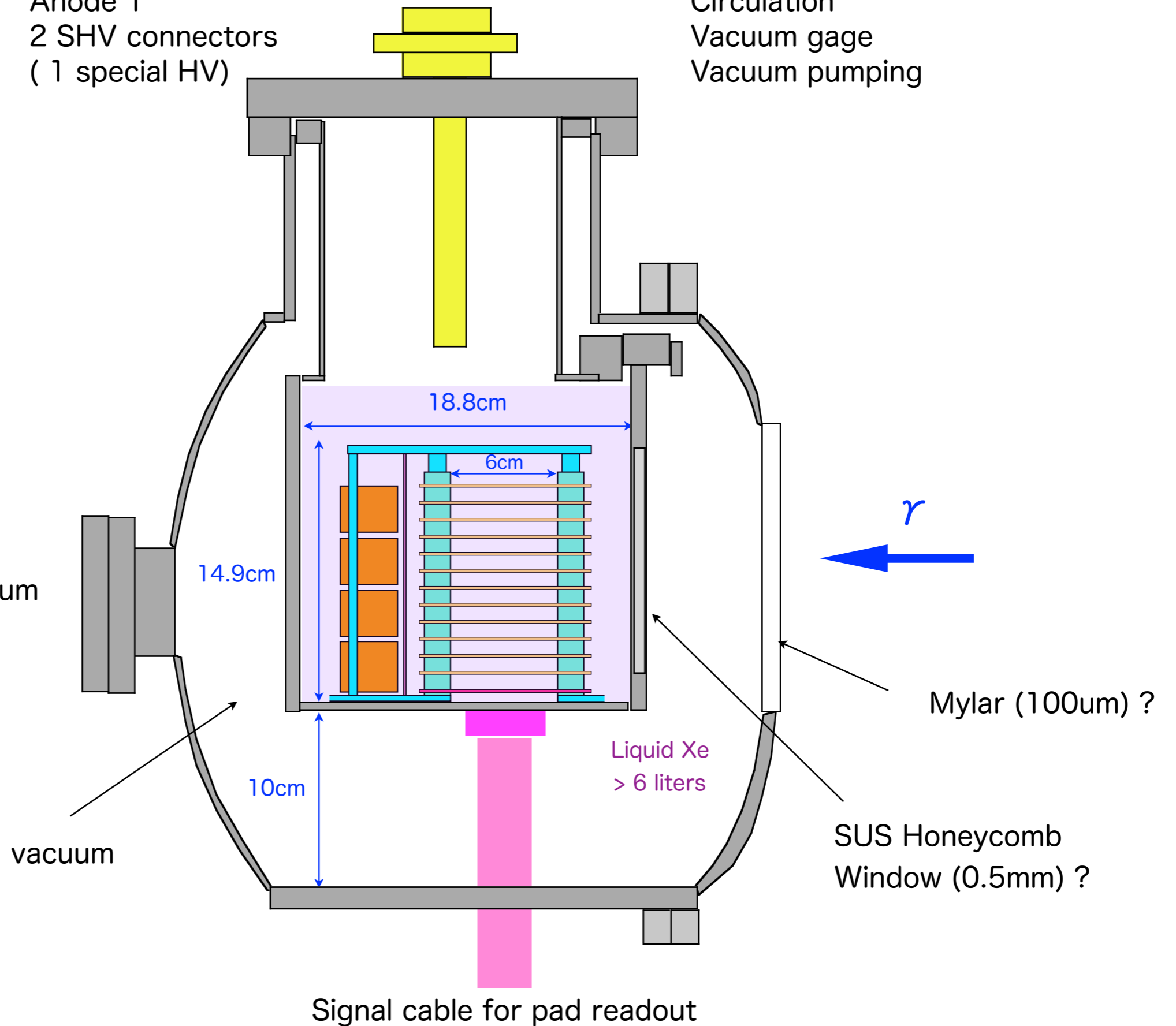
主催者連絡先 つくば・グローバルイノベーション推進機構 col@abo.system@un.tsukuba.ac.jp

Nice poster to be shown in our exhibition booth

PMT (in 4x2 matrix)
HV cables 8
signals 8
16 SHV connectors

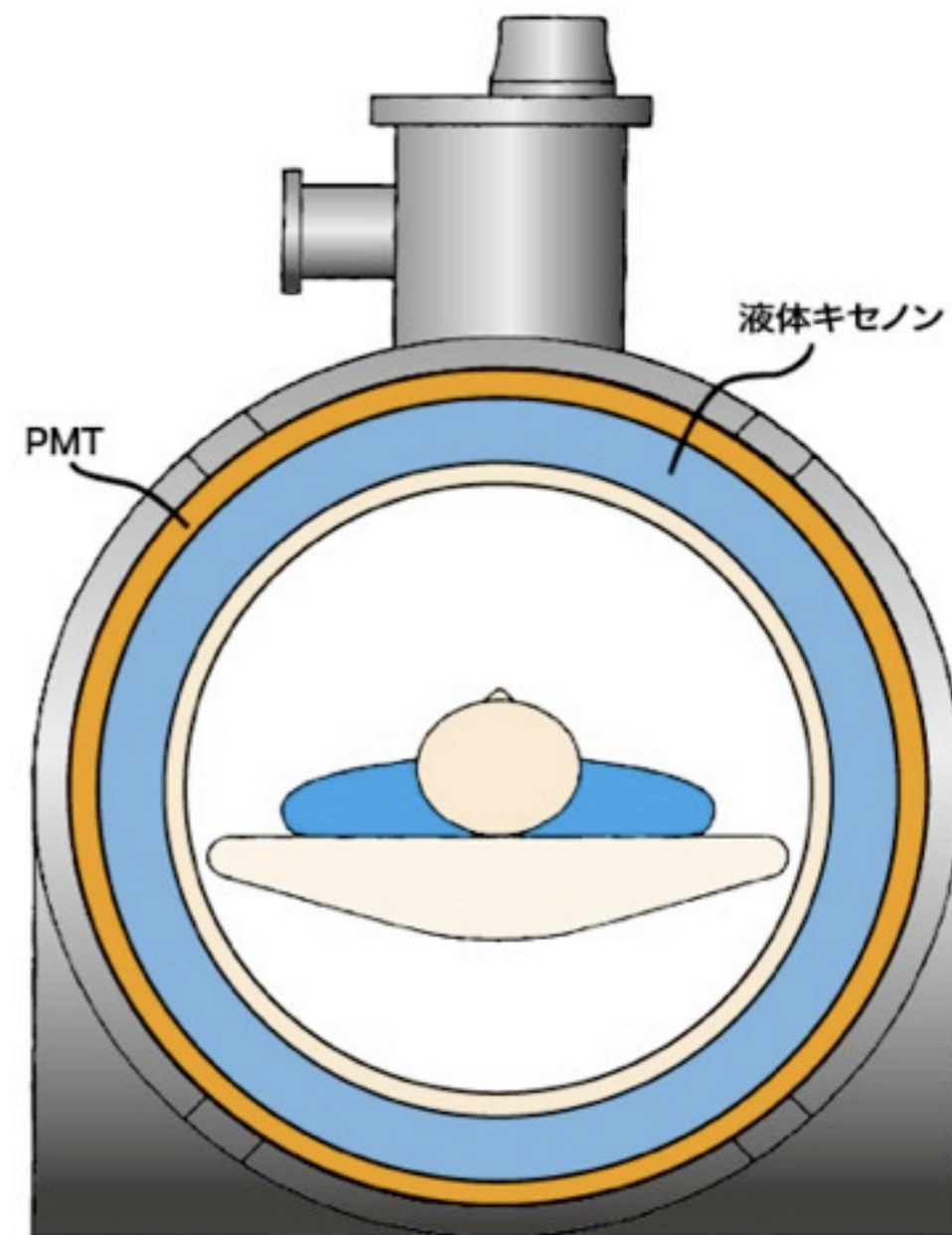
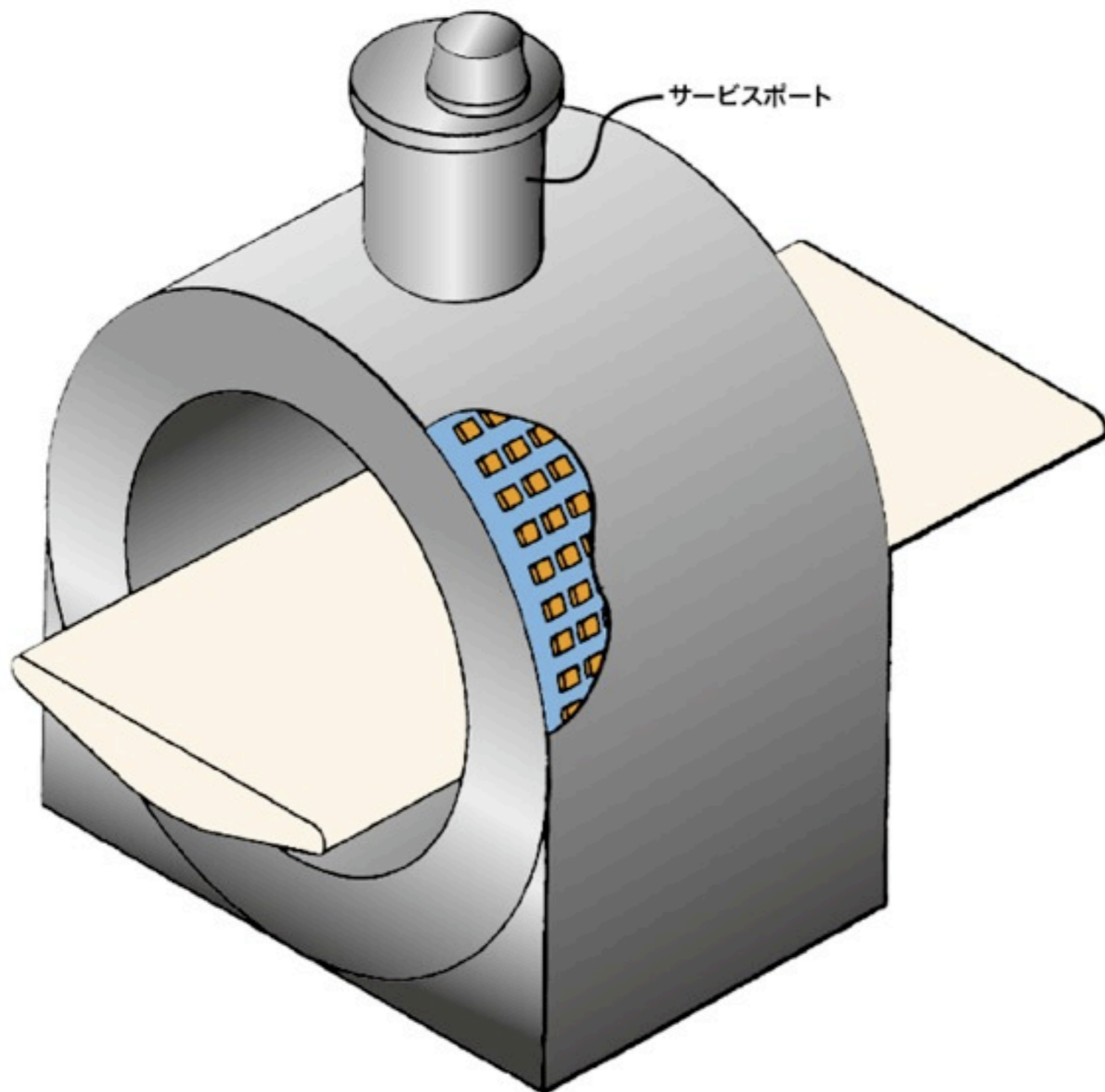
TPC
Cathode 1
Anode 1
2 SHV connectors
(1 special HV)

PTR
Heat exchanger
Circulation
Vacuum gage
Vacuum pumping

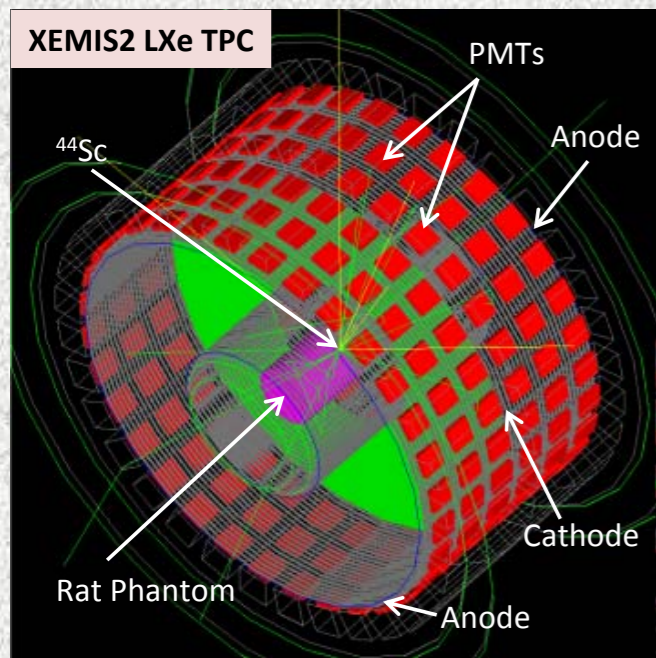


Next-generation PET with LXeTPC

TXePET



XEMIS2 pre-design study for small animal imaging with GATE



Cylindrical camera XEMIS2 (~ 100 kg LXe)

- radial $8 < r < 20$ cm
- axial (z) Length = 2×12 cm
- Electric Field in z direction 2 kV/cm
- 192 PMTs
- Micromegas ionization read-out
- FEE Idef-X, pixels 3.175×3.175 mm² (~25k channels)

TPC characteristics

- Intrinsic energy resolution: 5% @ 511 keV
- Spatial resolution: 0.5 mm (X, Y and Z)

R&D on liquid Xenon detector technology, presented by Wan-Ting Chen, FJPPL2012, Clemond-Ferrand, France, 28-29 May, 2012

Performances (simulation in progress, PhD student: A.F. Mohamad Hadi)

- Efficiency to measure LOR: 30%
- Efficiency to measure 1.157 MeV γ -rays: 43%
- 3 photons efficiency (after selection): ~5%
- Precision on localization along LOR ~ 1 cm (FWHM)

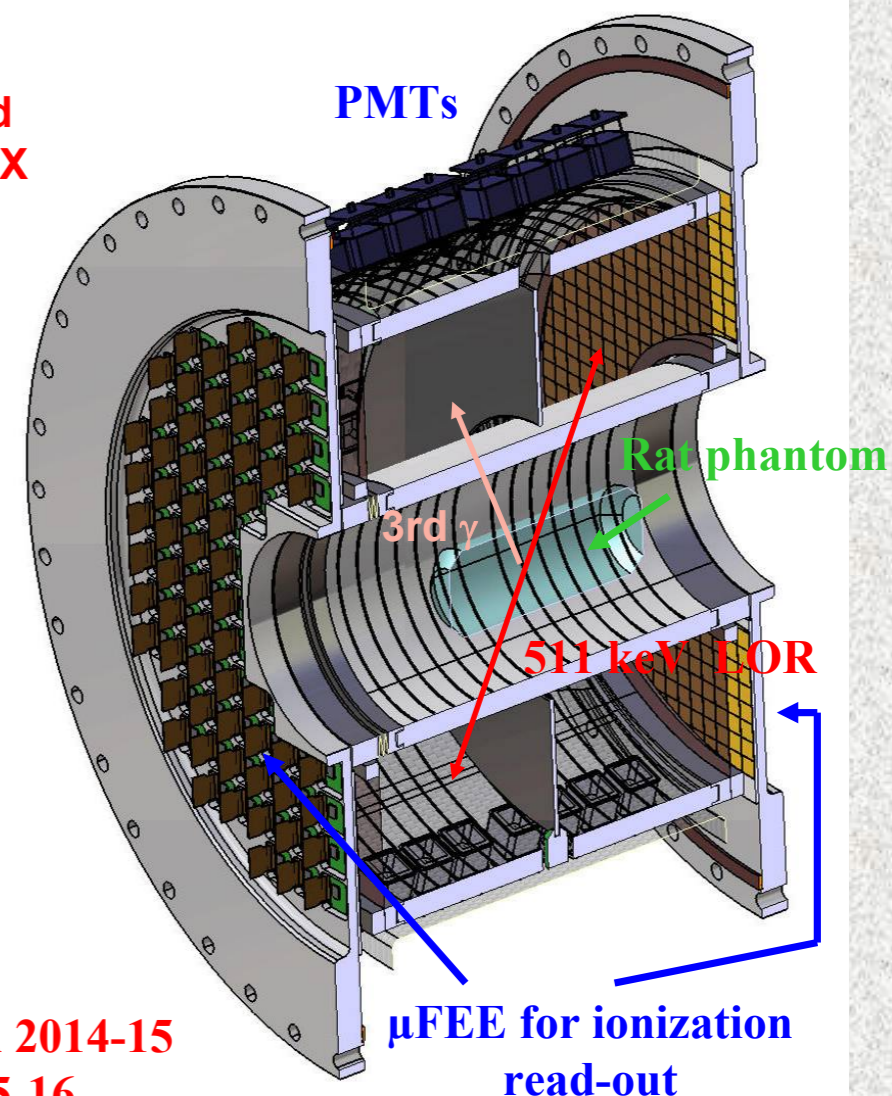
Simulation status:

- LXe Compton Telescope already implemented in GATE
 - Future => Simulation of test Phantoms (NEMA, Derenzo...) with
- Wan-Ting CHEN, Annual FJPPL Work



Funding issues almost addressed with the ARRONAXPLUS EQUIPEX

Improved reliability and safety :
ReStoX (liquid xenon station)



Expected to run at Subatech in 2014-15
→ Nantes Hospital in 2015-16



XEMIS2 pre-design study for small animal imaging with GATE

