

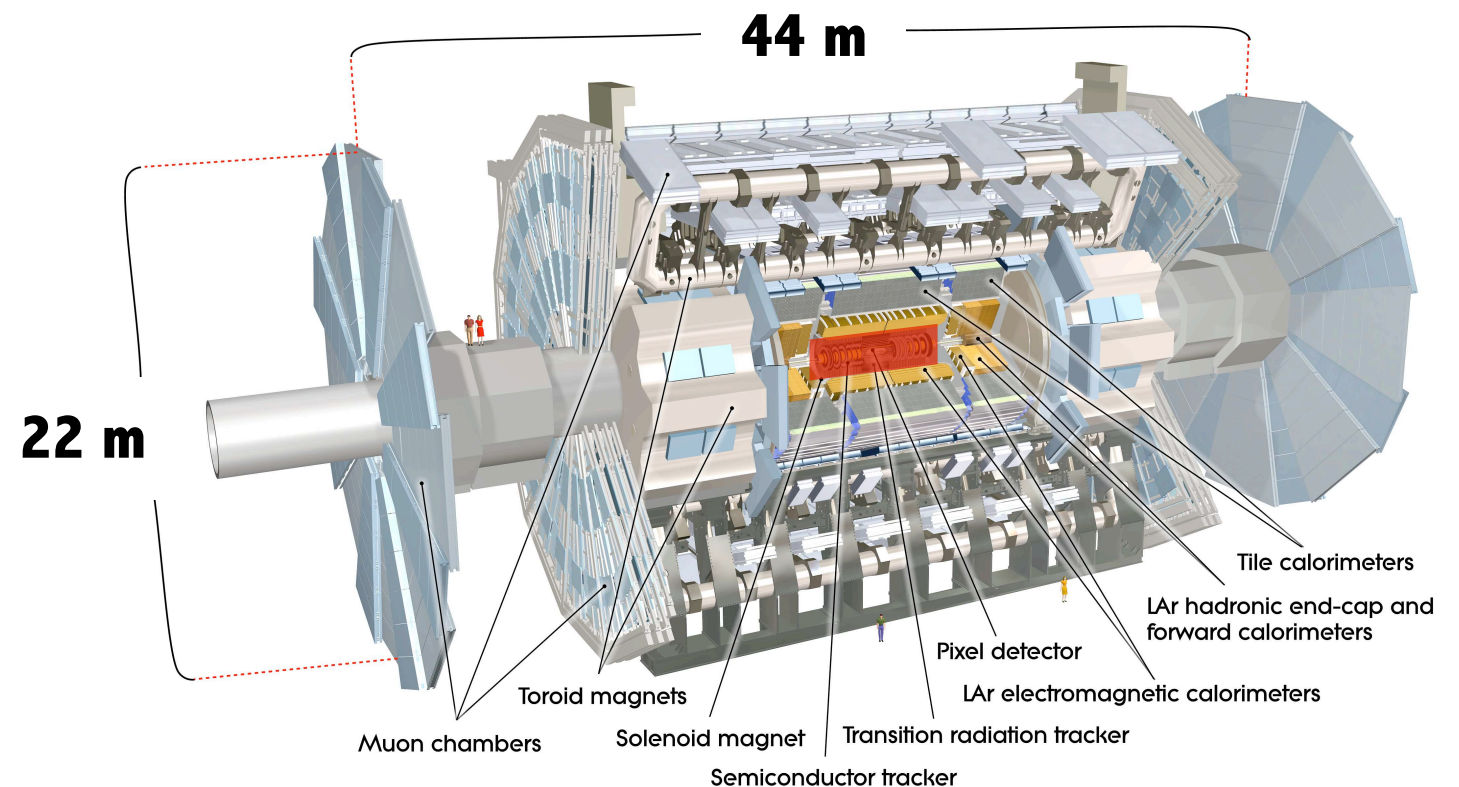
ATLAS実験シリコンストリップ飛跡検出器の較正

山中卓研究室 D1 岡村航

2011年12月9日 年末発表会

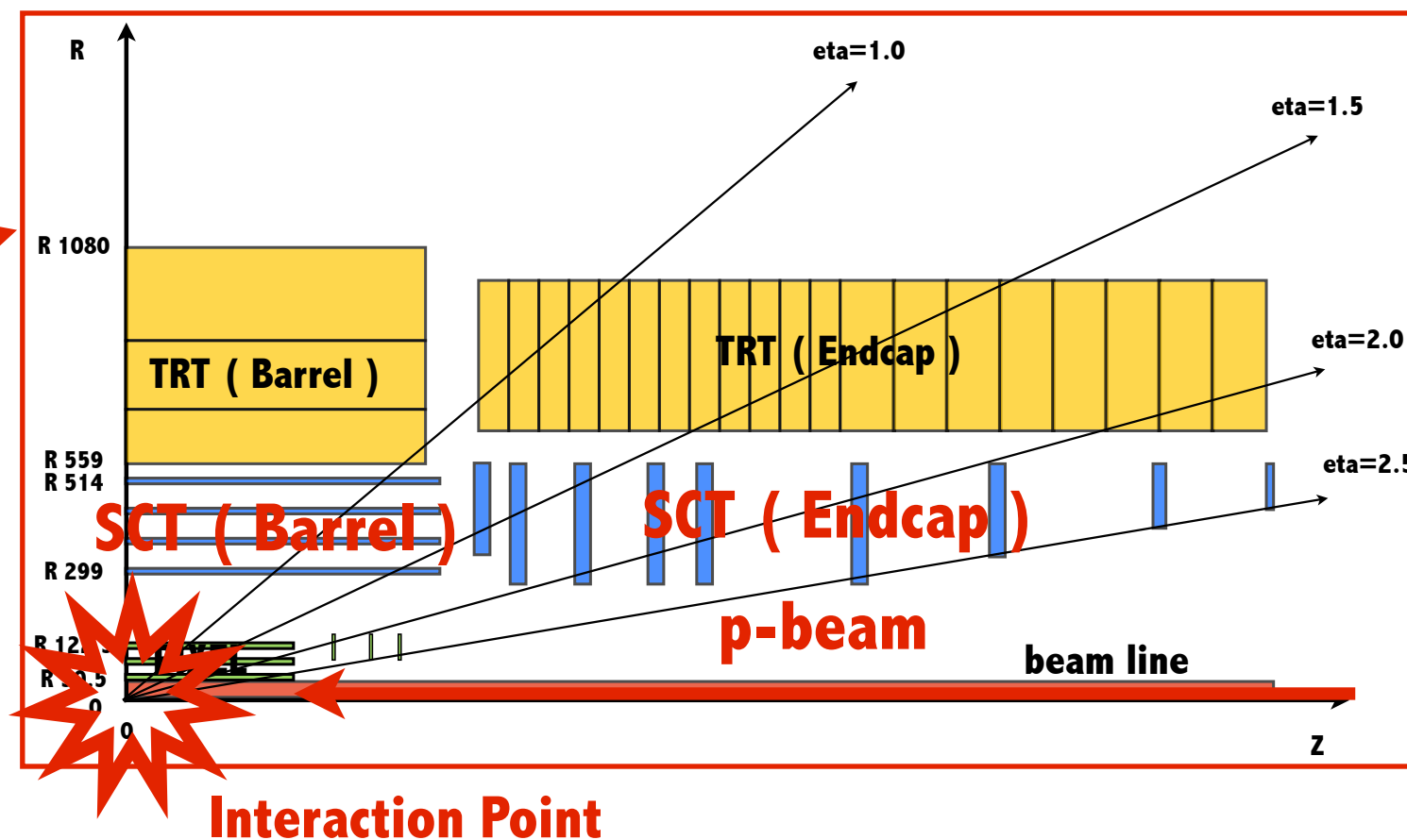
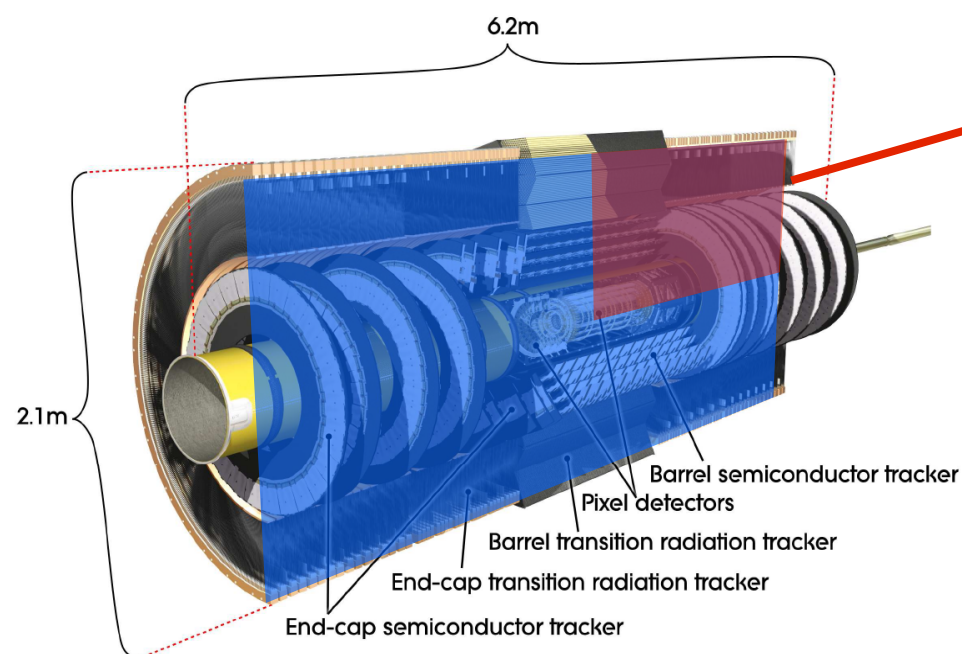
LHC (Large Hadron Collider) / ATLAS detector

- LHC
 - CERNにある陽子・陽子衝突型円形加速器
 - 現在、 $\sqrt{s}=7$ TeVで物理データが蓄積されている
- ATLAS検出器
 - LHCの衝突点の1つに置かれた汎用粒子検出器
 - Higgs粒子や、標準模型を超える物理現象の探索を行う



SCT(シリコンストリップ飛跡検出器)

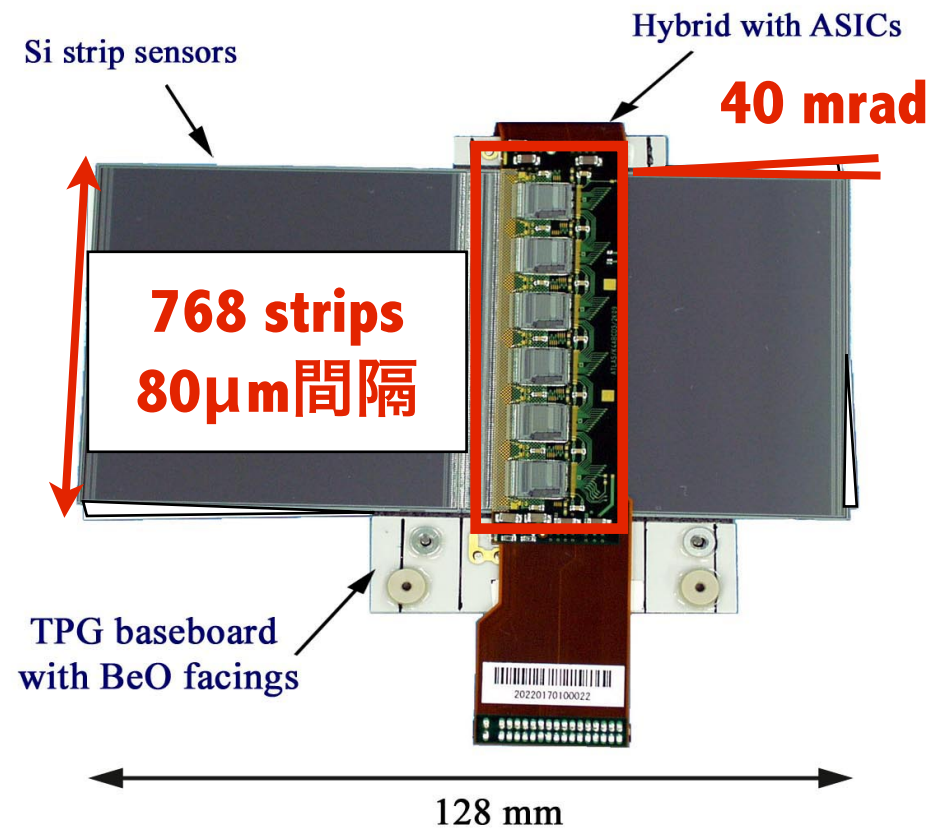
- 内部飛跡検出器



- SCT(SemiConductor Tracker)

- Barrel 4 layers、Endcap 9 disks × 2 から構成
- 荷電粒子の飛跡を精密に測定
 - ▶ b-taggingなどに重要

SCTモジュール

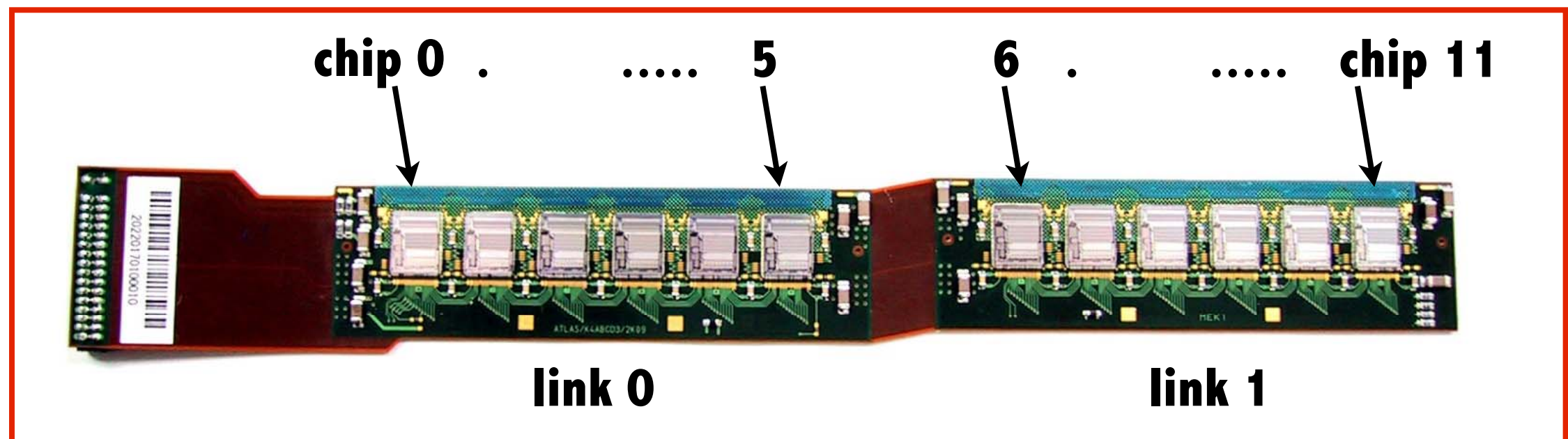
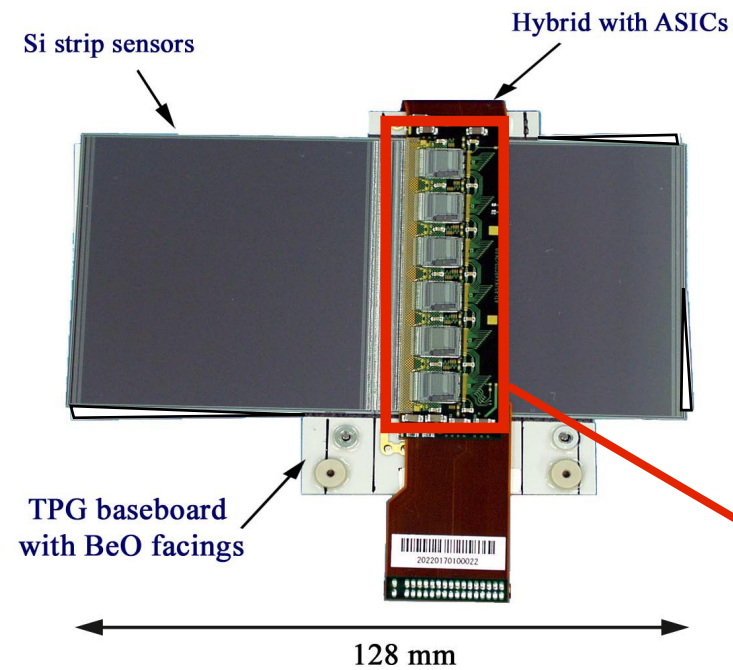


	Barrel (4 layers)	Endcap (9 disks)×2
module数	2112	988×2
chip数	6×2	6×2
strip数	768×2	768×2
全channel数	324万	150万×2

- 2枚のシリコンセンサーから構成
 - ストリップの交点から荷電粒子の通過位置を検出
- Chip に ADC がなく、各チャンネルで閾値を越えたヒット情報だけが読み出される
 - バイナリ読み出し

Chip numbering

- **Chip position**

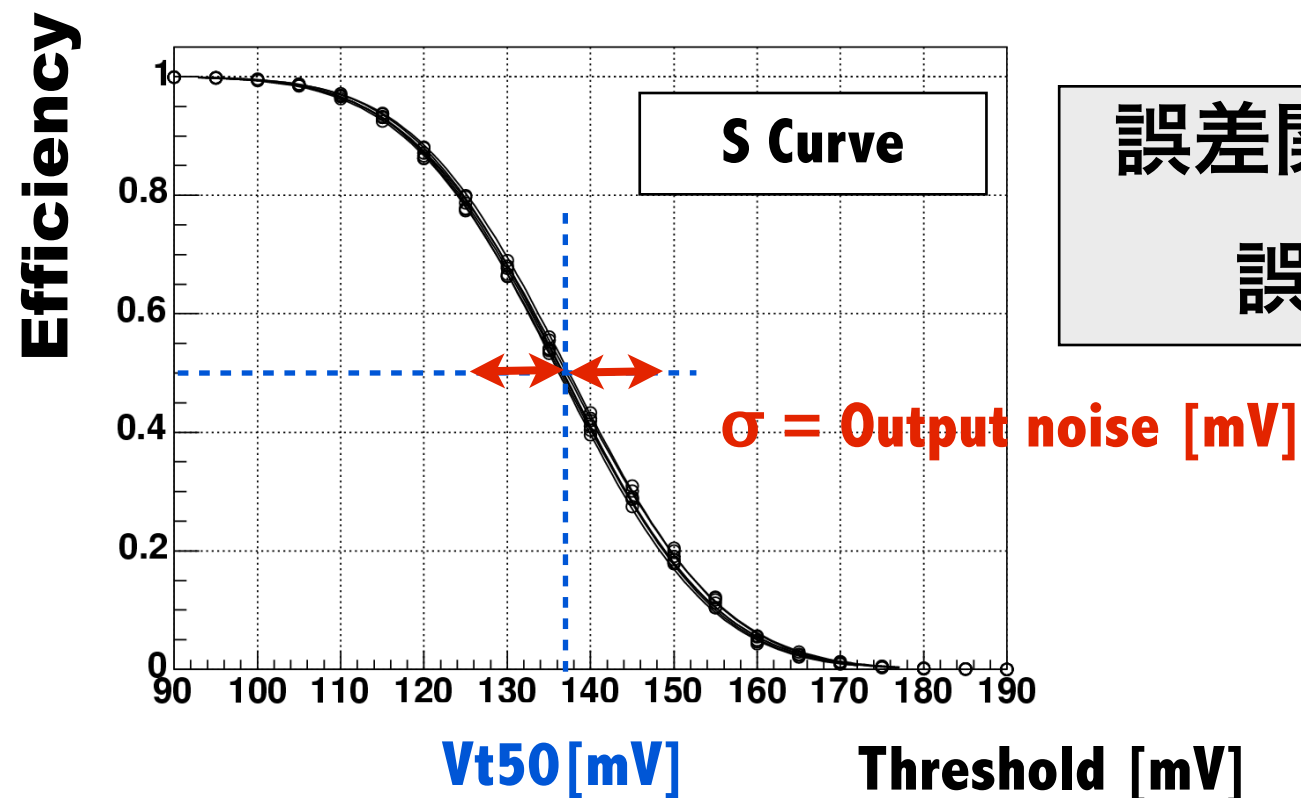


SCTの校正

- **Calibration run**
 - **Physics run とは異なり、beam が出ていない時に行われるSCTの性能を評価するための run**
- **3Pt Gain test**
 - **Calibration run の1つであり、SCTモジュールの上の読み出し chip のアンプの Gain や Noise を評価する試験**

Gain & Noise測定 (1)

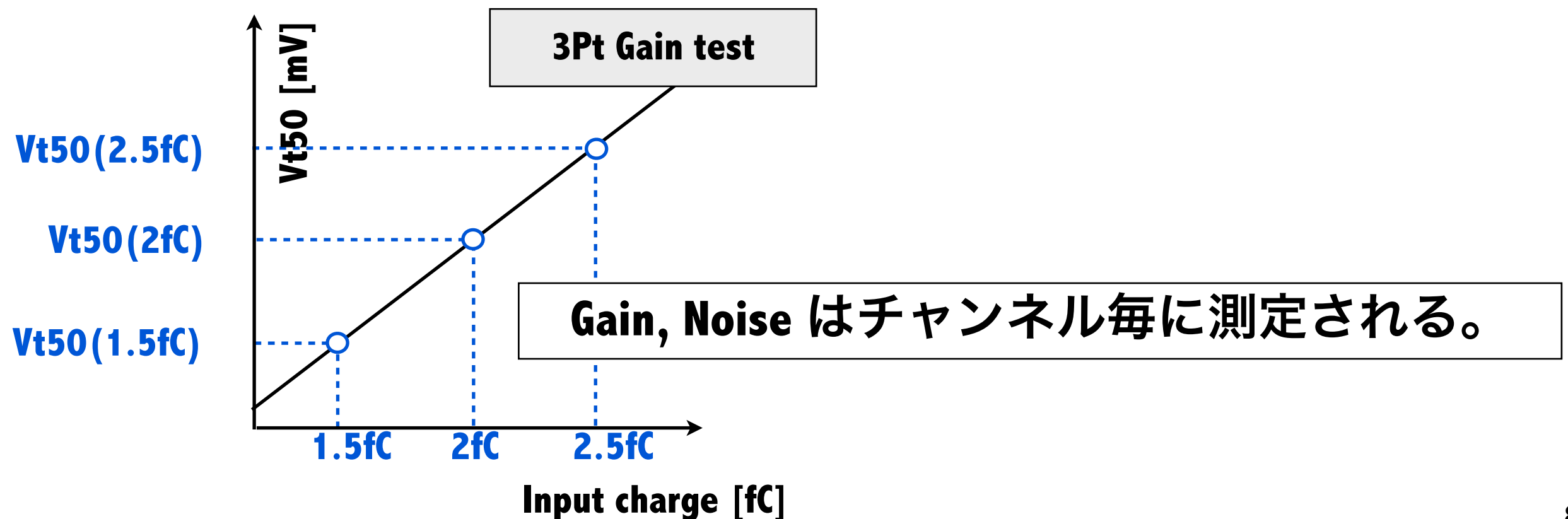
- **Threshold Scan Curve (S Curve)**
 - Calibration Pulse を入射し、閾値を変化させ、チャンネル毎にSカーブを測定
 - Efficiency が 50% になる閾値 (V_{t50} [mV]) と Output noise [mV] を求める



誤差関数でフィットして、 V_{t50} を求める
誤差関数の σ をOutput noiseとする

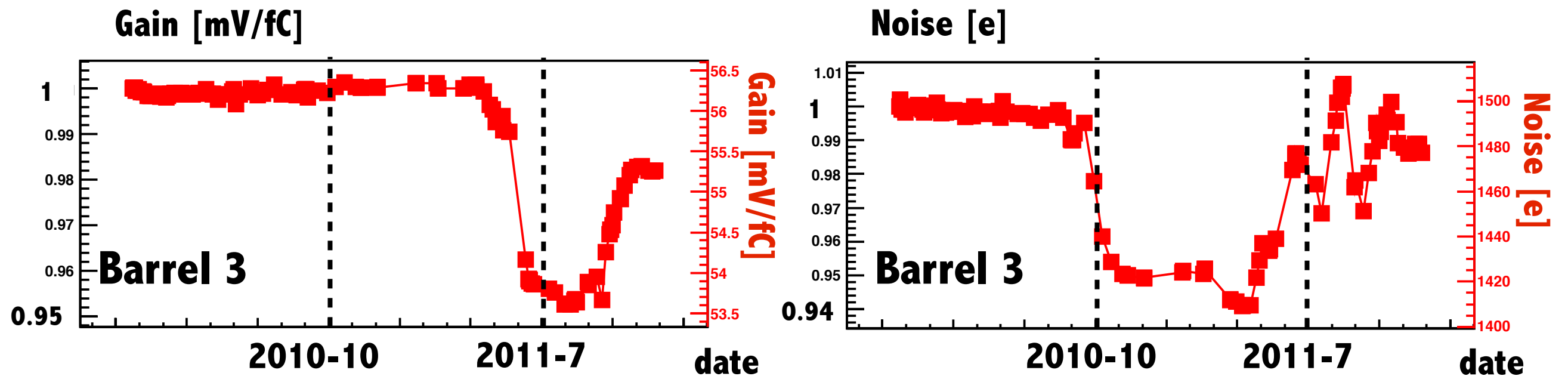
Gain & Noise測定 (2)

- 3Pt Gain test では、1.5 fC, 2.0 fC, 2.5 fCの3つの charge を用いて、それぞれで V_{t50} [mV] を求める
- 3点を直線でフィット
 - その傾きを Gain [mV/fC] とする
 - $\text{Noise [e]} = \text{Output noise [mV] (at 2fC)} / \text{Gain [mV/fC]}$



Gain / Noise の時間依存性

- Barrel 3 (最内層) の gain / noise の時間変化
 - 2010年1月~2011年12月

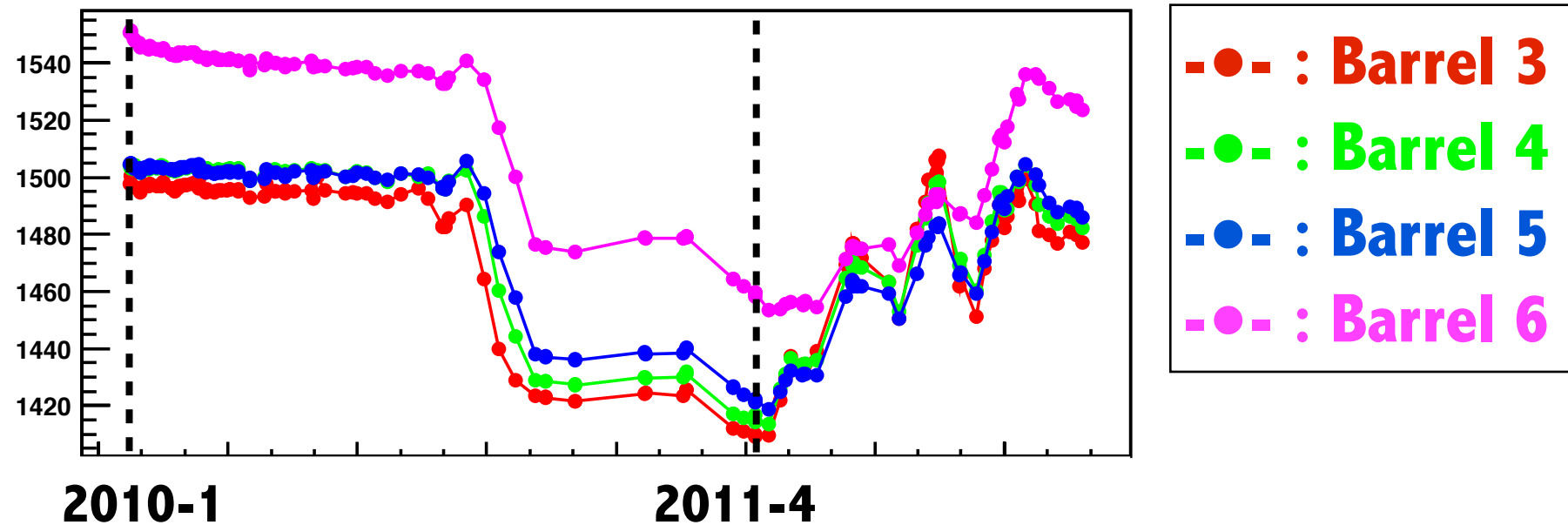


- 2011年6月に gain[mV/fC] が急激に減少し、2010年はじめ頃の値と比べて **~4.5%** 減少
- 2010年9月~11月の LHC のルミノシティ上昇 ($\sim 40 \text{ pb}^{-1}$) に伴って、noise [e] が2010年はじめ頃の値と比べて **~5%** 減少

Noise の減少問題

- 各バレルの noise [e] の時間変化

- 2010年1月~2011年12月



- 2010年1月と2011年4月の run での chip 毎の noise [e] の比較

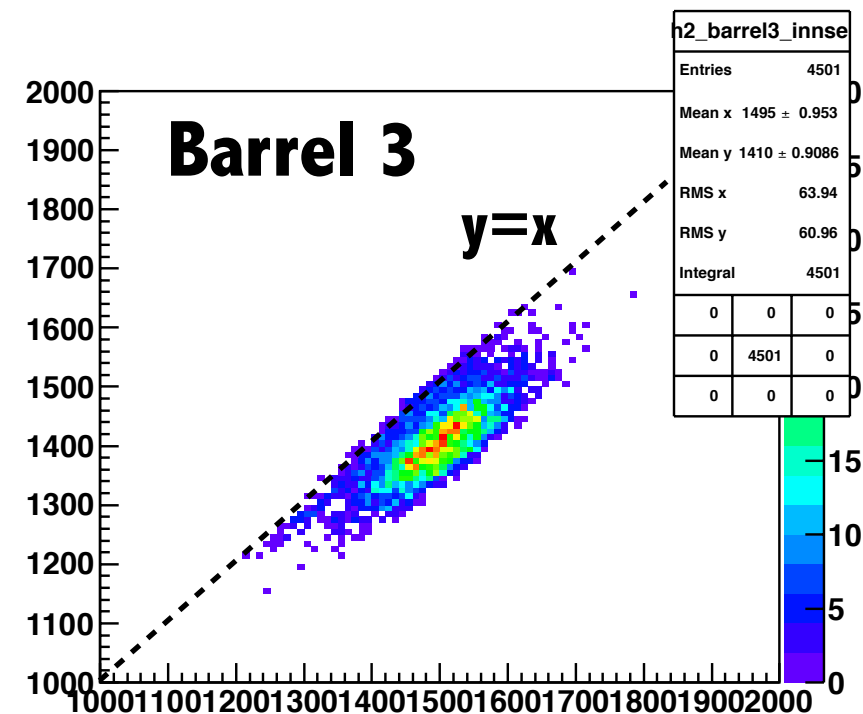
- X axis : Noise [e] (2010/1)

- Y axis : Noise [e] (2011/4)

❖ 減少の仕方に内部構造が有る

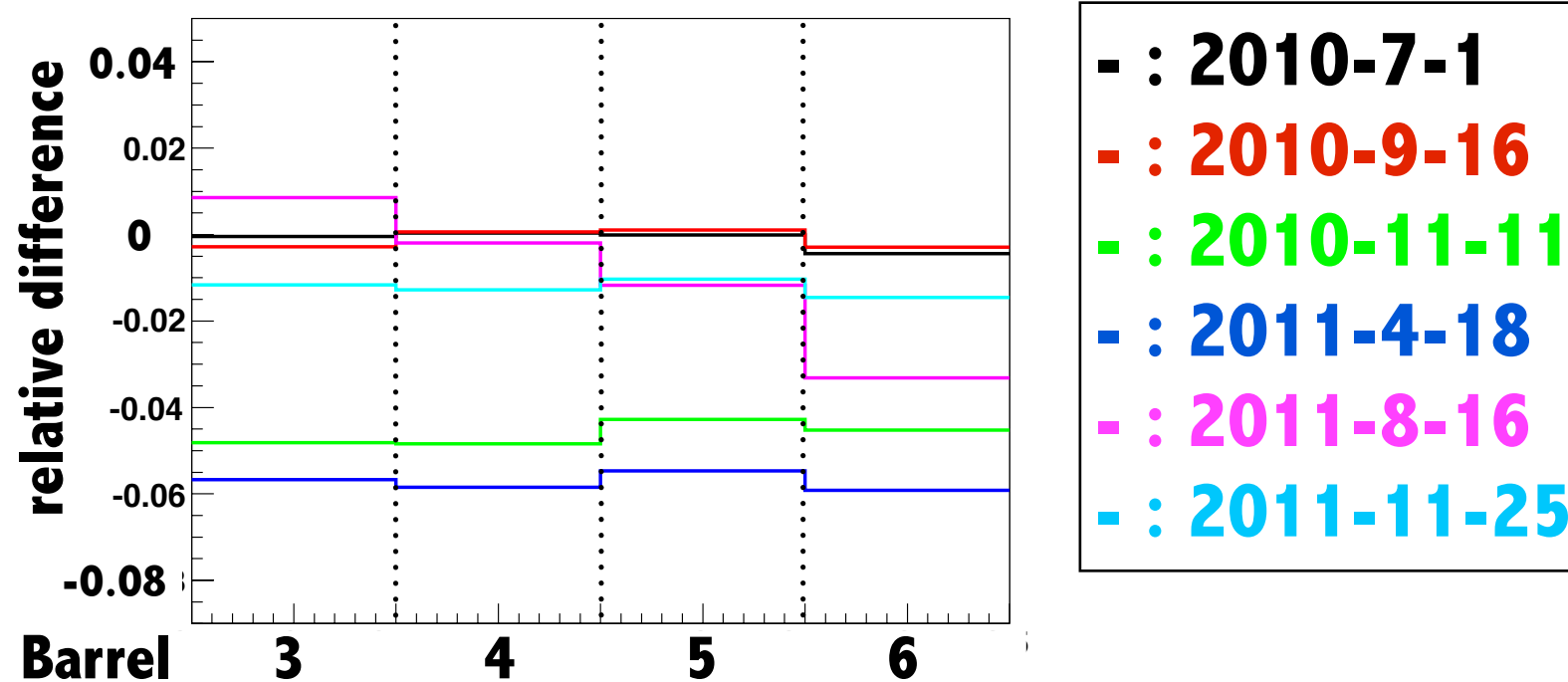
➡ Layer 依存性 ?

➡ Chip position 依存性 ?



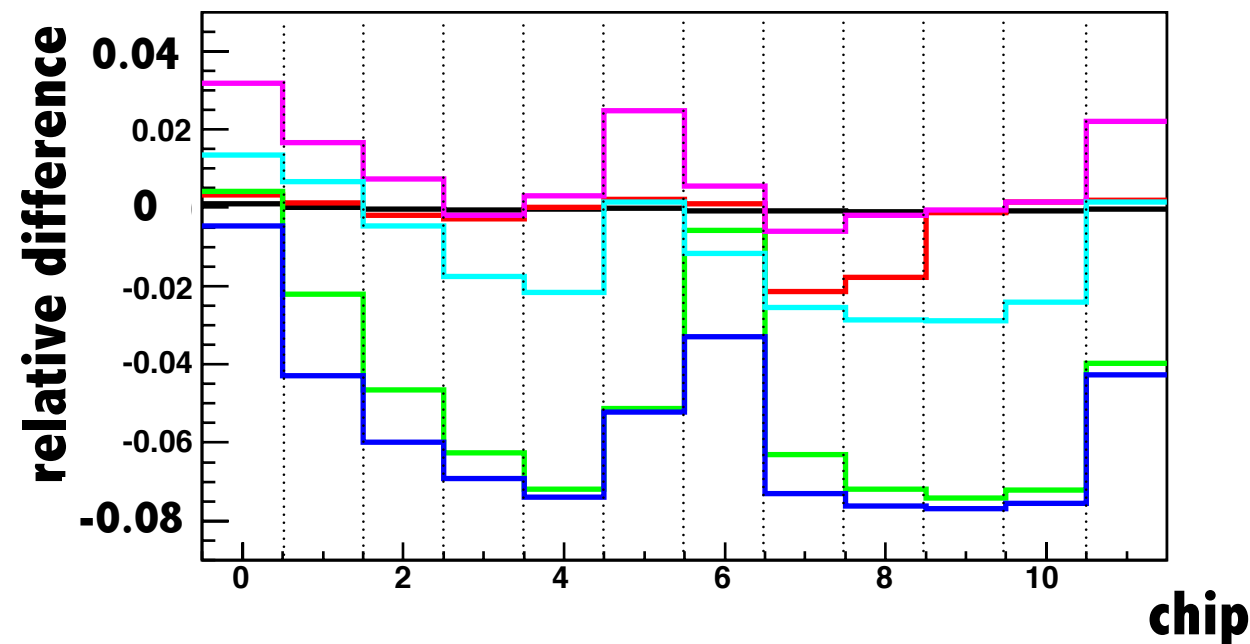
- 2010年1月の run のからの noise [e] の時間変化

- Layer 依存性



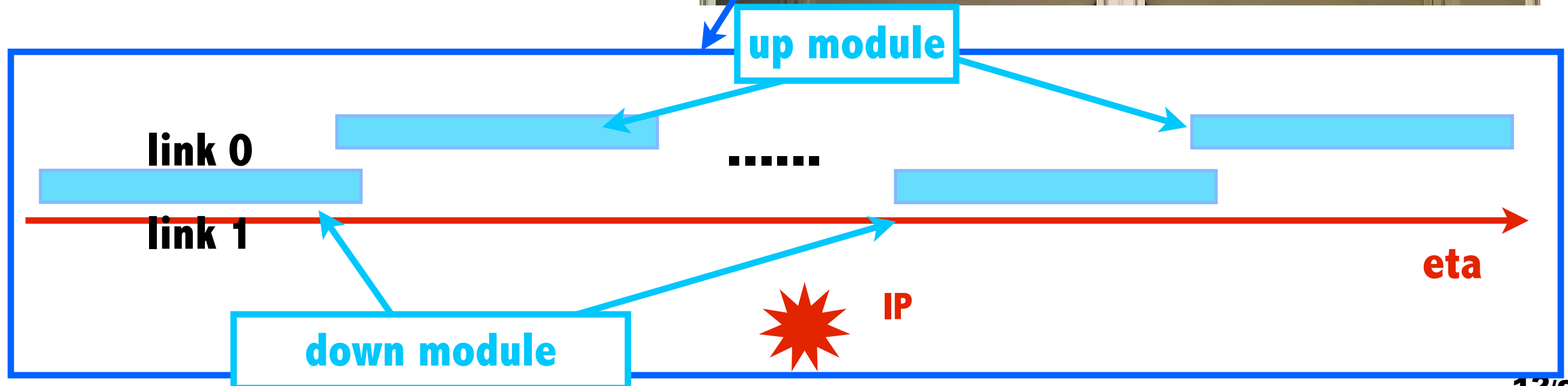
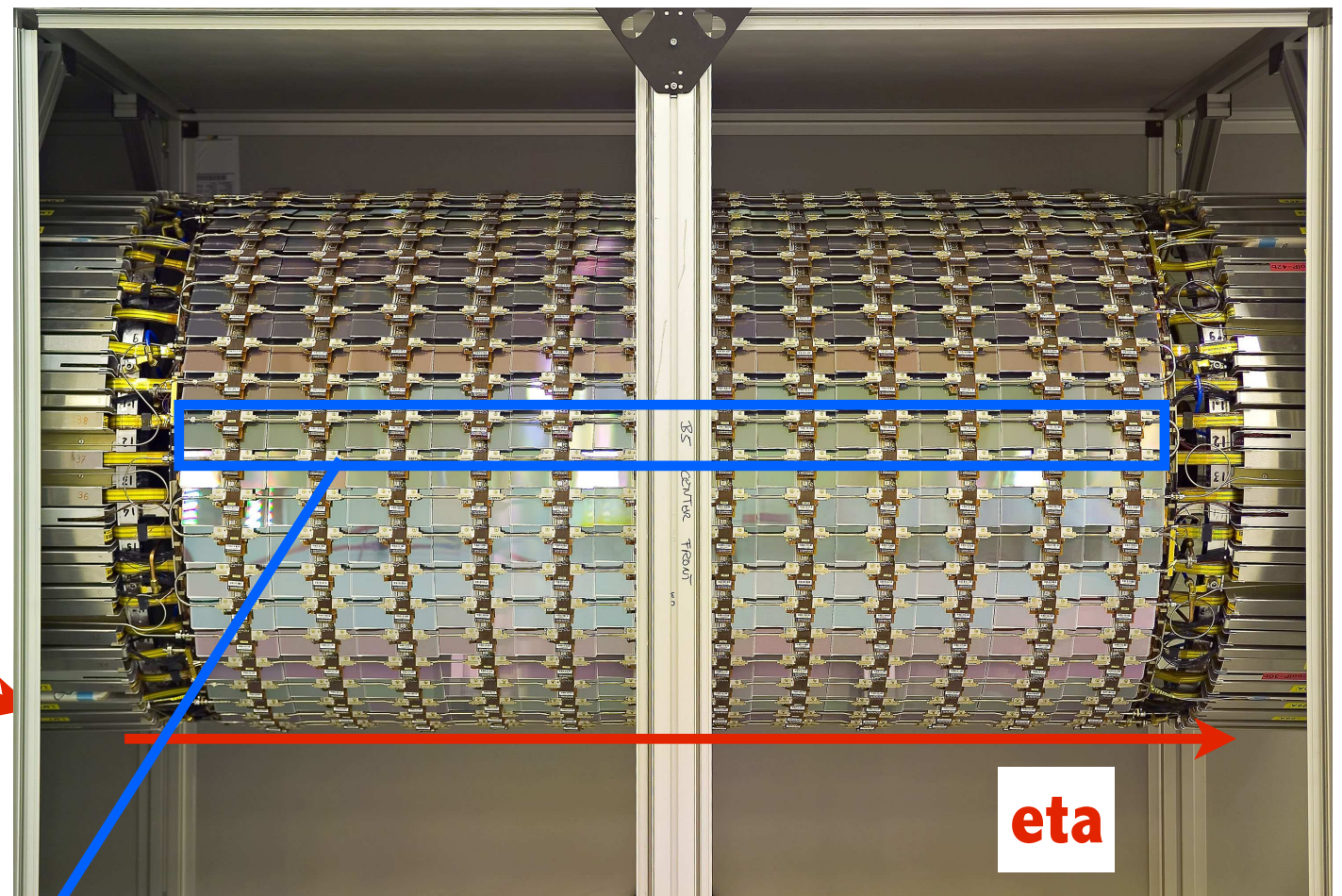
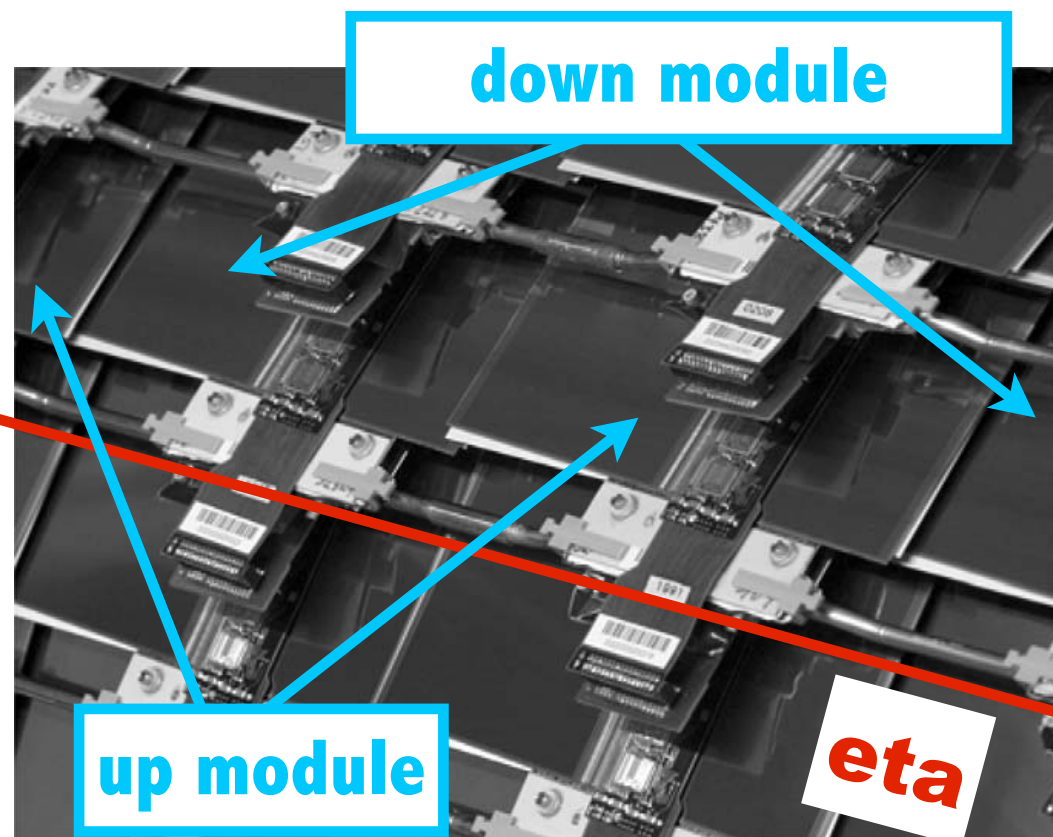
❖ Barrel layer 依存性はあまり無い

- Chip position 依存性 (Barrel 3)



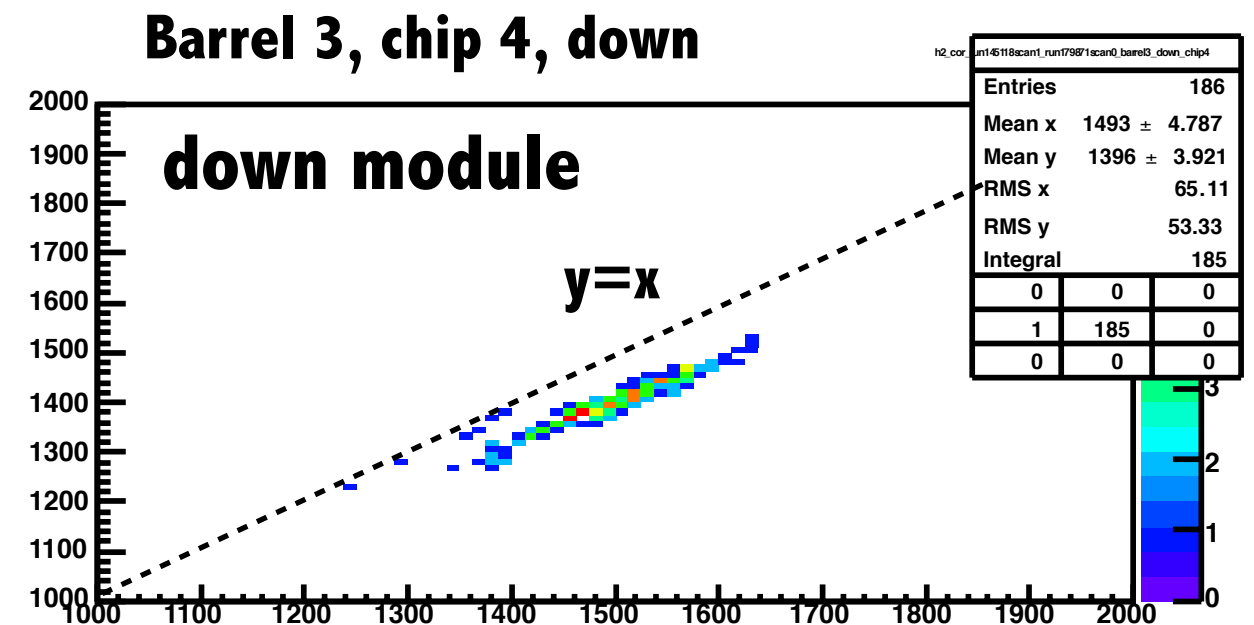
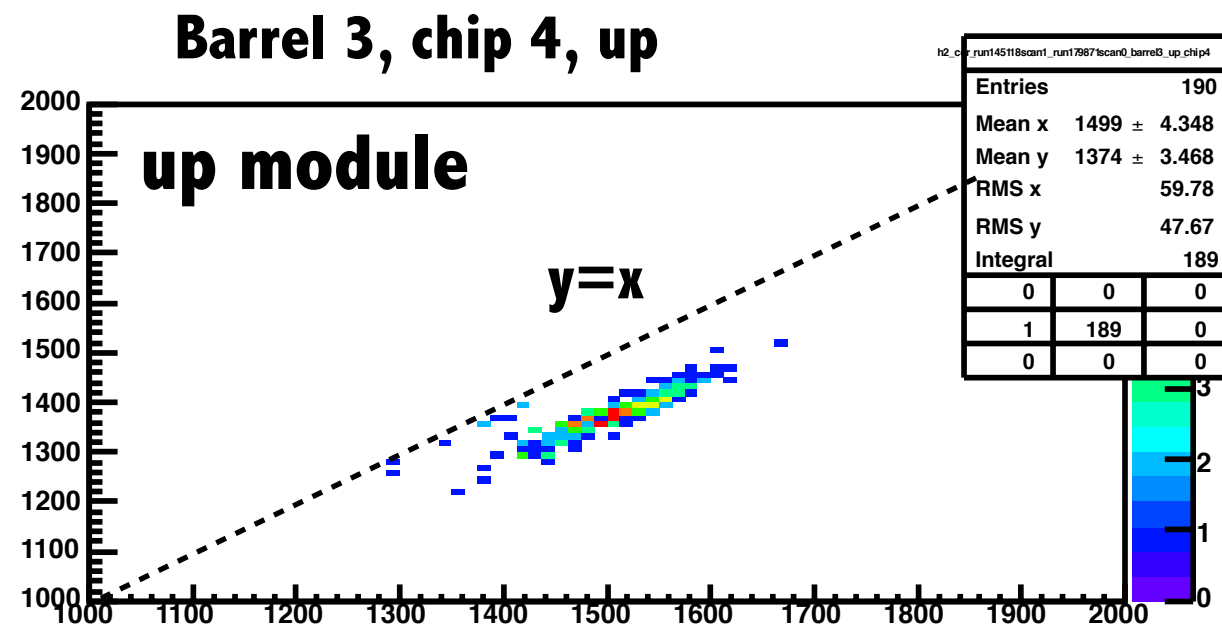
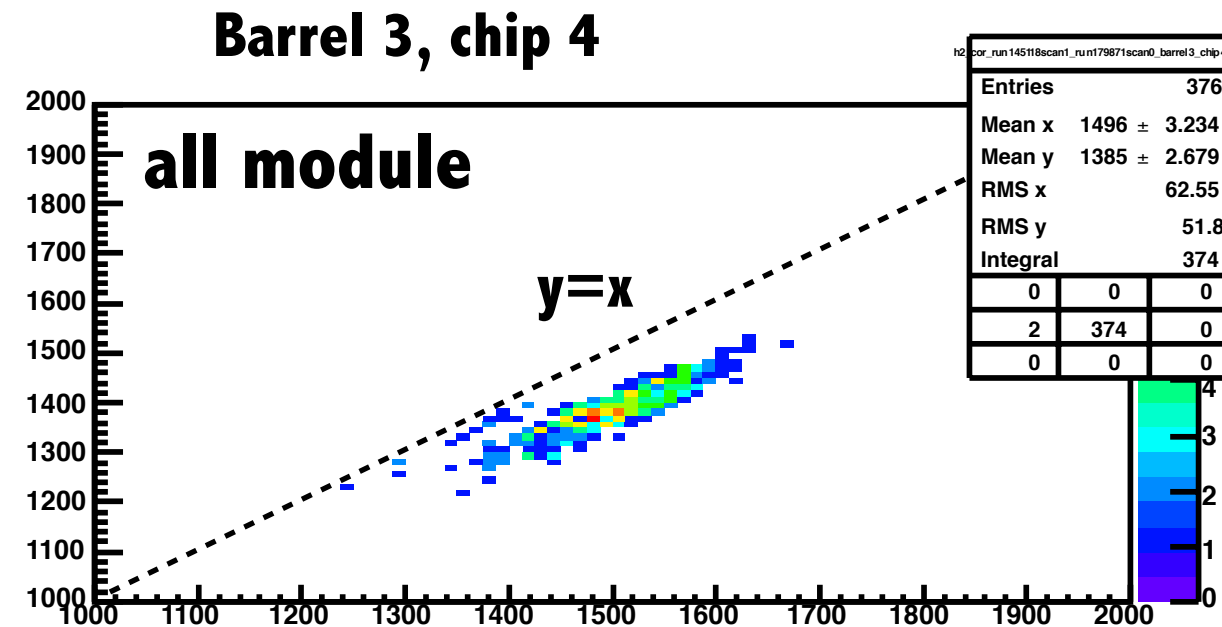
❖ Chip position 依存性は有る

- Barrelモジュールの geometry の観点から見た noise の変化
 - Barrelモジュールの geometry



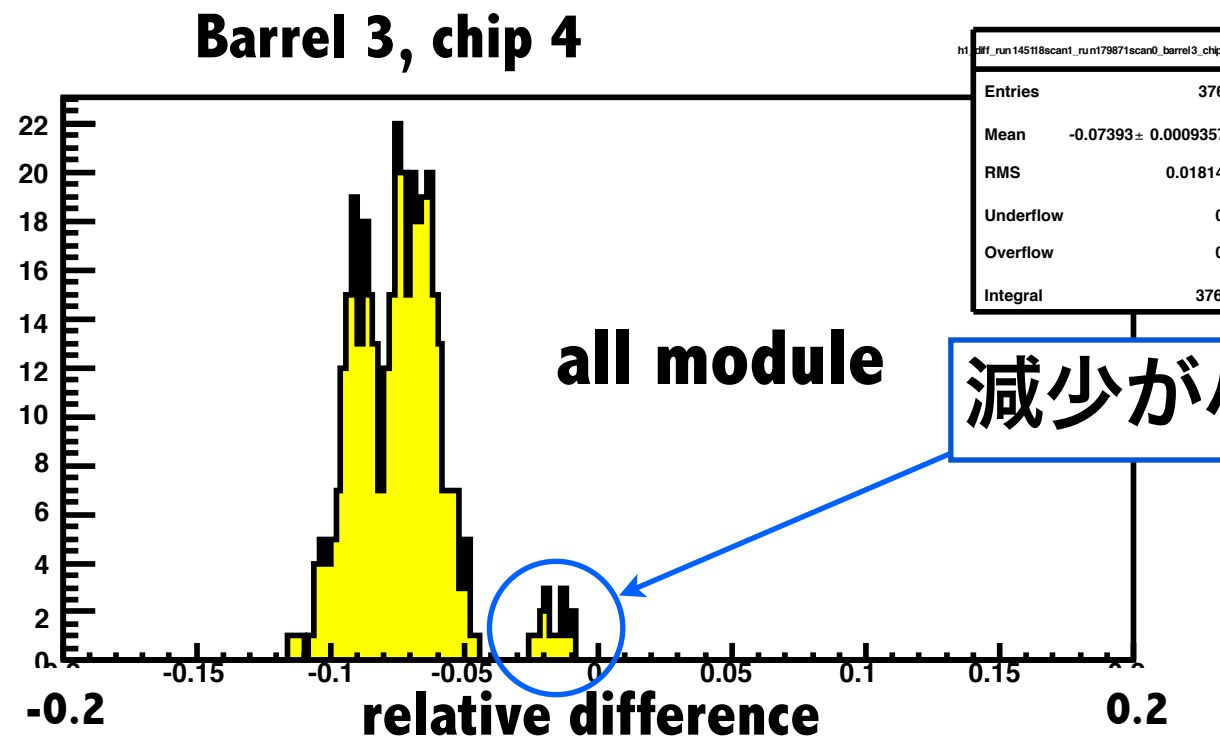
- 2010年1月と2011年4月の run での noise [e] の比較 (Barrel 3, chip 4)

- X axis : Noise [e] (2010-1)
- Y axis : Noise [e] (2011-4)

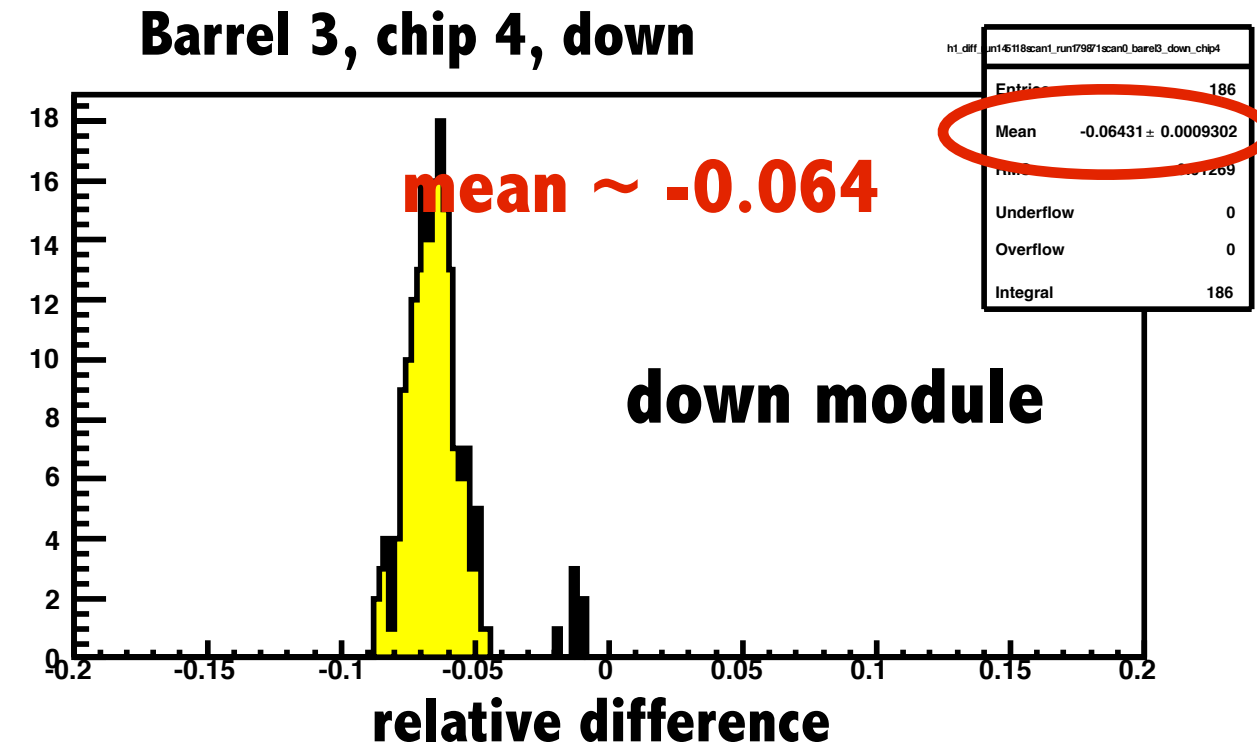
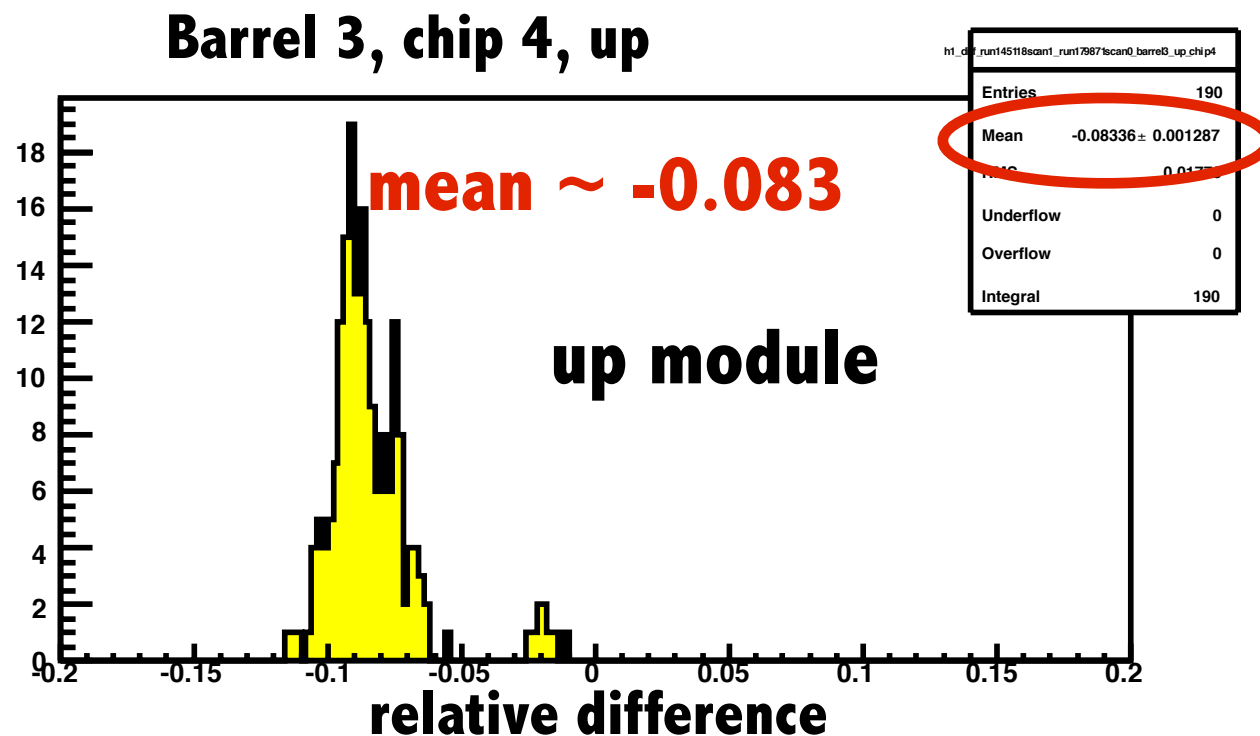


● Noise [e] の変化量 (Barrel 3, chip 4)

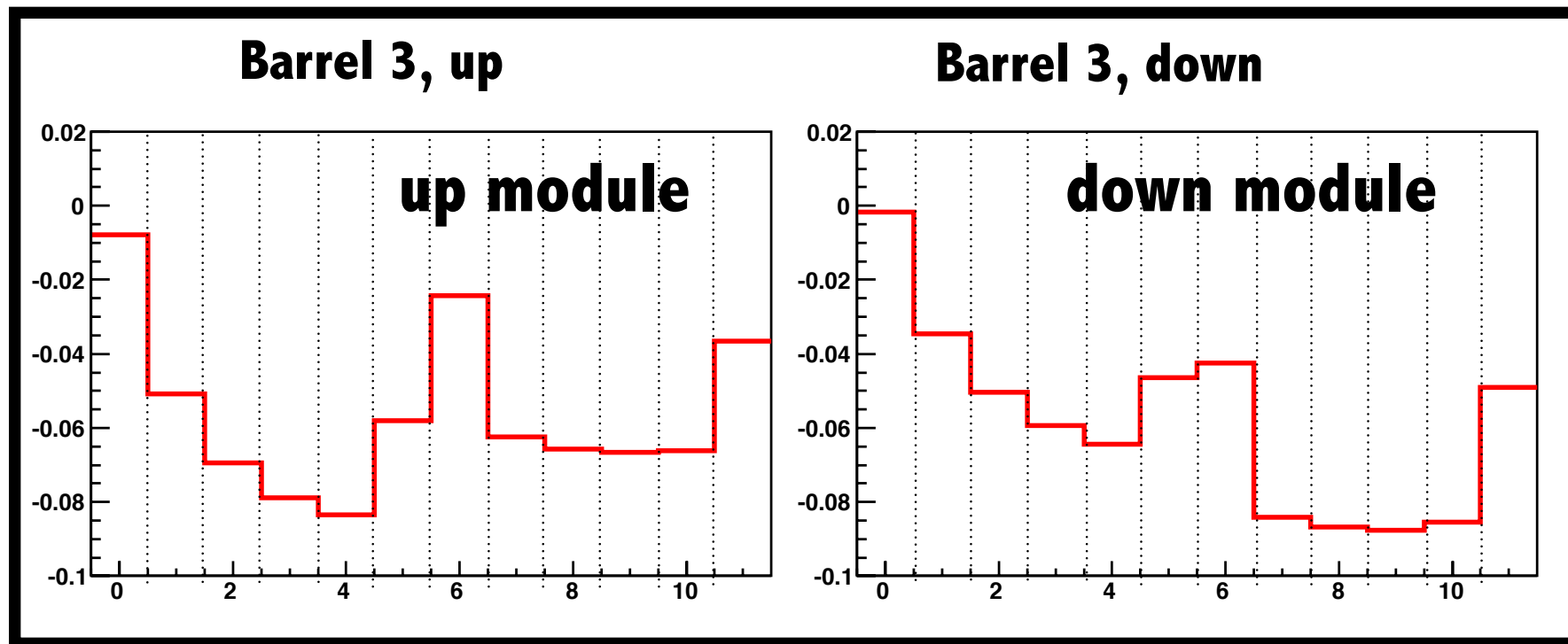
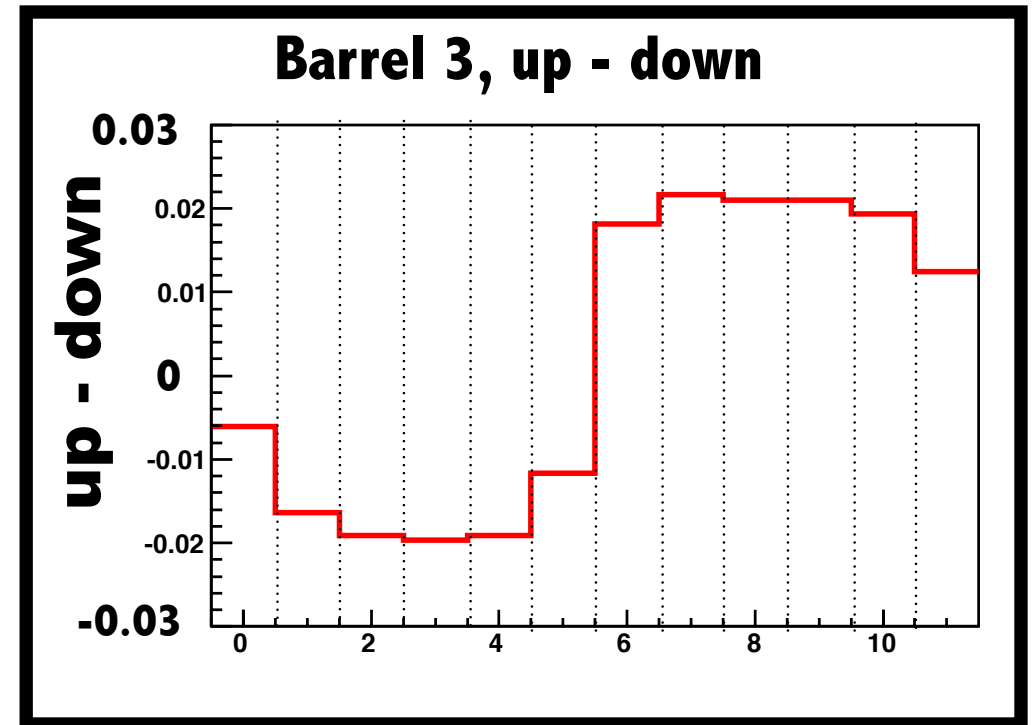
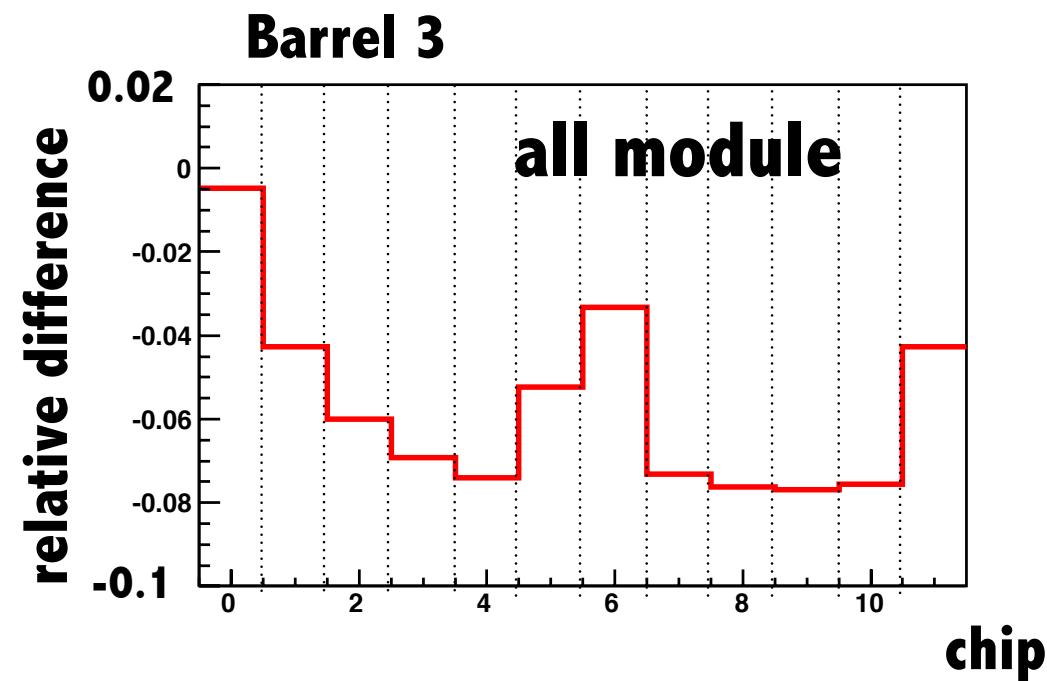
■ Relative difference =
$$\frac{\text{Noise [e]} (2010 - 1) - \text{Noise [e]} (2011 - 4)}{\text{Noise [e]} (2010 - 1)}$$



減少が小さいモジュールもある



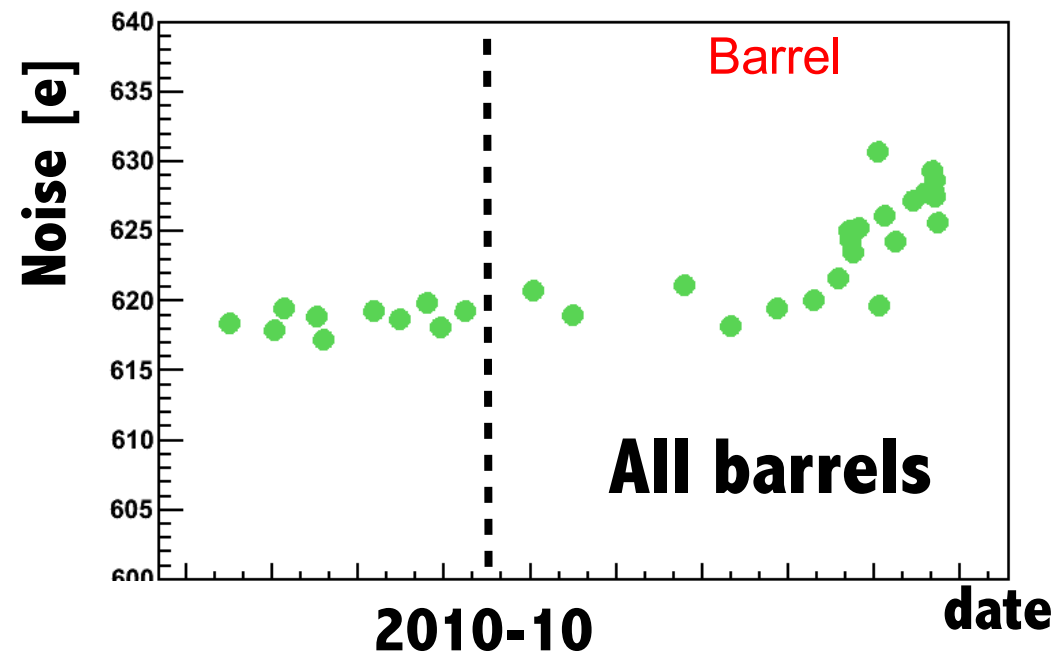
- Noise の変化の chip position 依存性



**difference between up
and down**

❖ Barrel 部分の noise の減少は geometry にも依存している

- Unbonded チャンネルの noise [e] の時間変化



❖ 減少が見られない

➡ Noise の減少はセンサーに起因している可能性が高い

- シリコンセンサーの表面配向による noise の減少量の違い

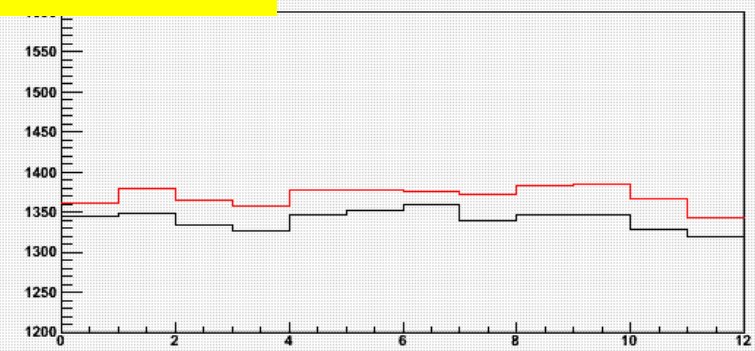
- 2種類のセンサーが SCT で使われている

▶ 6''<100> と 4''<111>

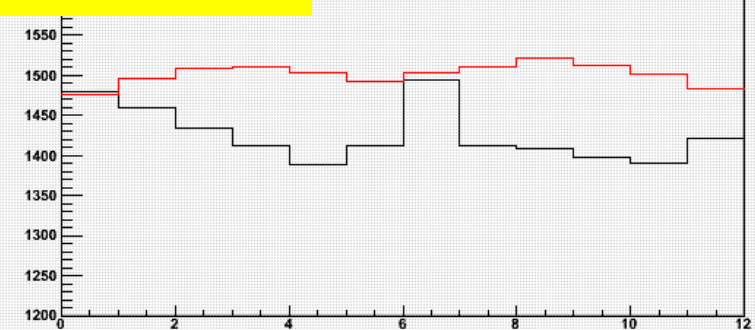
Runs
Red=145944
5th Feb 2010

Black=169008
11th Nov 2010

Barrel 3 <100> modules



Barrel 3 <111> modules

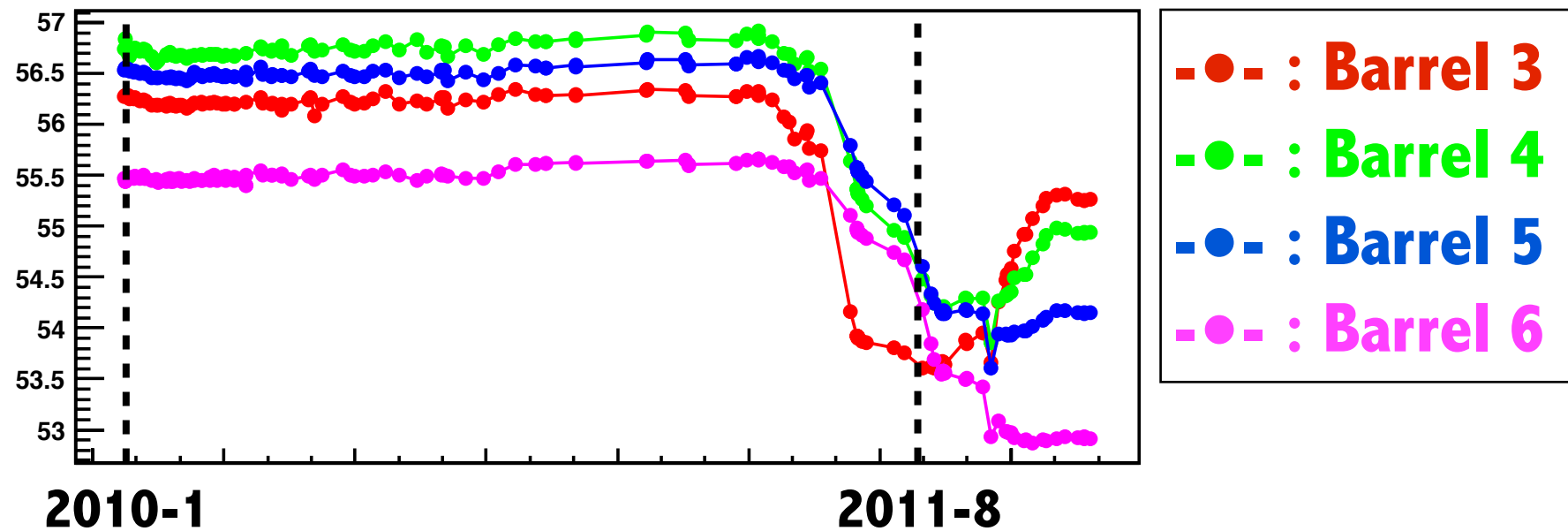


❖ 6''<100>の方が減少が小さい

Gain の減少問題

- 各バレルの gain [mV/fC] の時間変化

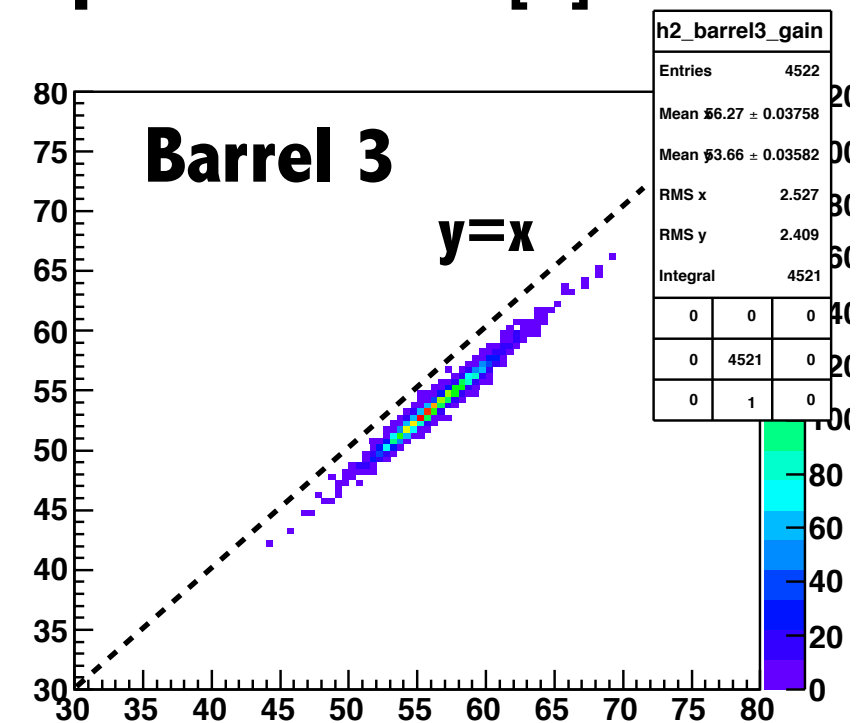
- 2010年1月~2011年12月



- 2010年1月と2011年8月の run での chip 毎の noise [e] の比

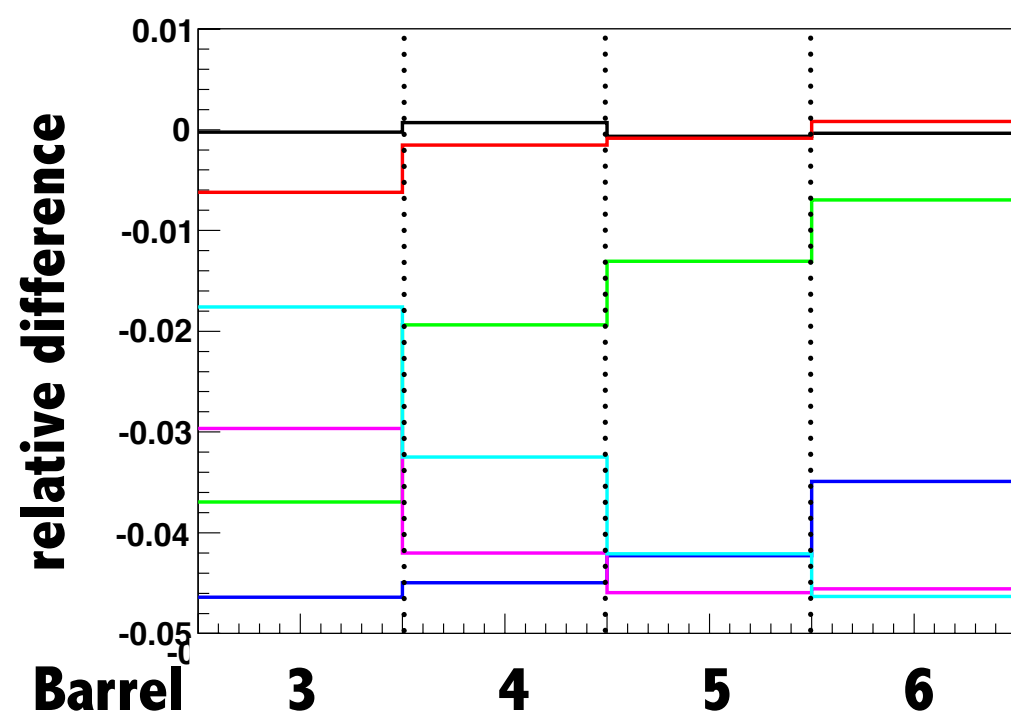
- X axis : Gain [mV/fC] (2010/1)
- Y axis : Gain [mV/fC] (2011/8)

❖ 内部構造は見られない



- 2010年1月の run のからの gain [mV/fC] の時間変化

- Layer 依存性

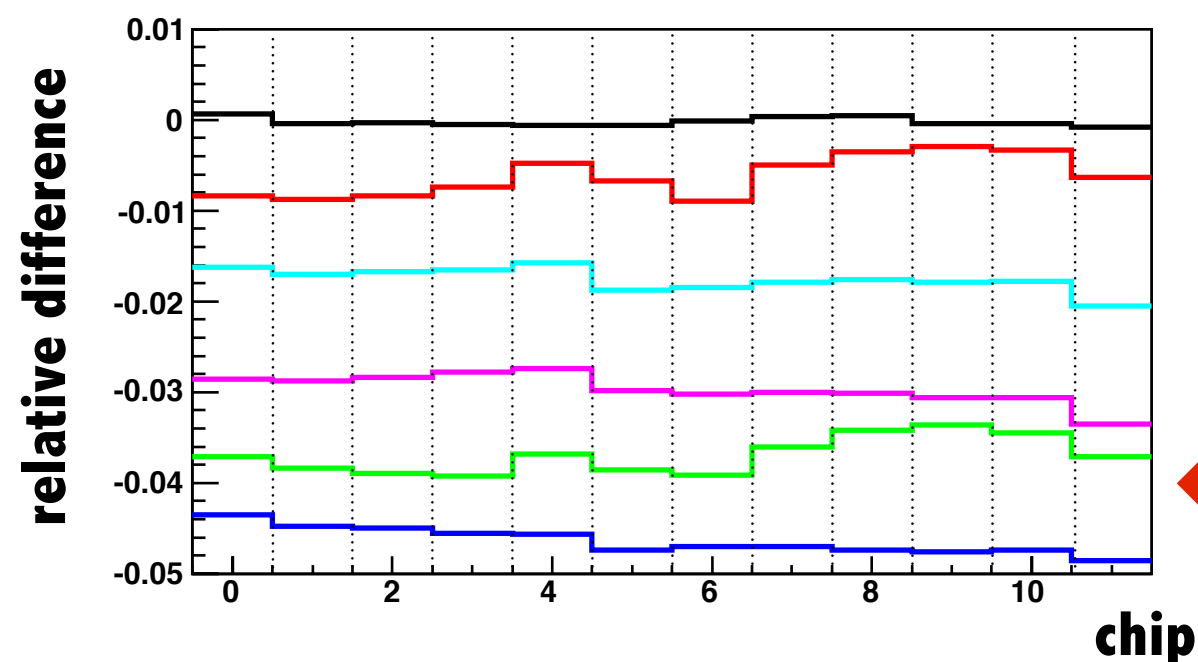


- : 2010-9-16
- : 2011-4-18
- : 2011-6-11
- : 2011-8-16
- : 2011-10-1
- : 2011-11-25

❖ Barrel layer 依存性は有る

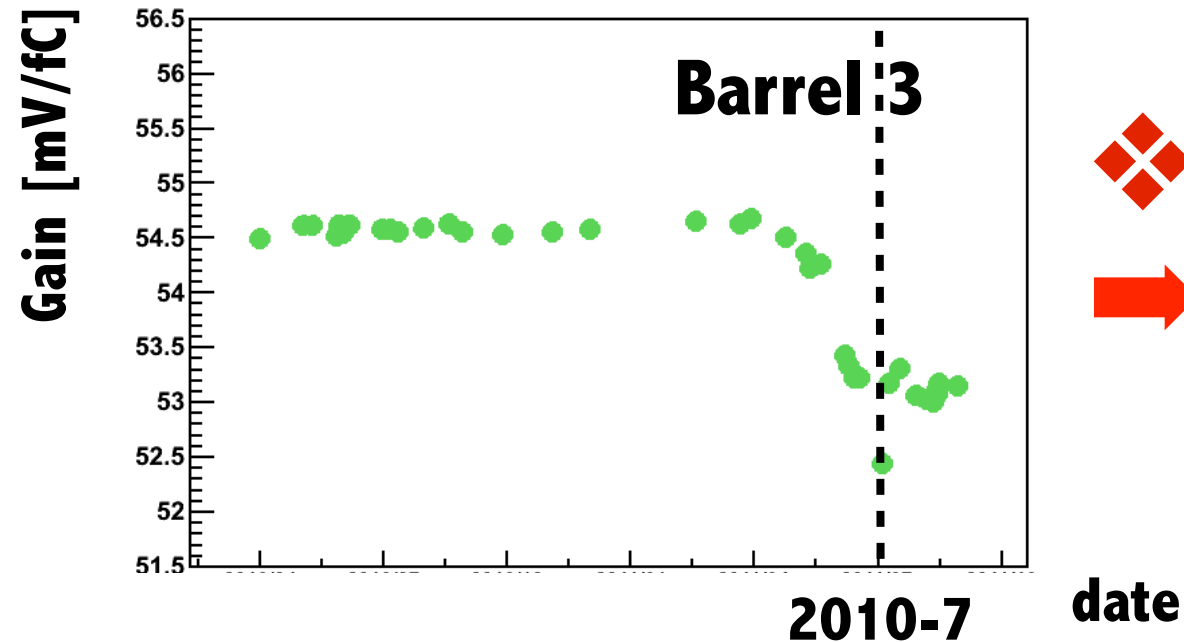
- Chip position 依存性 (Barrel 3)

➡ 放射線損傷の可能性が高い



❖ Chip position 依存性はあまり無い

- **Unbonded チャンネルの gain [mV/fC] の時間変化**

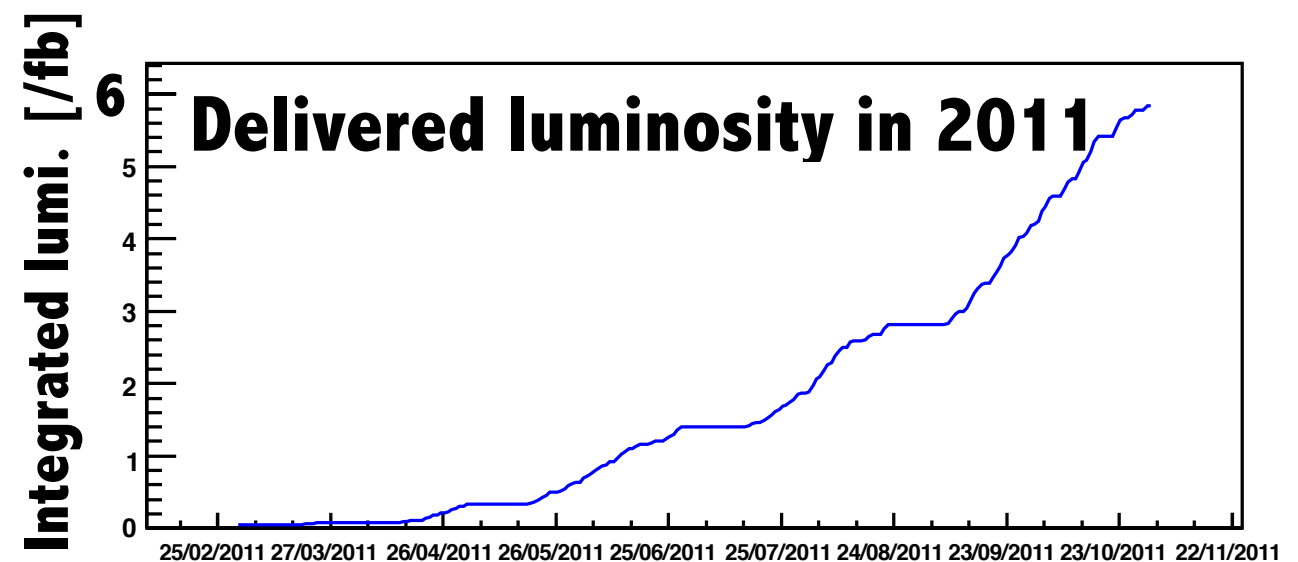


❖ 減少が見られる

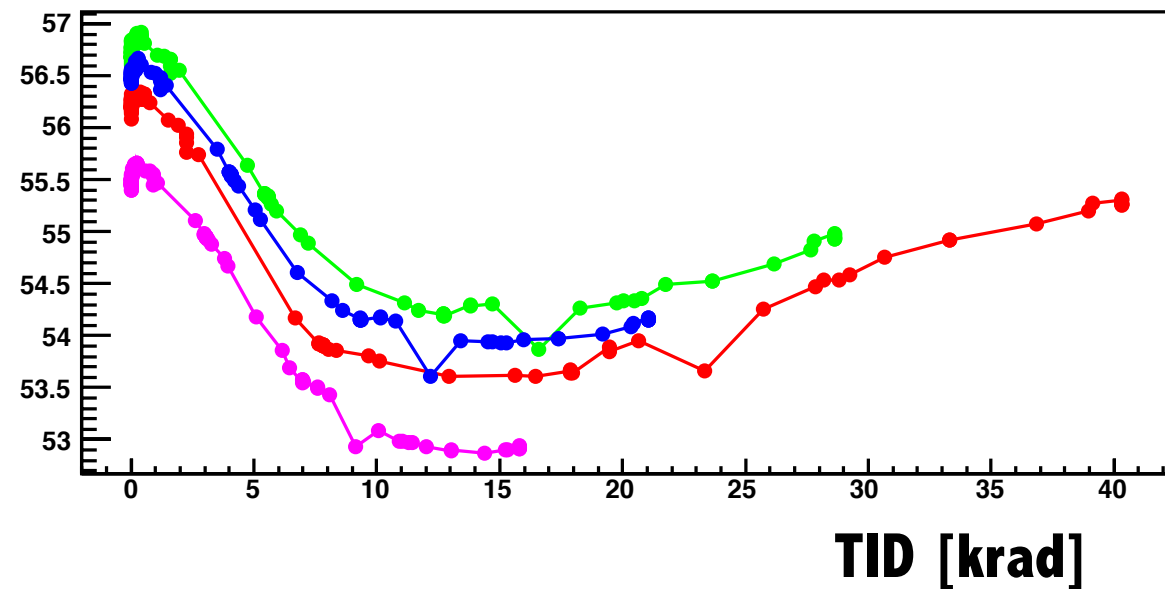
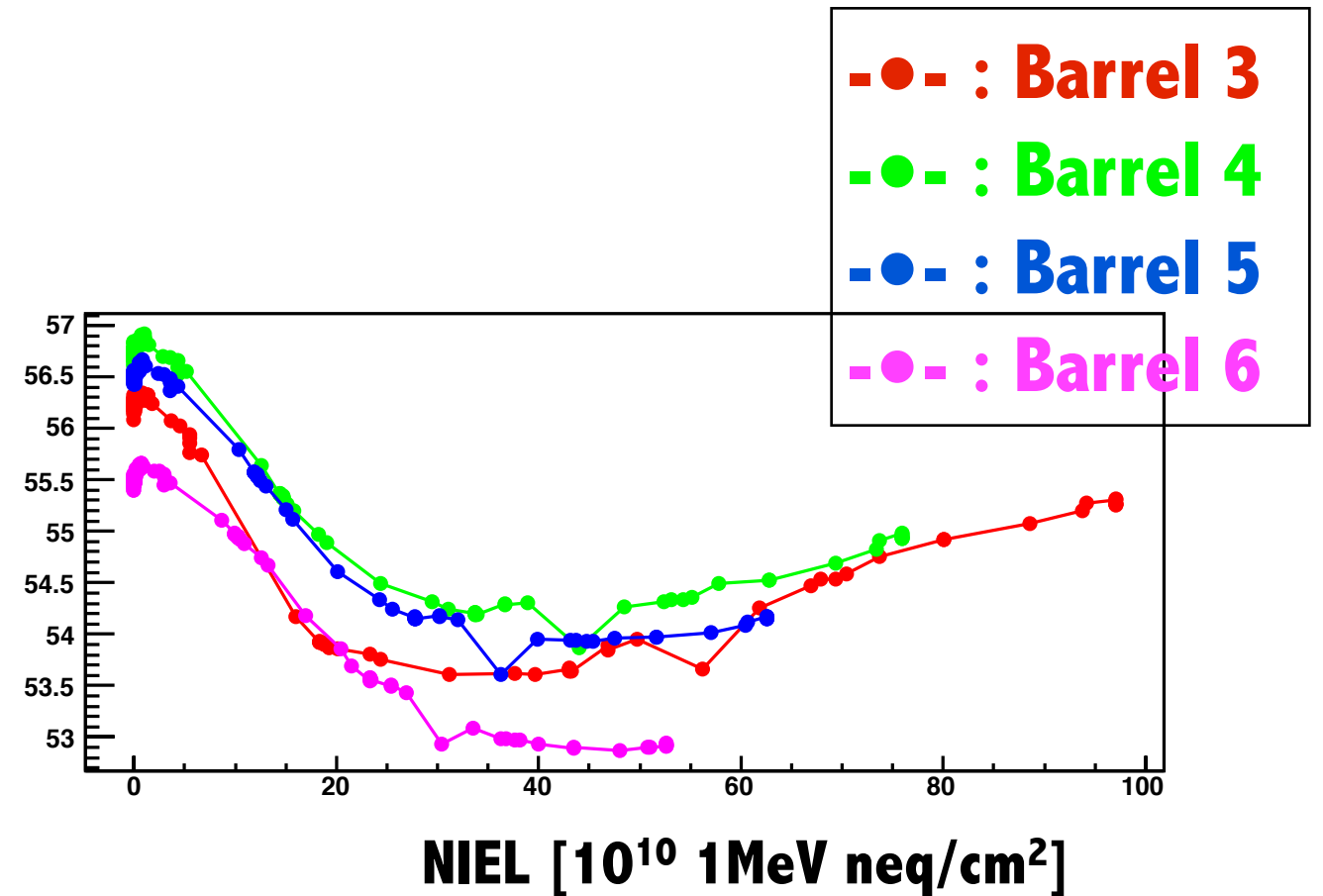
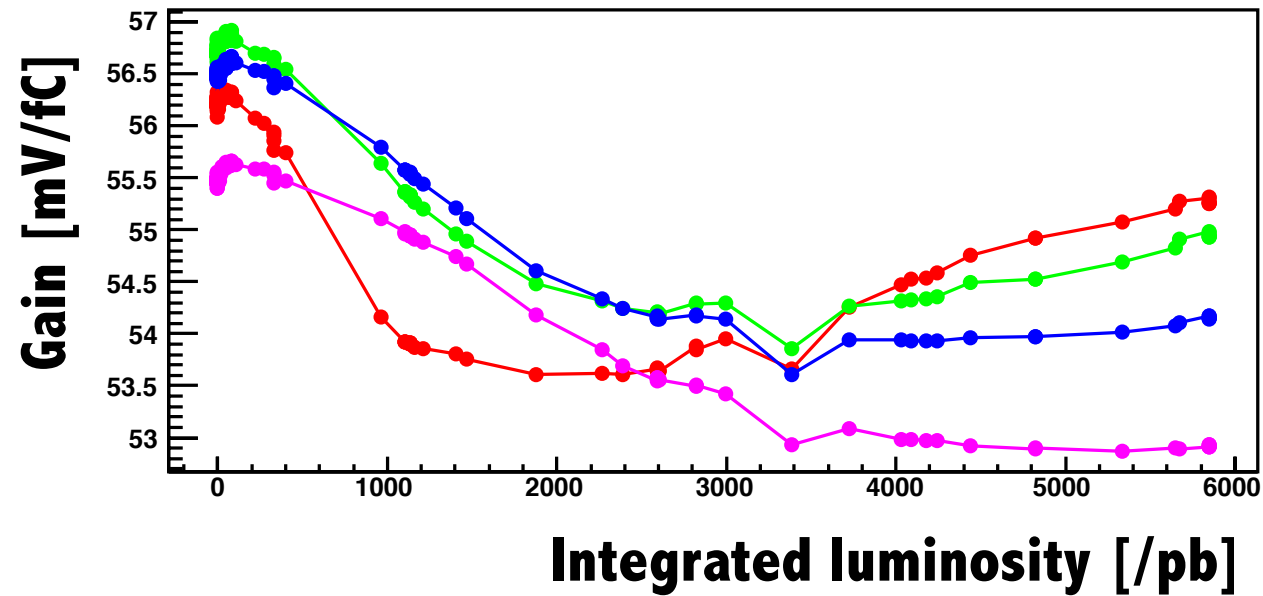
➡ Gain の減少は chip の放射線損傷が原因である可能性が高い

- **放射線損傷の程度の評価**

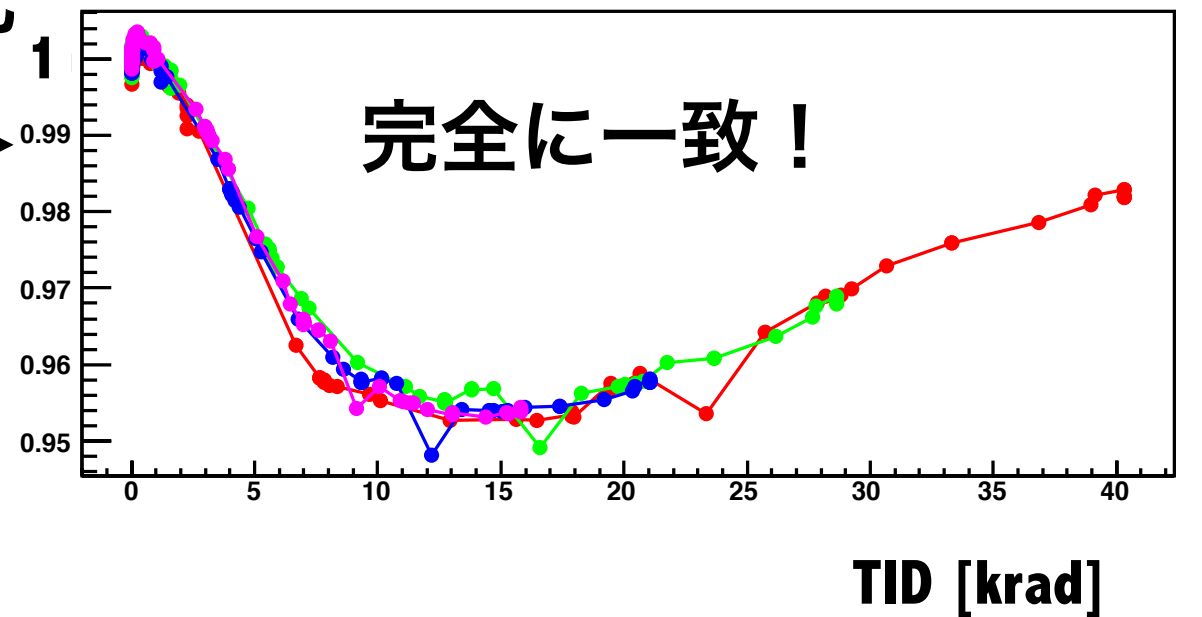
- **Luminosity 依存性**
- **Non Ionizing Energy Loss (NIEL) 依存性**
- **Total Ionizing Dose (TID) 依存性**



● Luminosity, NIEL, TID 依存性



規格化



❖ Gain の layer 依存性は Total Ionizing Dose (TID) で理解できそう

まとめと結論

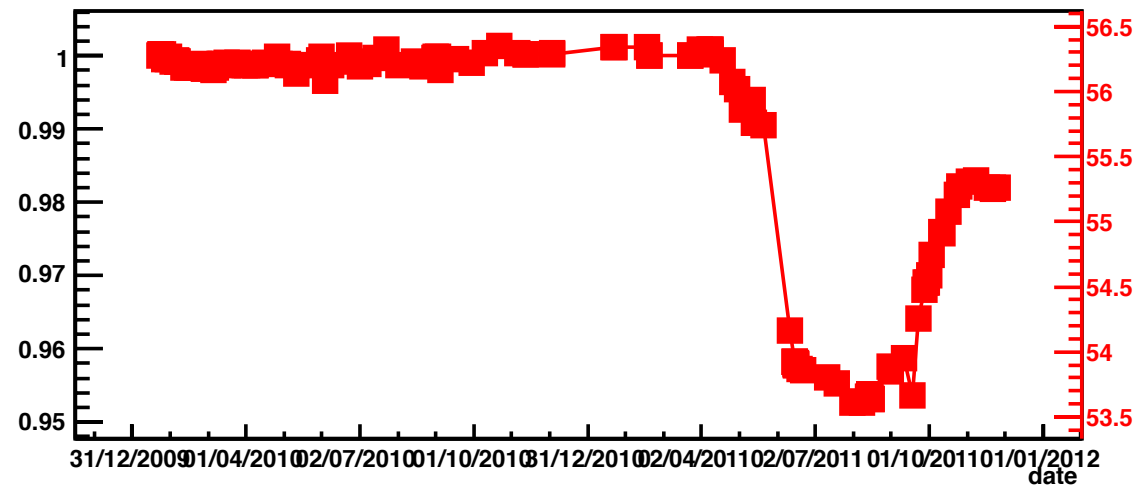
- **Noise の減少の問題**
 - 2010年のLHCのルミノシティ上昇に伴って、**~5% 減少**
 - ❖ **Chip position** に依存しており、**geometry** にも依存している
(Barrelのみではなく、**endcap**も同様)
 - ❖ **センサーに起因している可能性が高い**
- **Gain の減少の問題**
 - 2010年の頃の **Gain** と比べて **~4.5% 減少**
 - ❖ **Layer 依存性があるが、それは TID により理解できる**
- これらの問題に様々な方法 / 観点からアプローチを行っており、問題の理解は進んでいるが、根本的な解決策に至っていないのが現状

backup

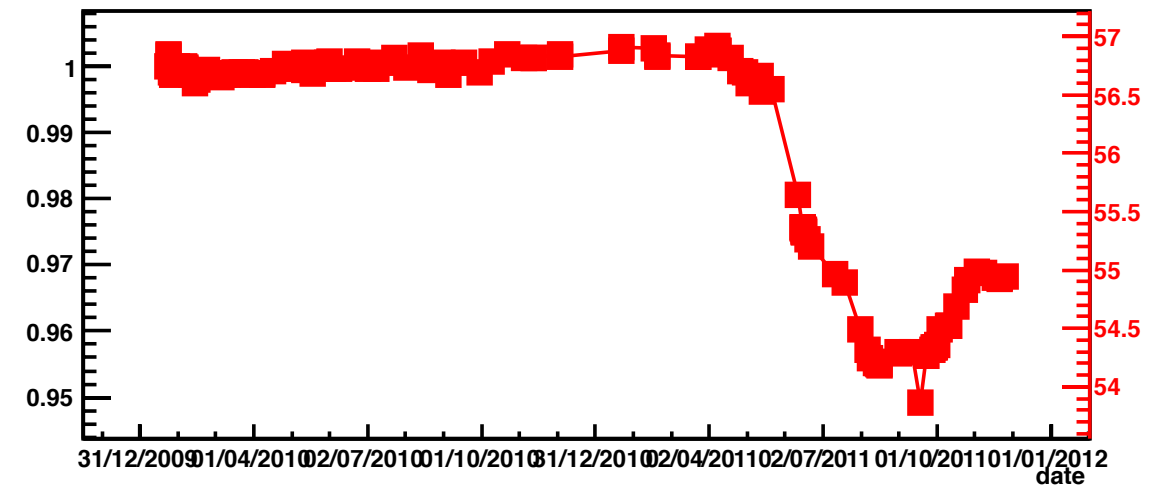
Gain [mV/fC]

- 1 January 2010 ~ 31 August 2011

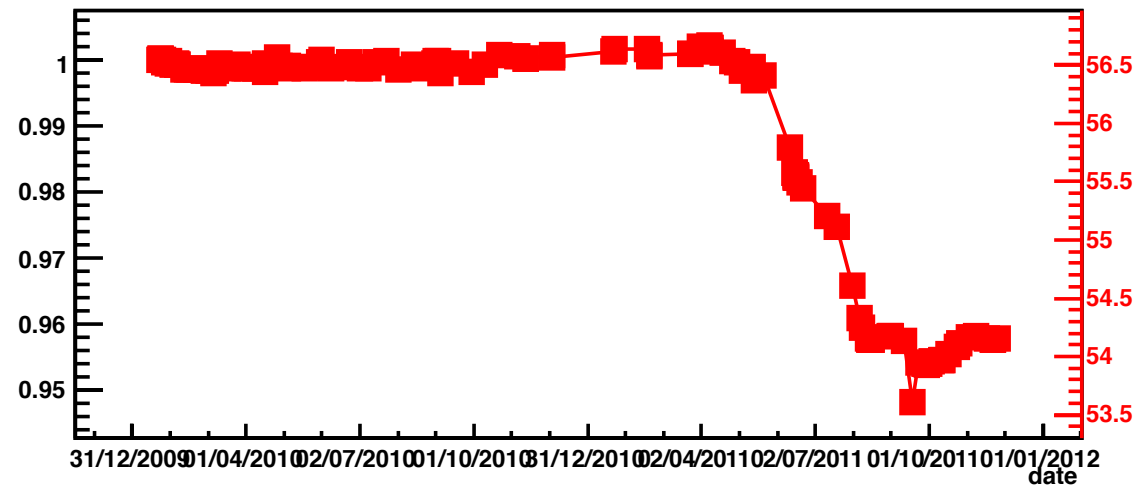
barrel3_gain



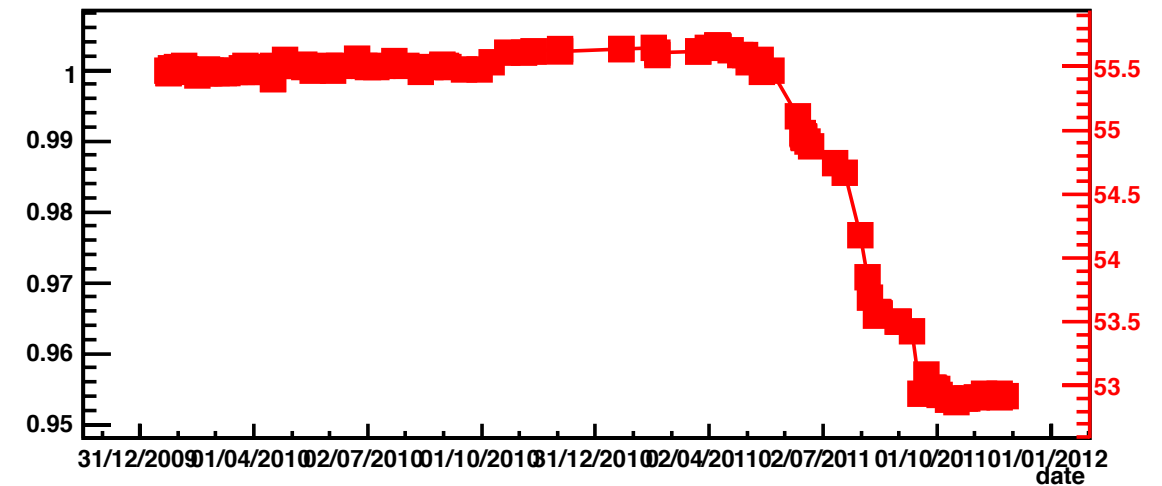
barrel4_gain



barrel5_gain



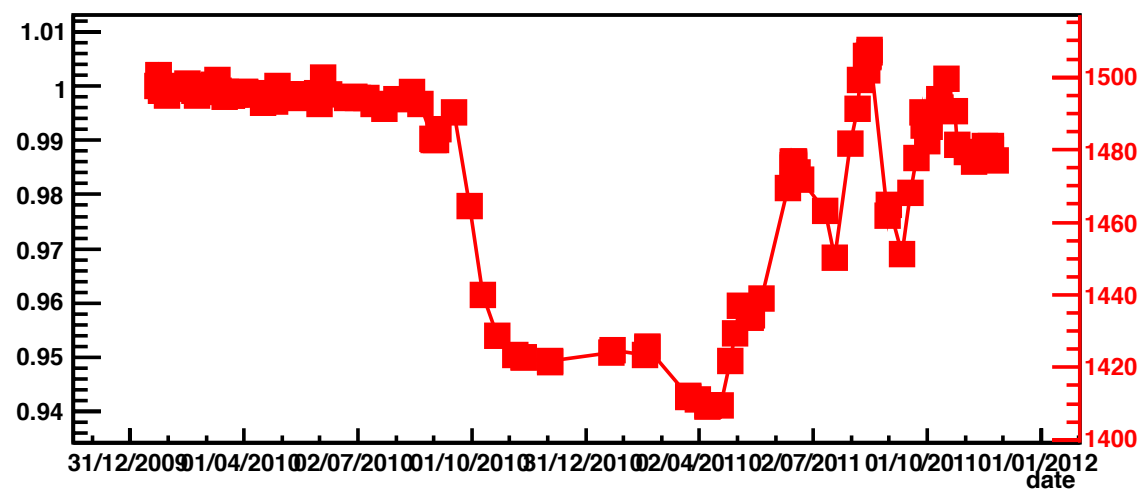
barrel6_gain



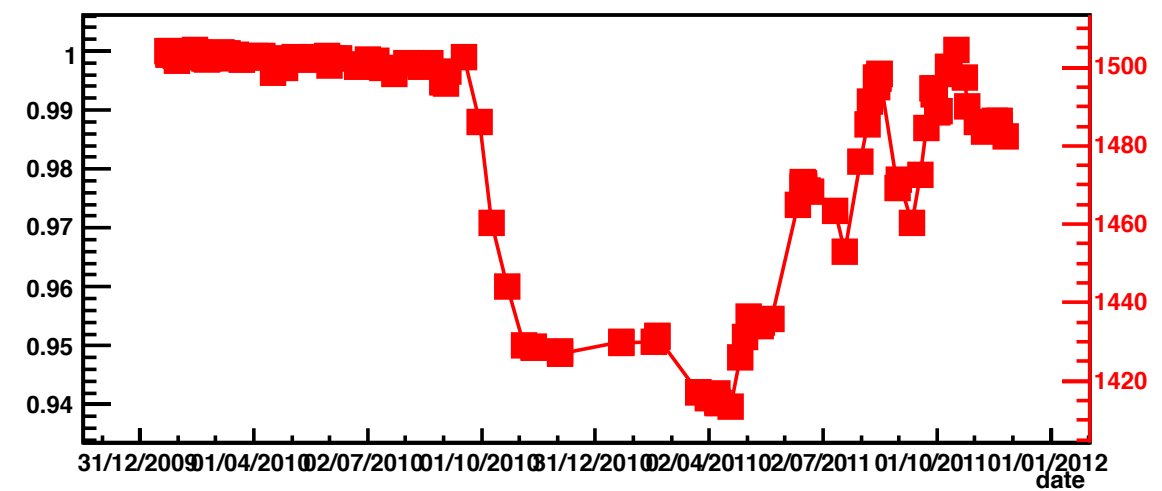
Input noise [e]

- 1 January 2010 ~ 31 August 2011

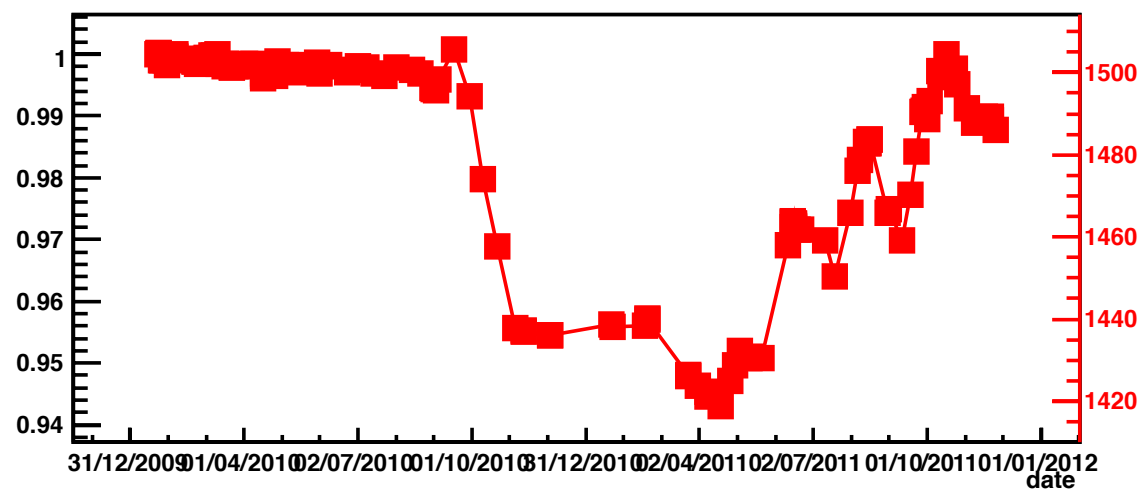
barrel3_innse



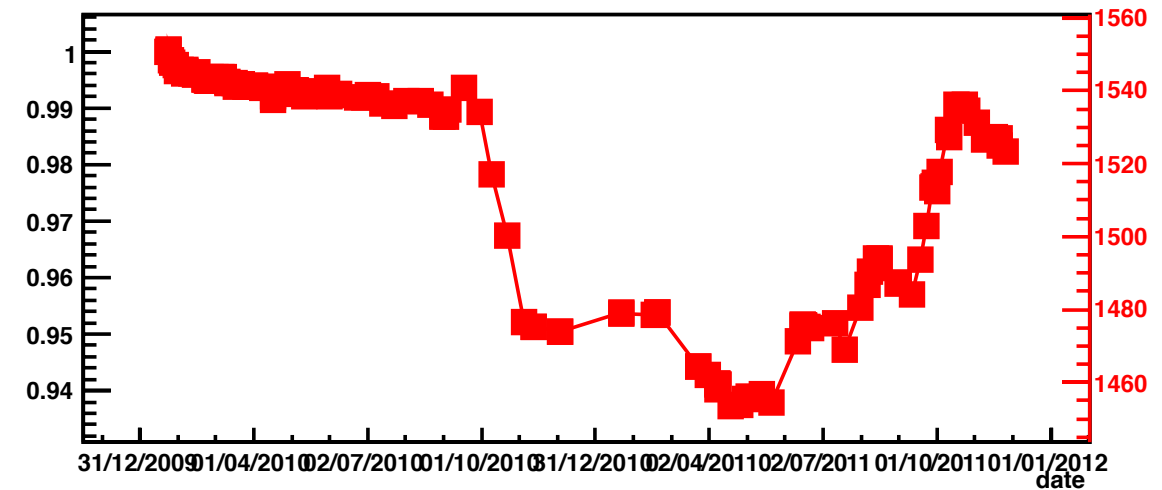
barrel4_innse



barrel5_innse



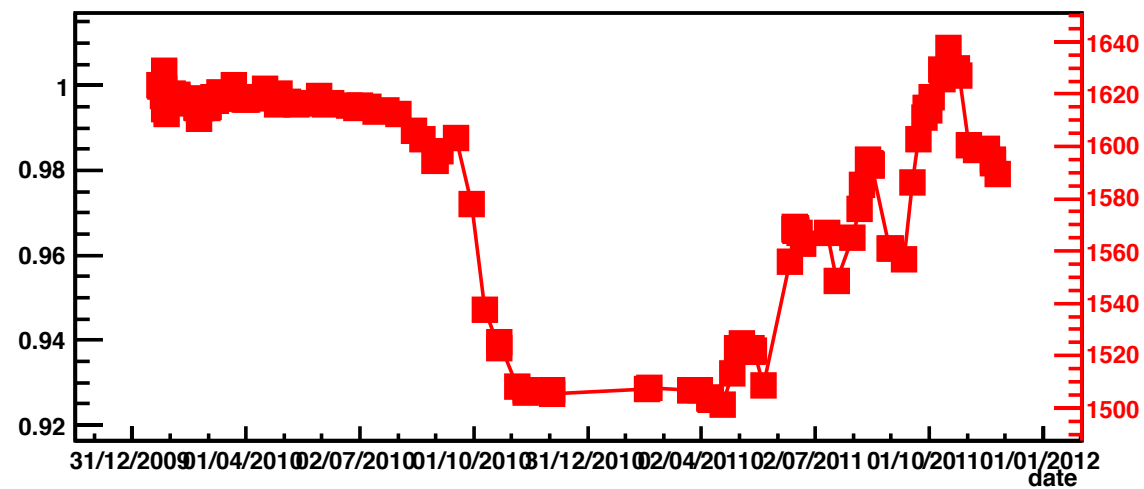
barrel6_innse



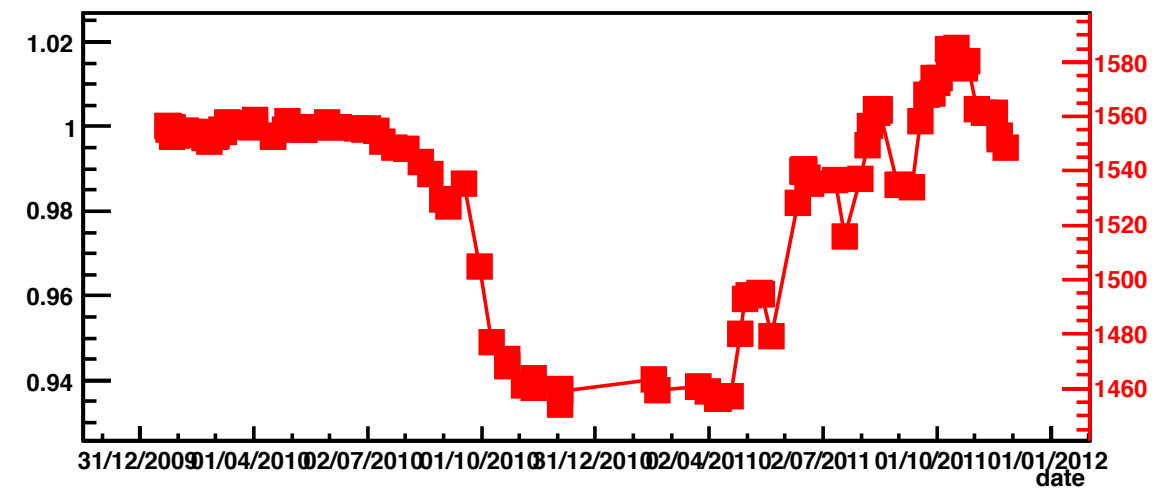
Vt50 [mV]

- 1 January 2010 ~ 31 August 2011

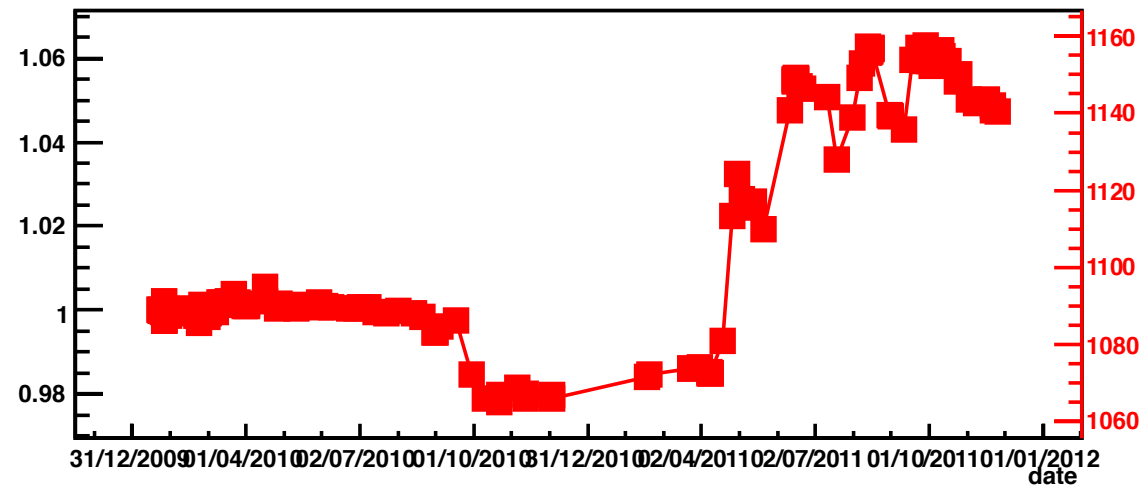
endcapA_outer_innse



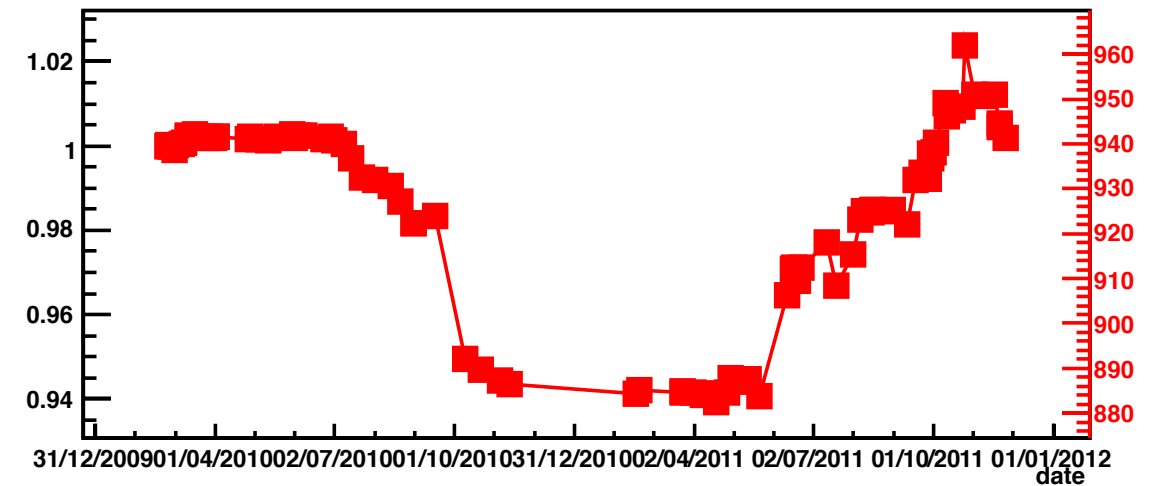
endcapA_middle_innse



endcapA_inner_innse



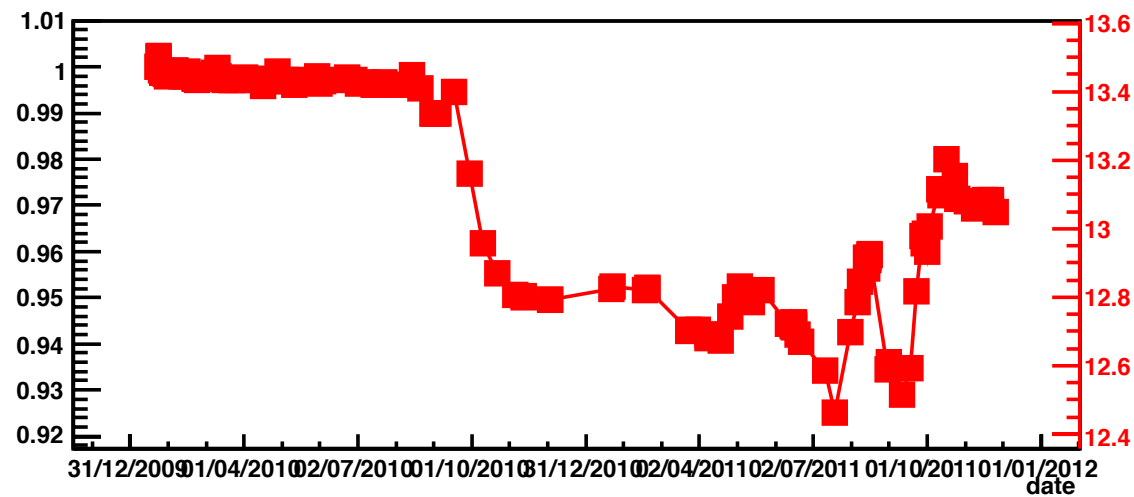
endcapA_shortMiddle_innse



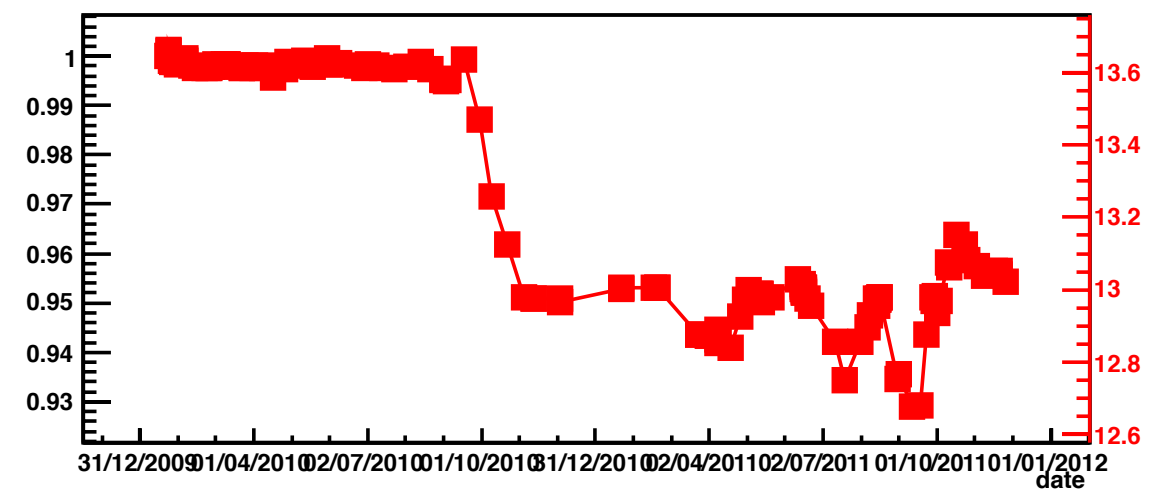
Output noise [mV]

- 1 January 2010 ~ 31 August 2011

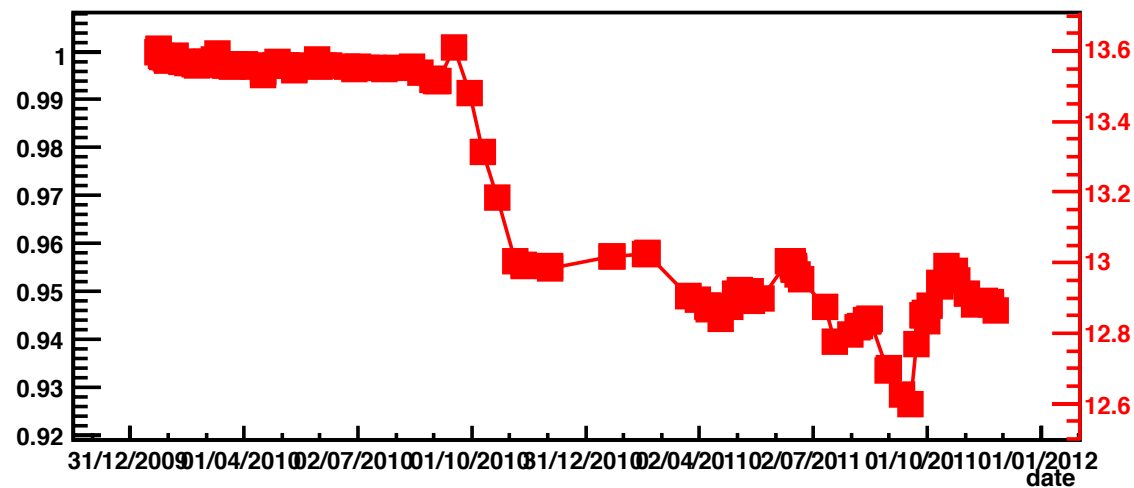
barrel3_outnse



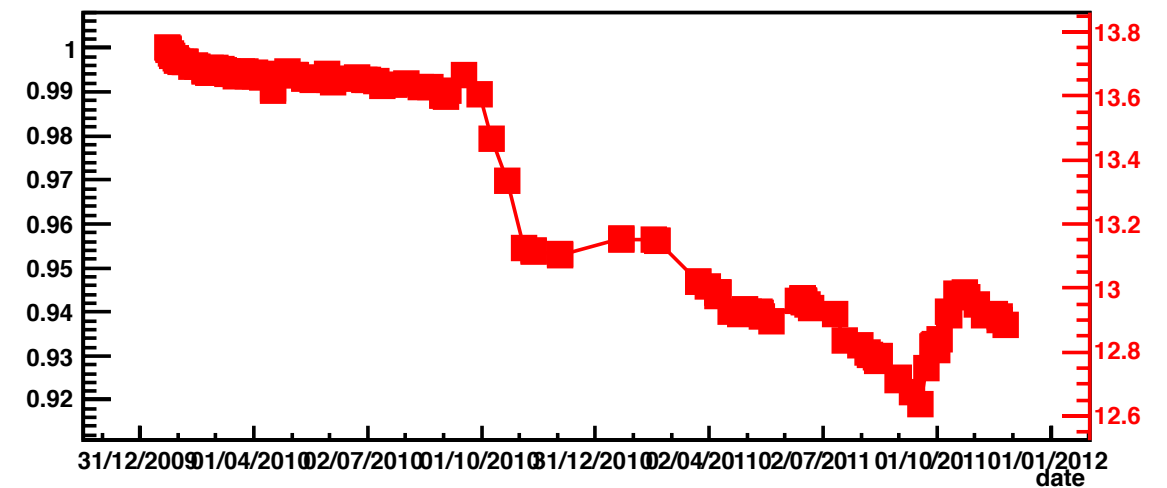
barrel4_outnse



barrel5_outnse



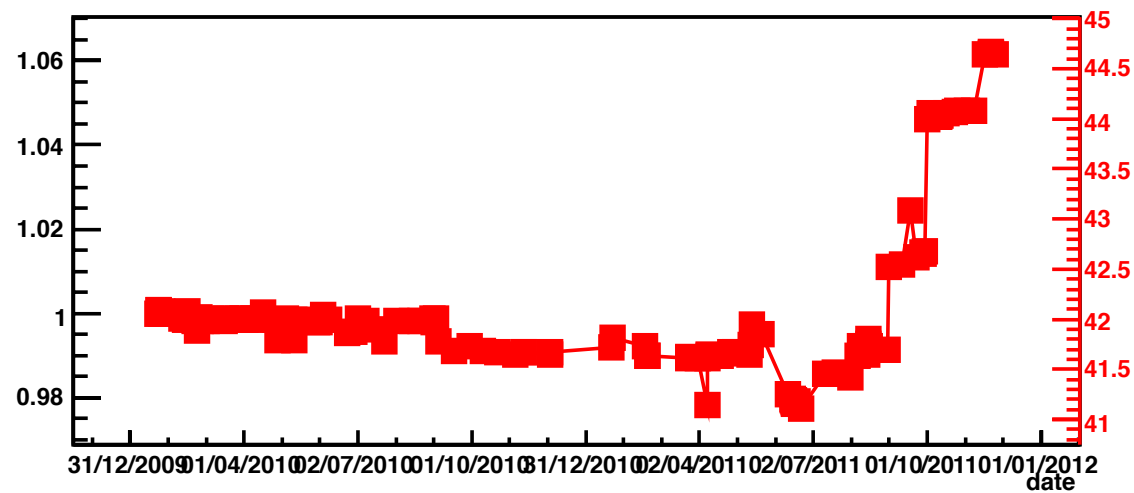
barrel6_outnse



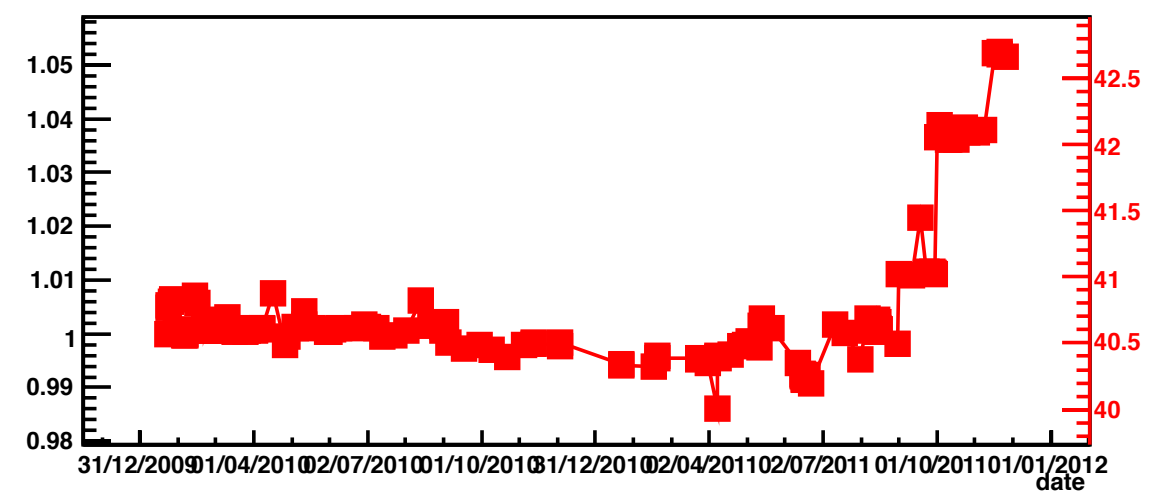
Offset [mV]

- 1 January 2010 ~ 31 August 2011

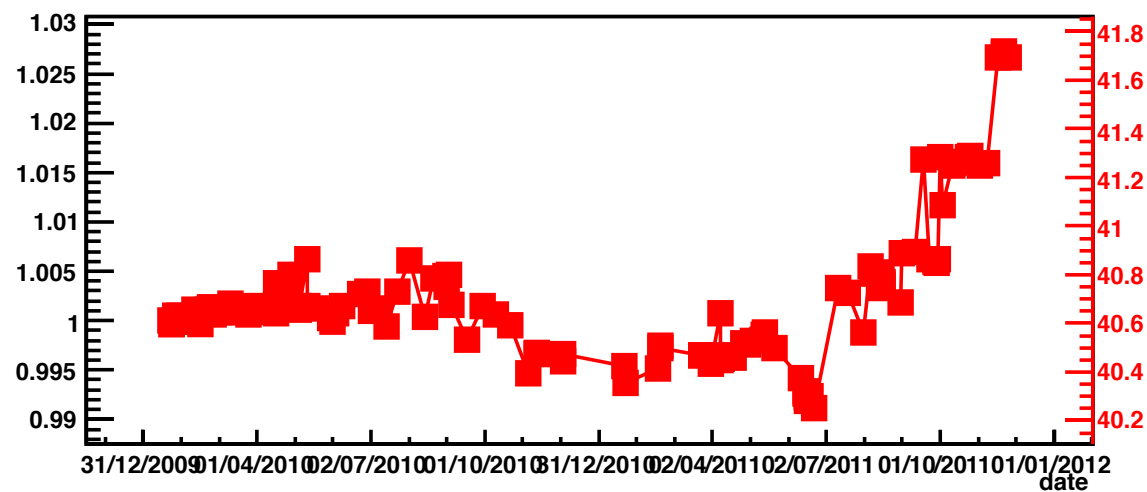
barrel3_offset



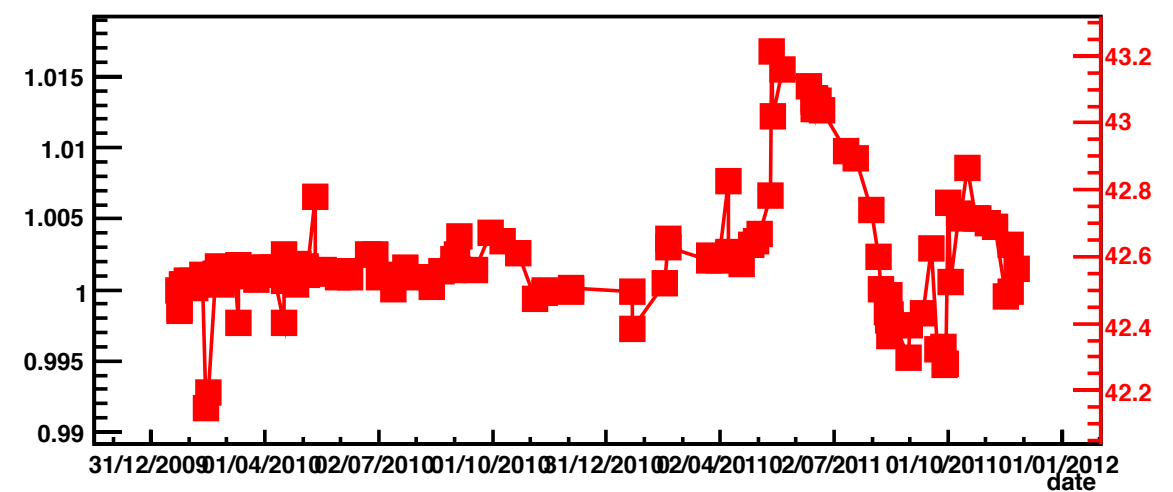
barrel4_offset



barrel5_offset



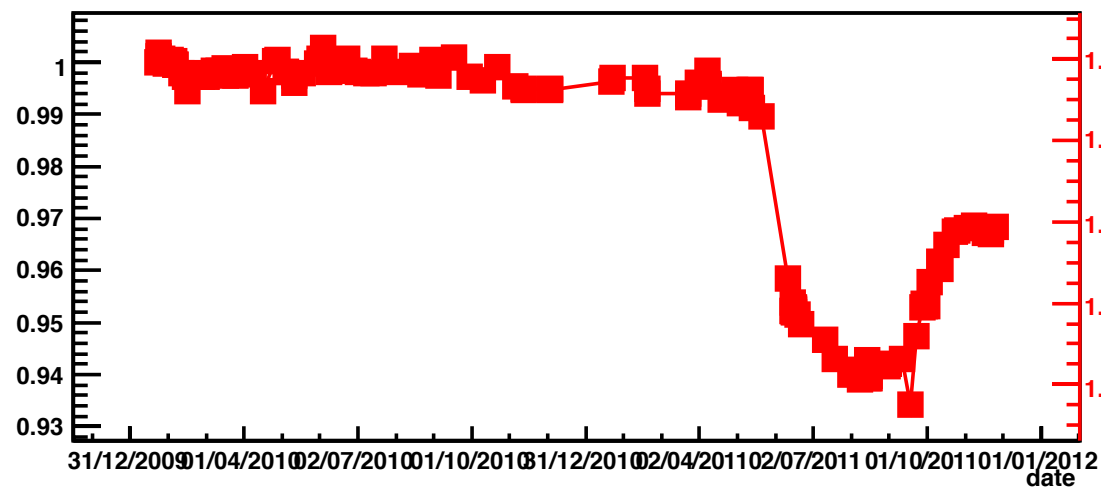
barrel6_offset



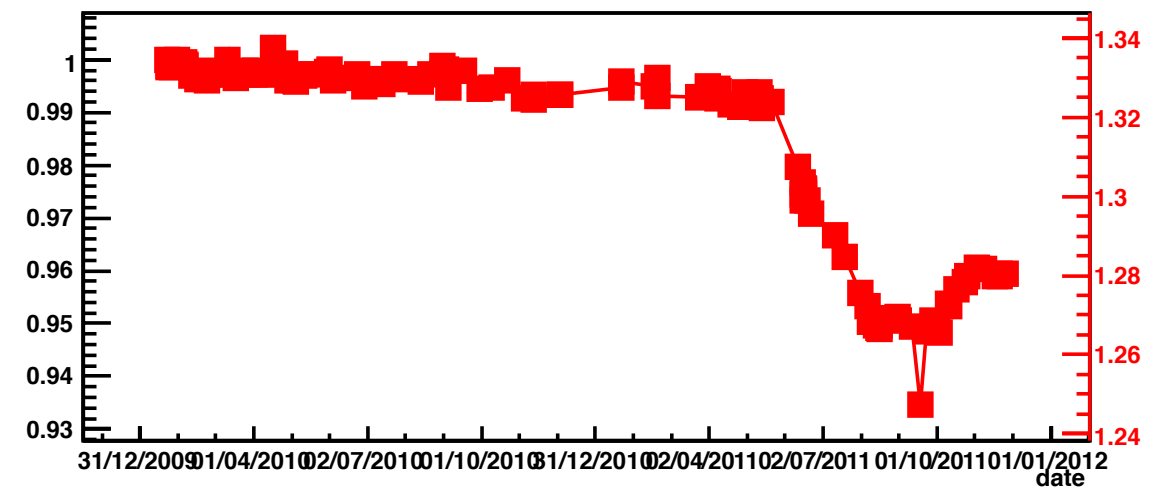
Gain RMS [mV/fC]

- 1 January 2010 ~ 31 August 2011

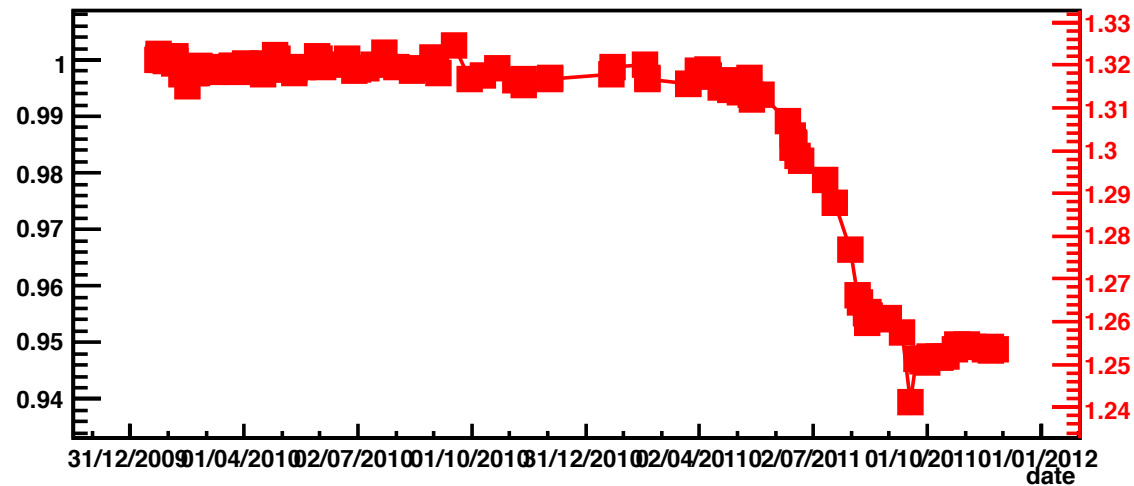
barrel3_gainrms



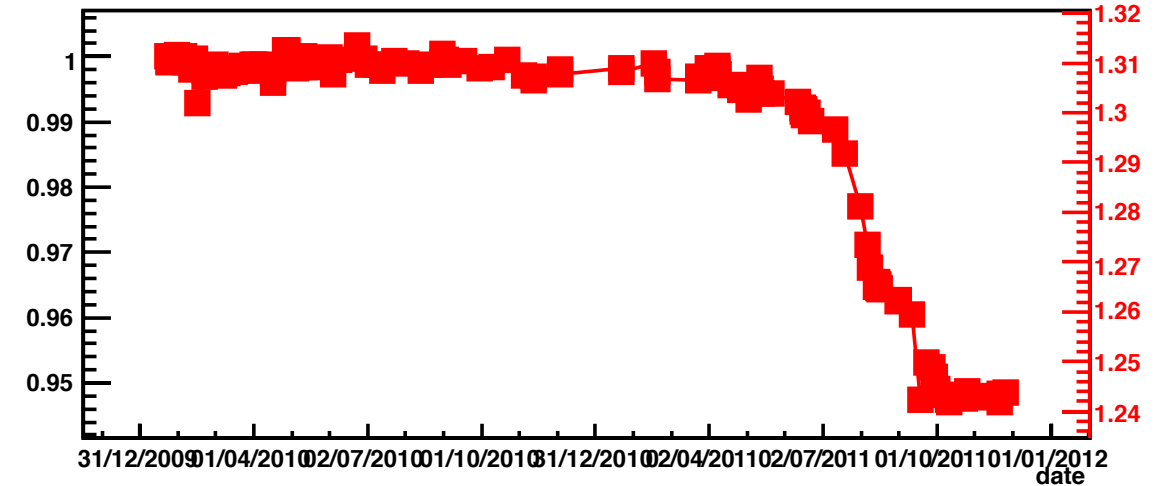
barrel4_gainrms



barrel5_gainrms



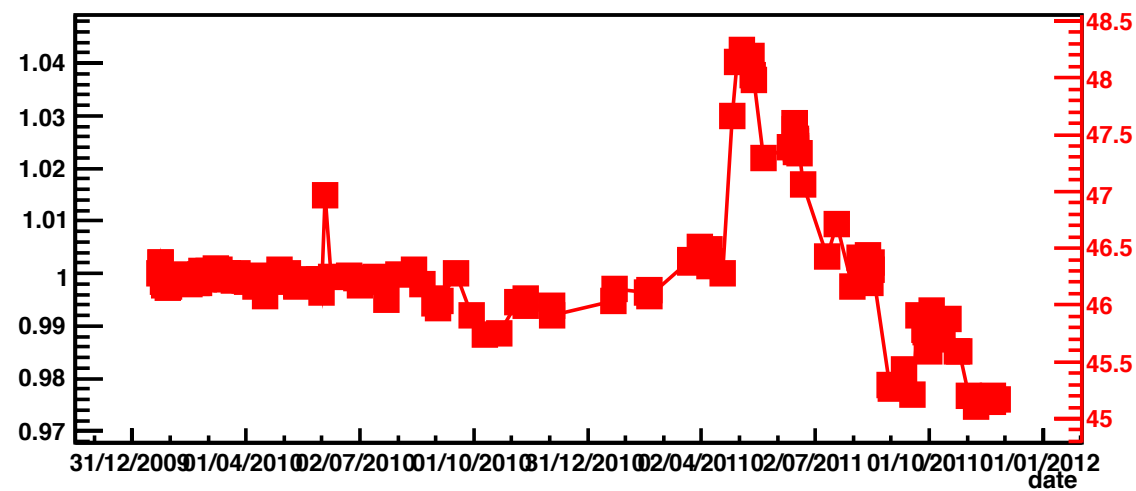
barrel6_gainrms



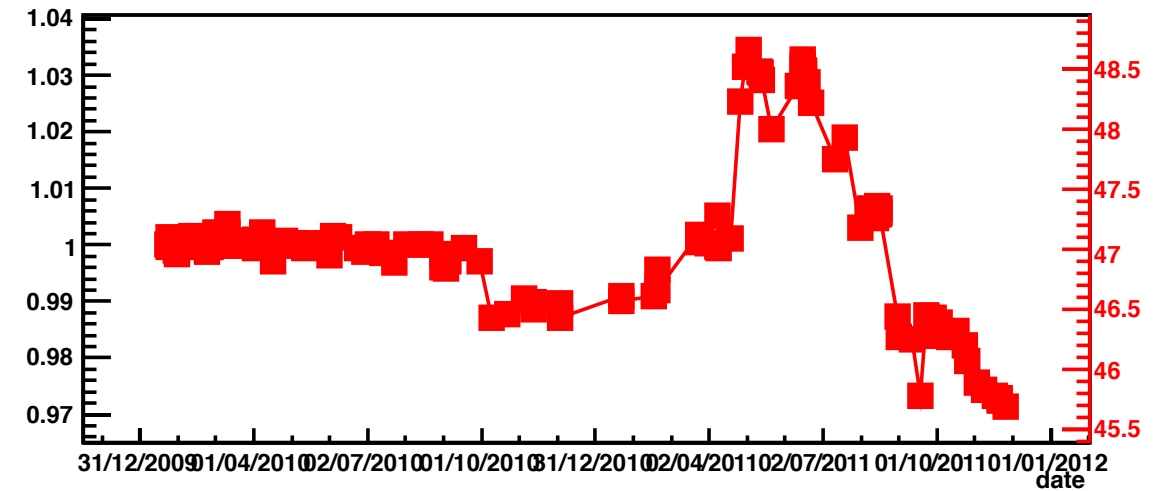
Noise RMS [e]

- 1 January 2010 ~ 31 August 2011

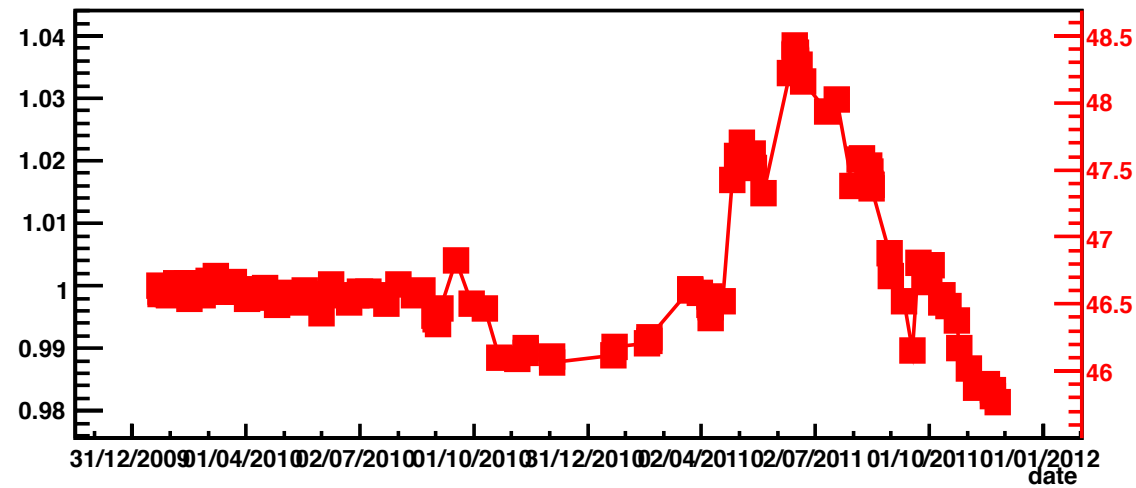
barrel3_nserms



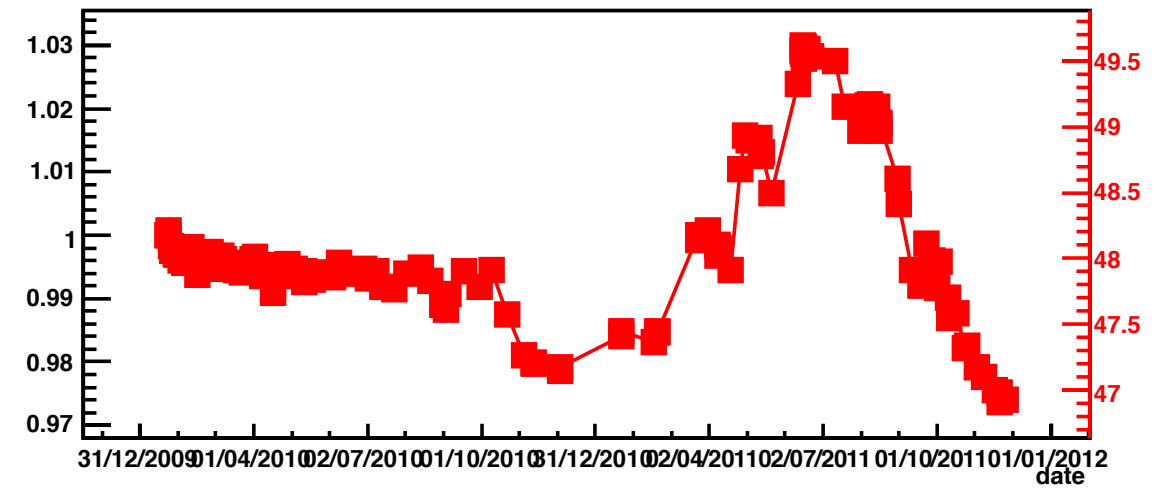
barrel4_nserms



barrel5_nserms



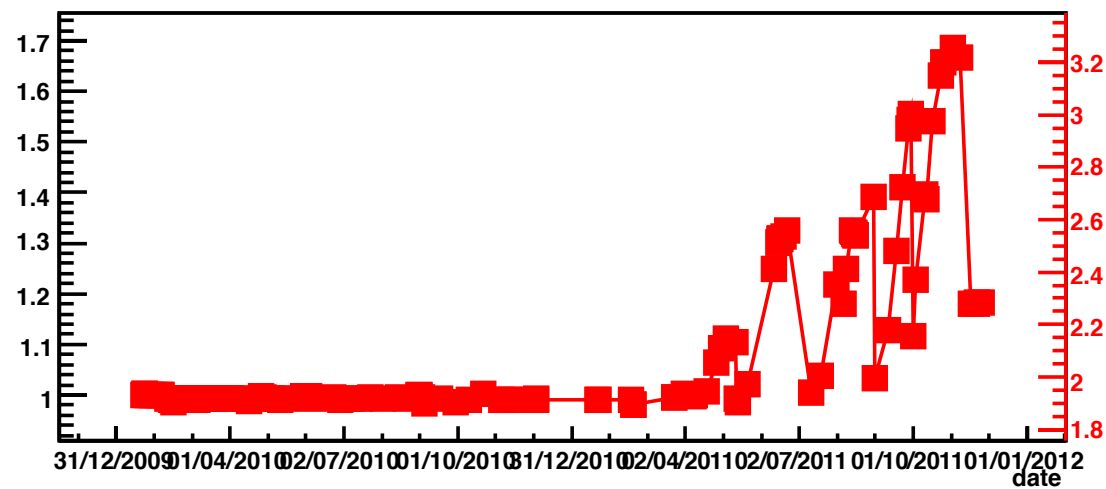
barrel6_nserms



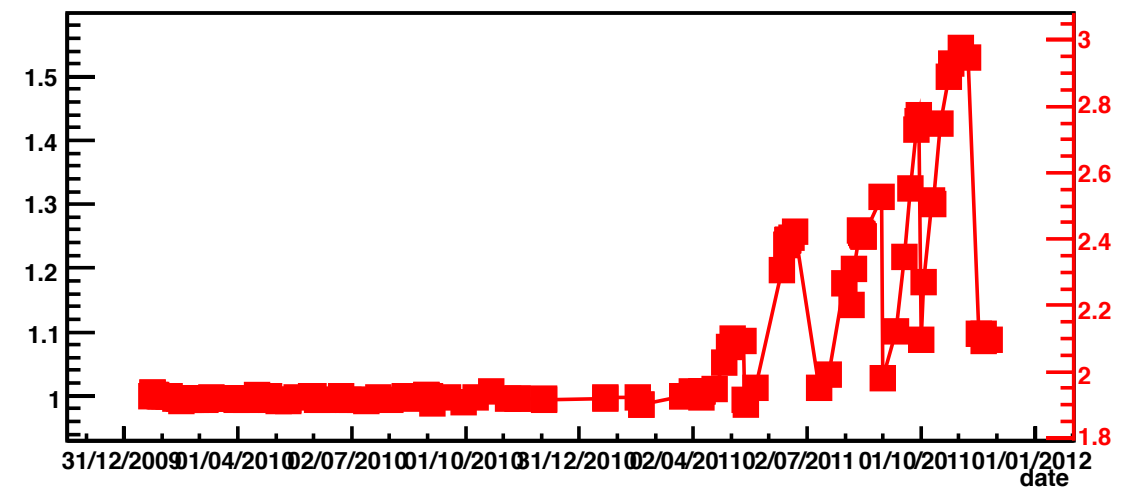
Vt50 RMS [mV]

- 1 January 2010 ~ 31 August 2011

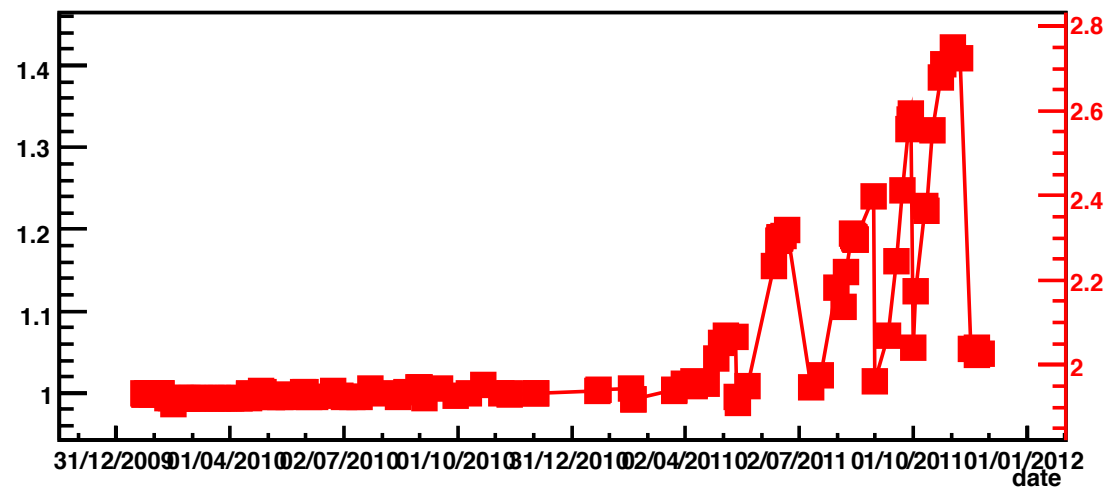
barrel3_vt50rms



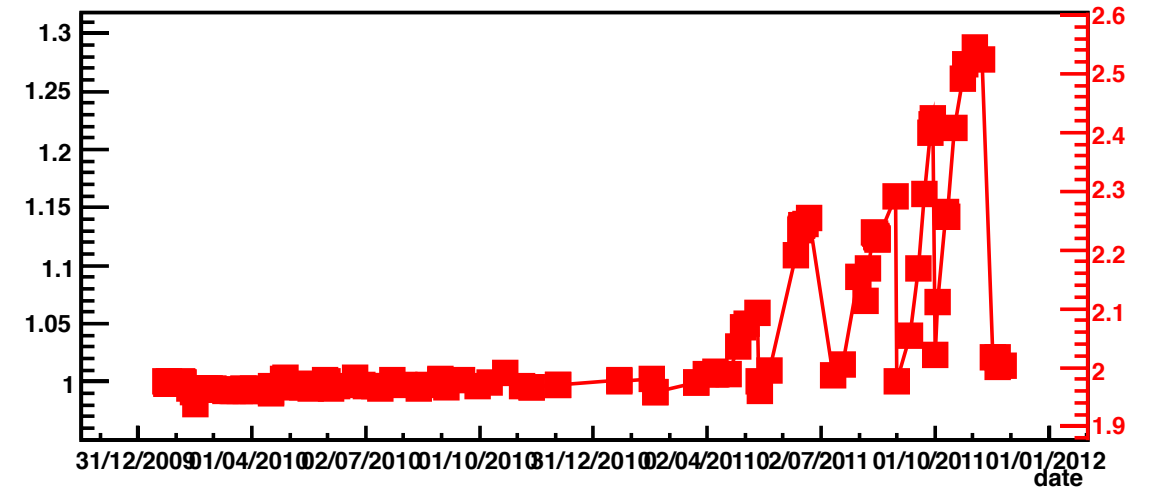
barrel4_vt50rms



barrel5_vt50rms



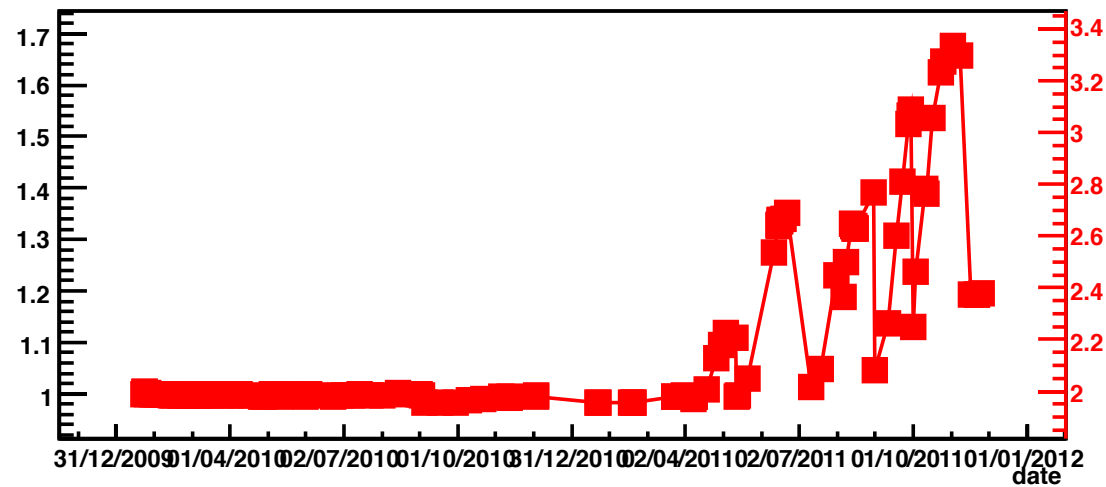
barrel6_vt50rms



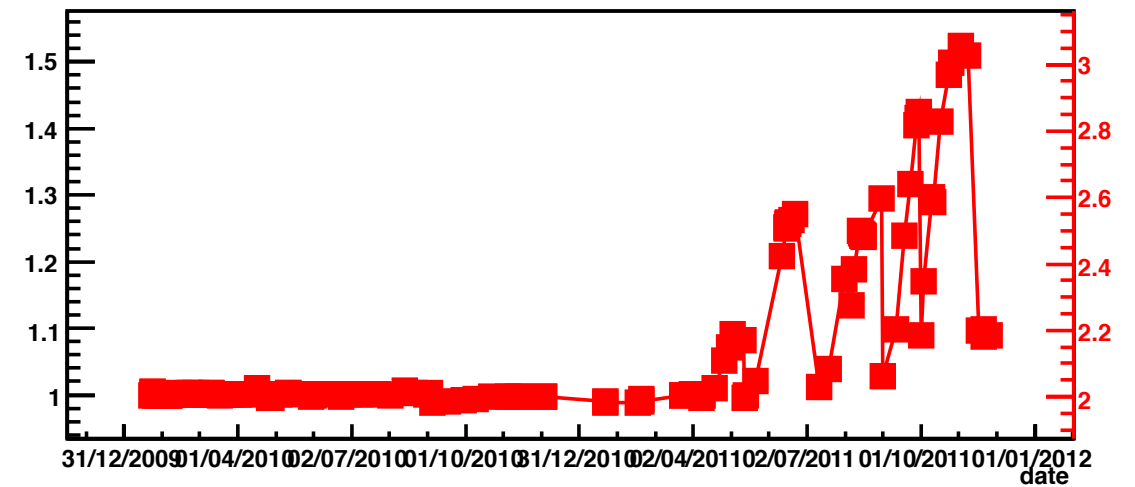
Offset RMS [mV]

- 1 January 2010 ~ 31 August 2011

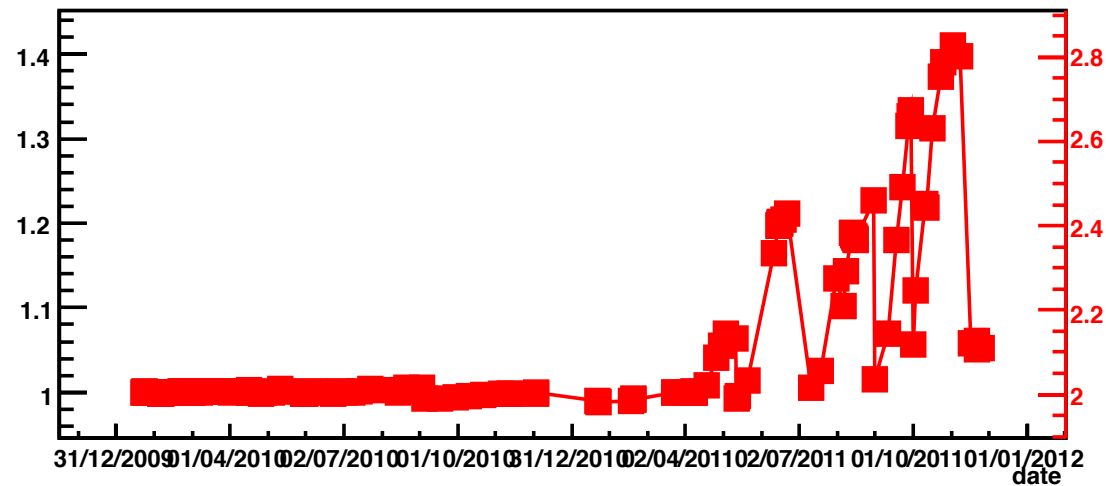
barrel3_offsetrms



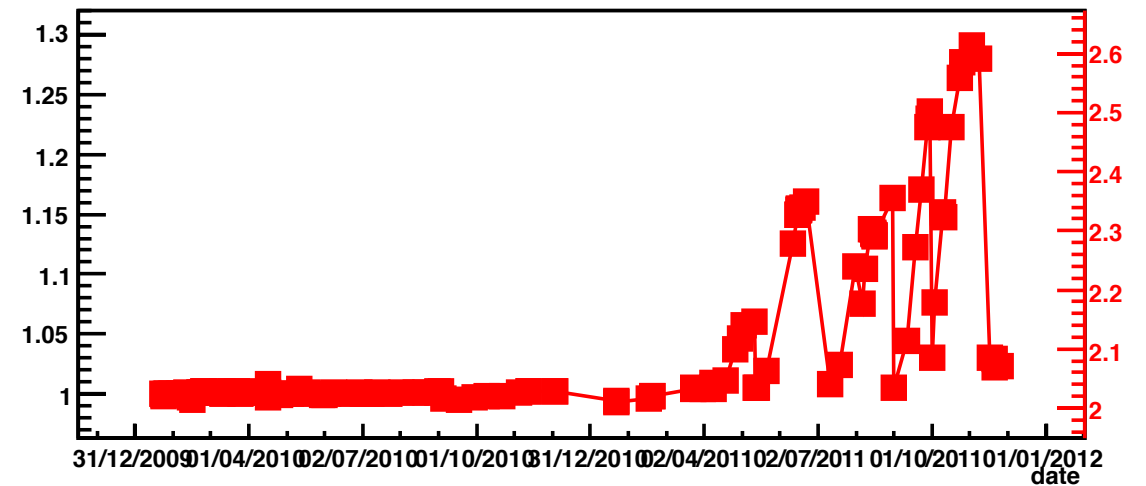
barrel4_offsetrms



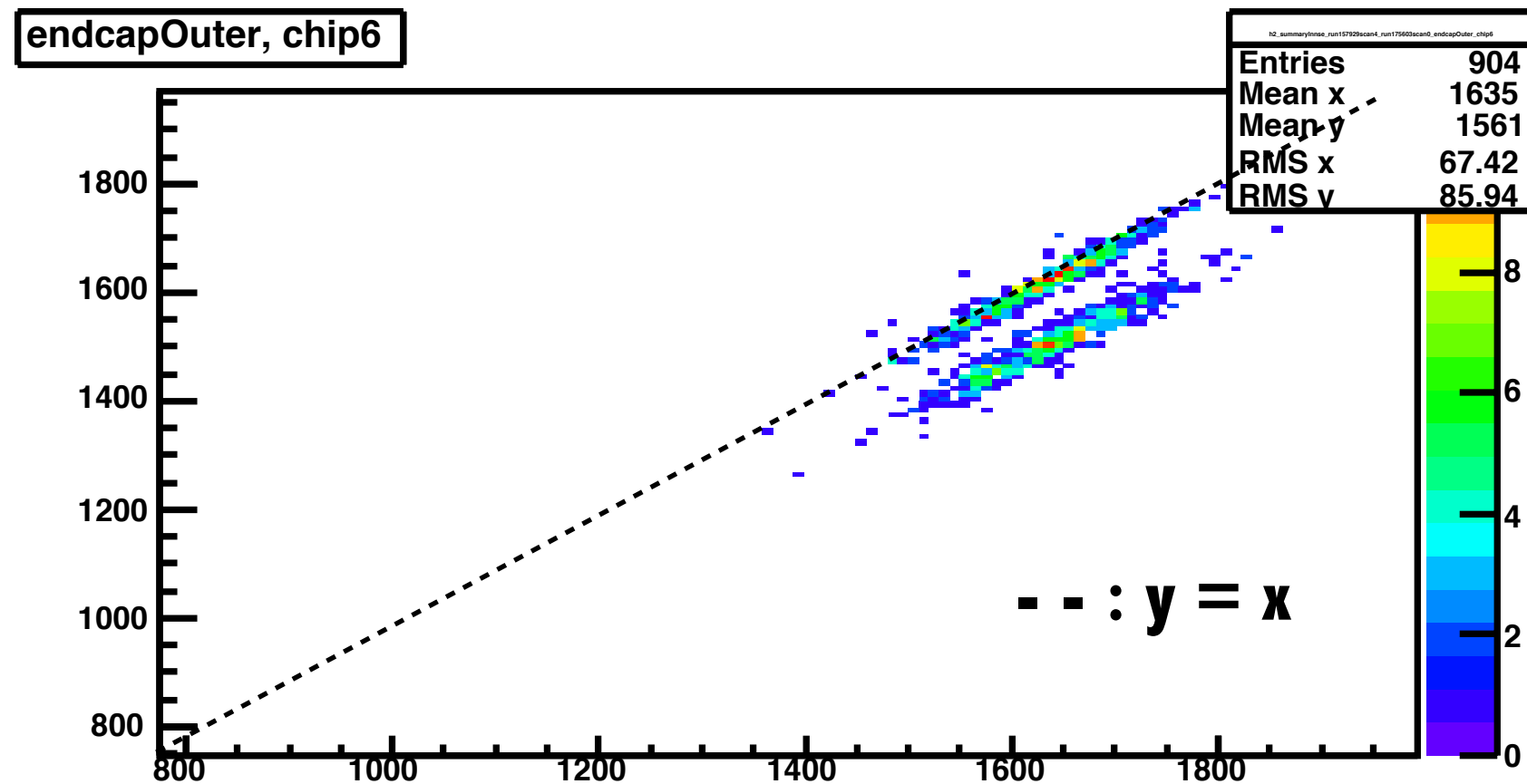
barrel5_offsetrms



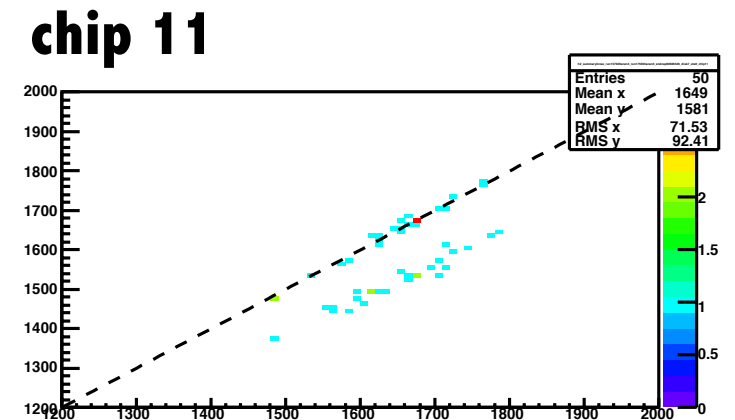
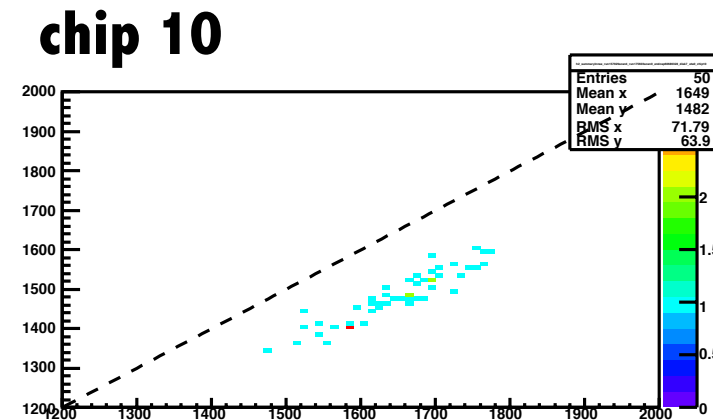
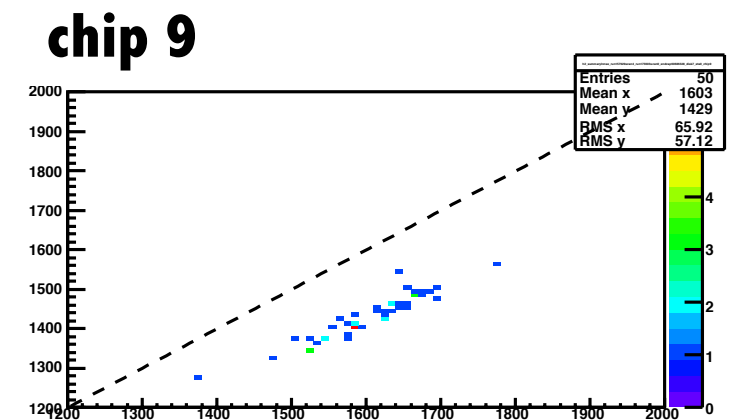
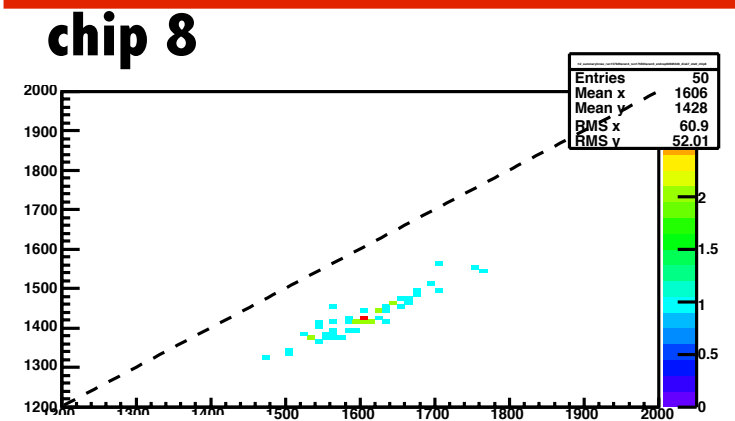
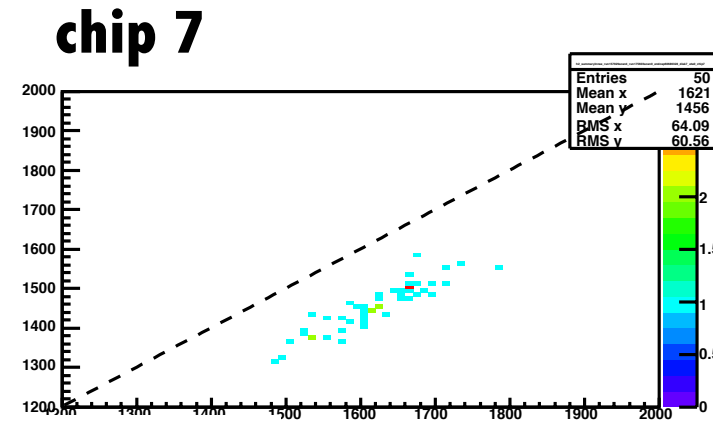
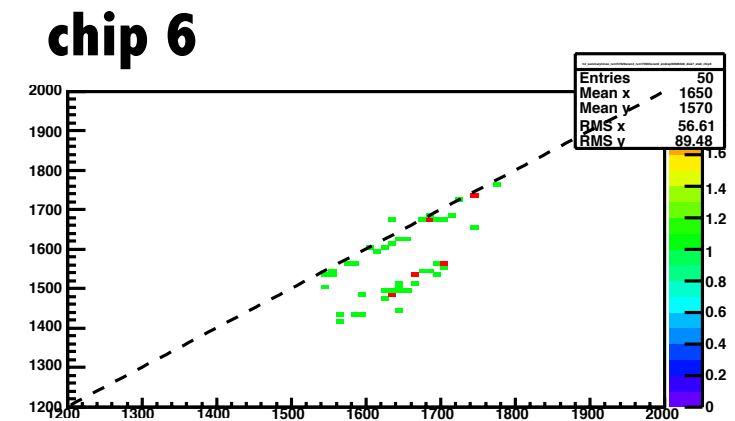
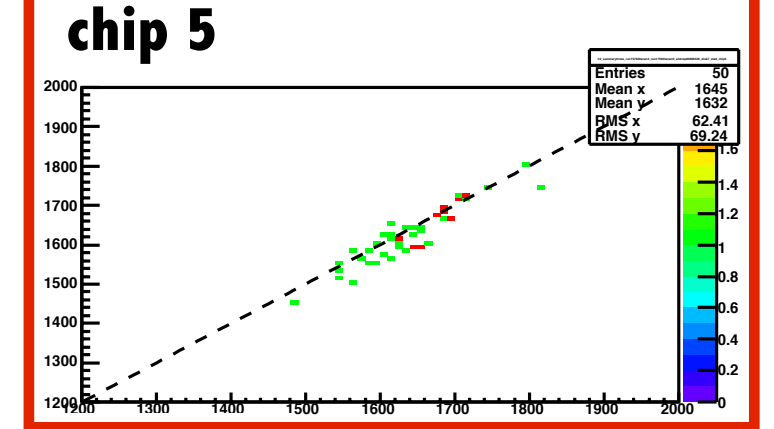
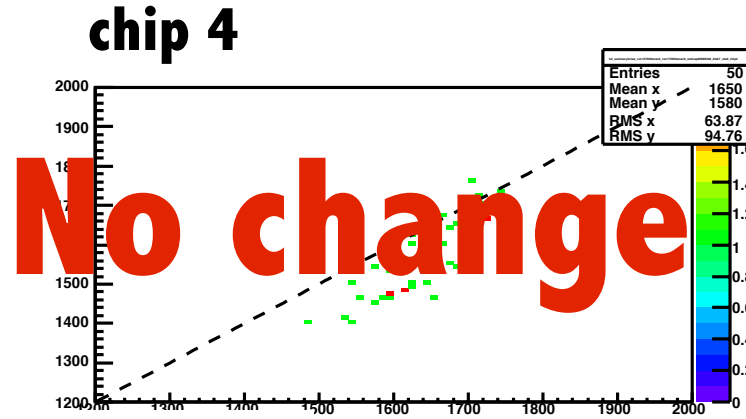
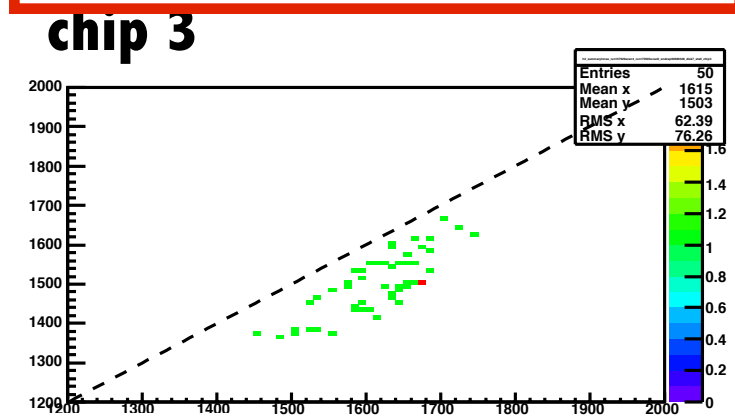
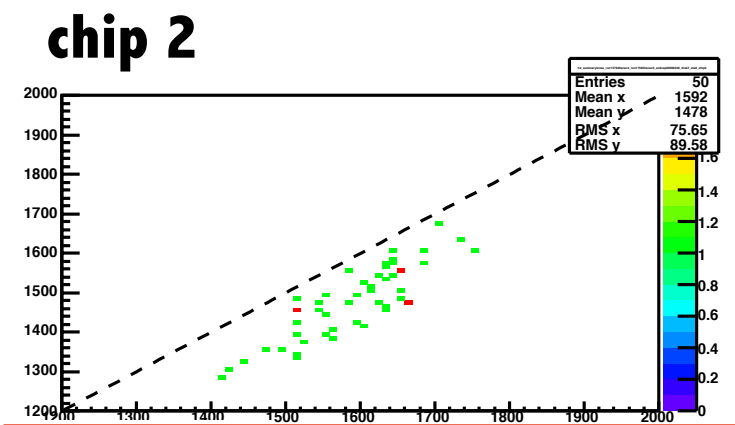
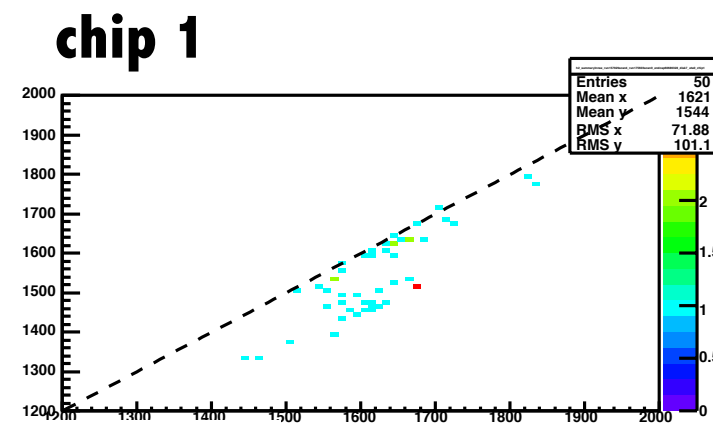
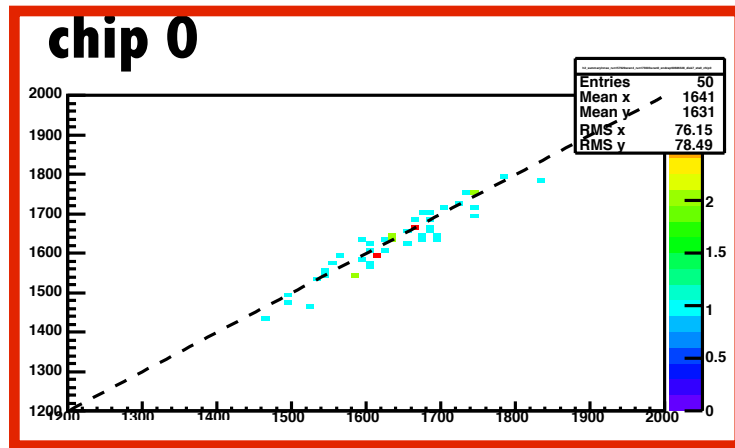
barrel6_offsetrms



- **Noise decrease phenomena for Endcap**
 - **Correlation plot (Endcap Outer modules)**
 - ▶ **X axis : Input noise in run 157929 (Jun. 23 2010)**
 - ▶ **Y axis : Input noise in run 175603 (Feb. 18 2011)**



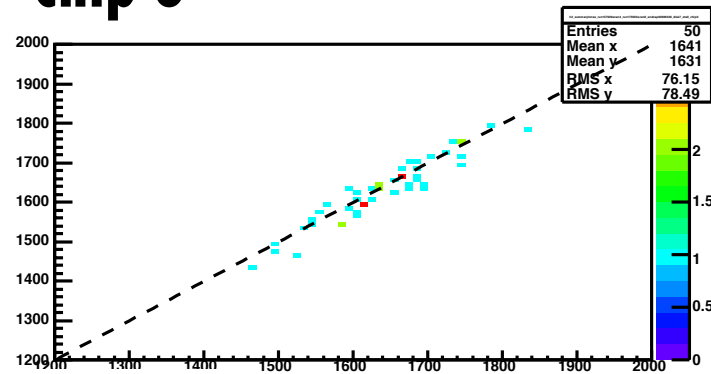
- **EndcapC, Disk7, Outer module**



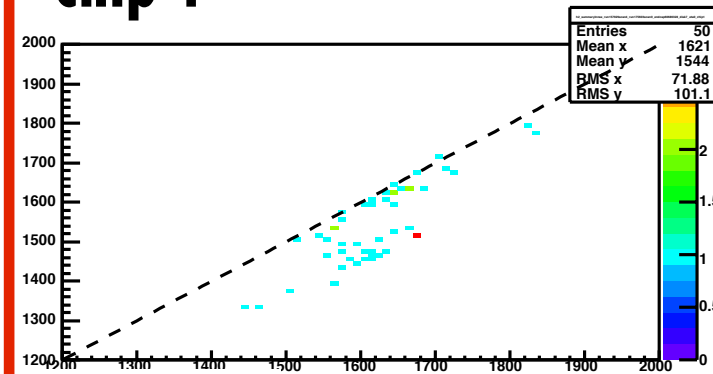
No change

- **EndcapC, Disk7, Outer module**

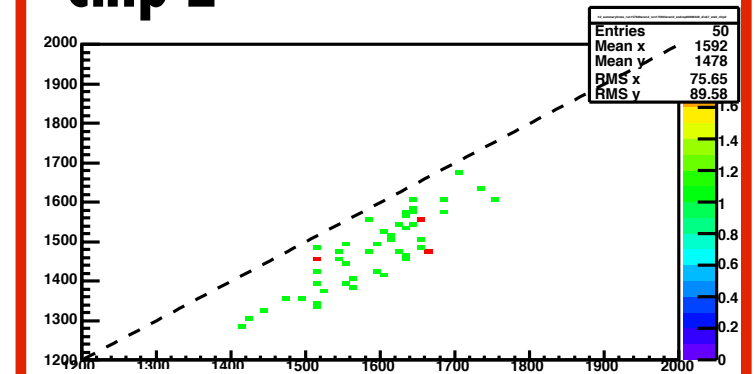
chip 0



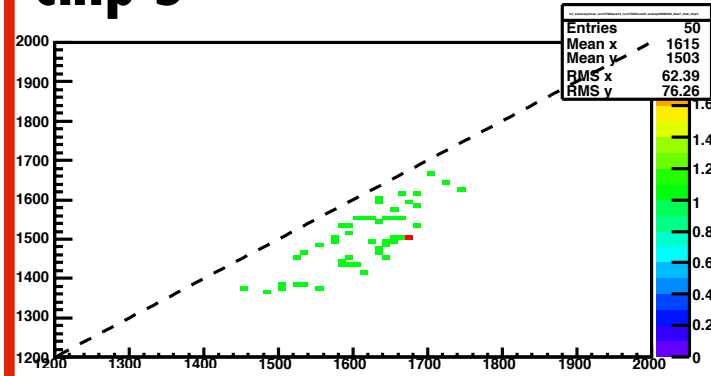
chip 1



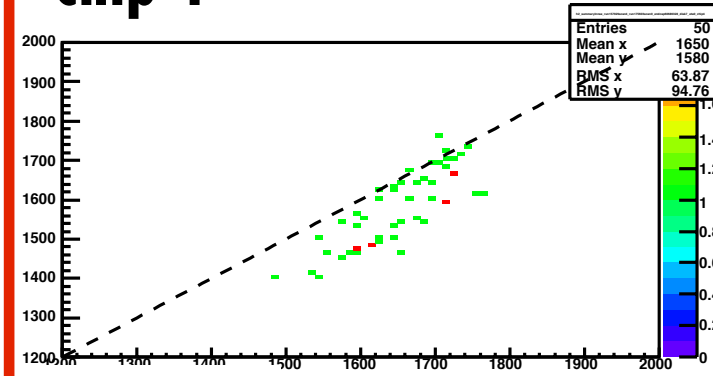
chip 2



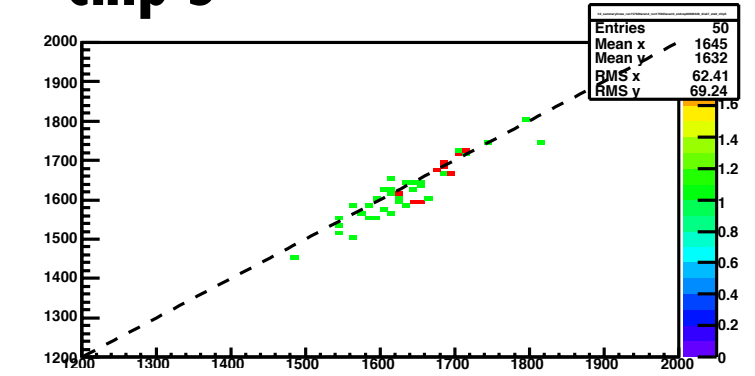
chip 3



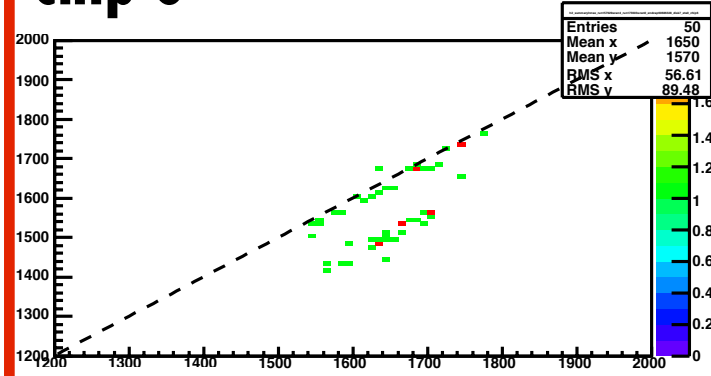
chip 4



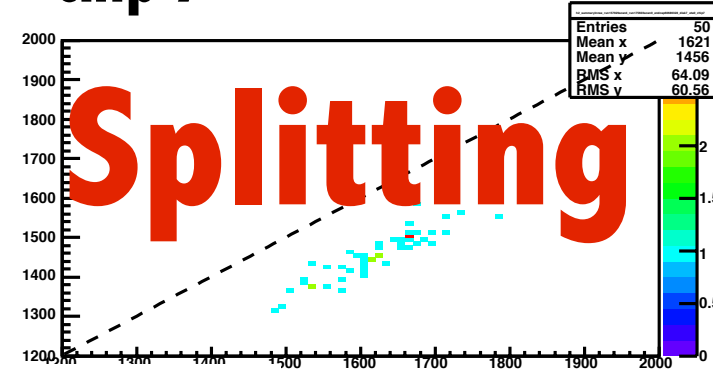
chip 5



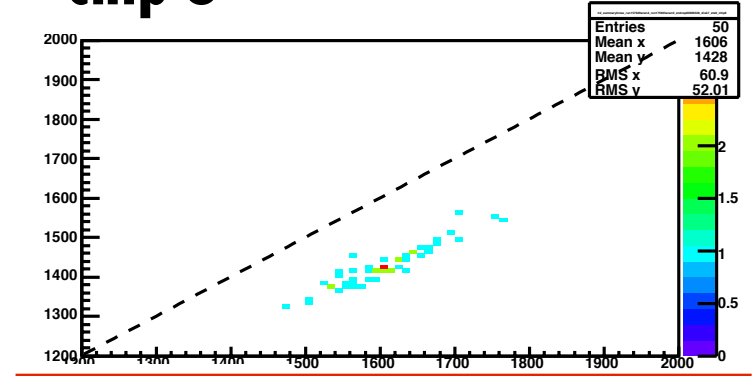
chip 6



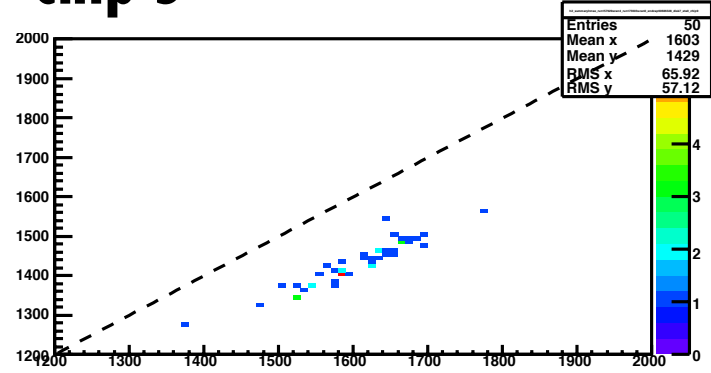
chip 7



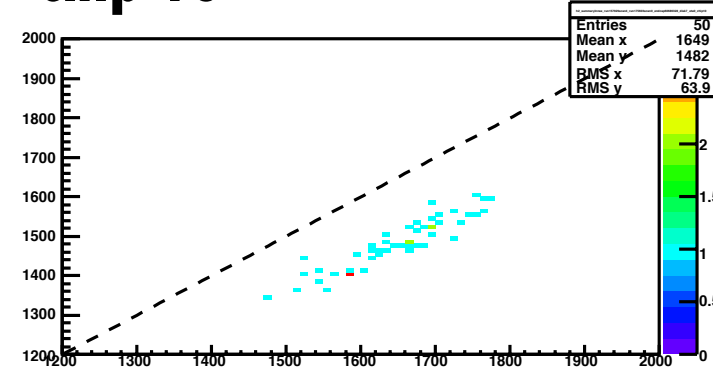
chip 8



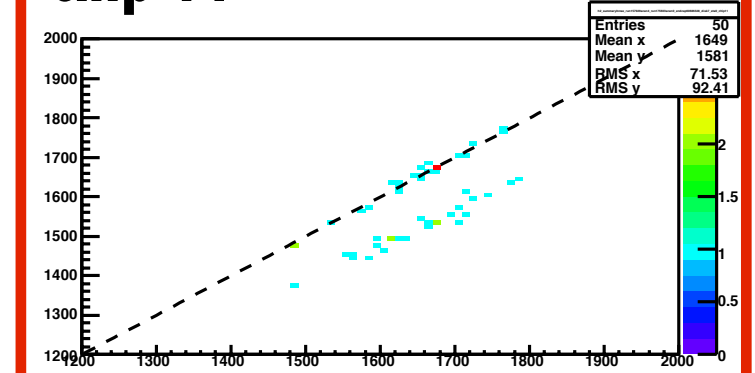
chip 9



chip 10



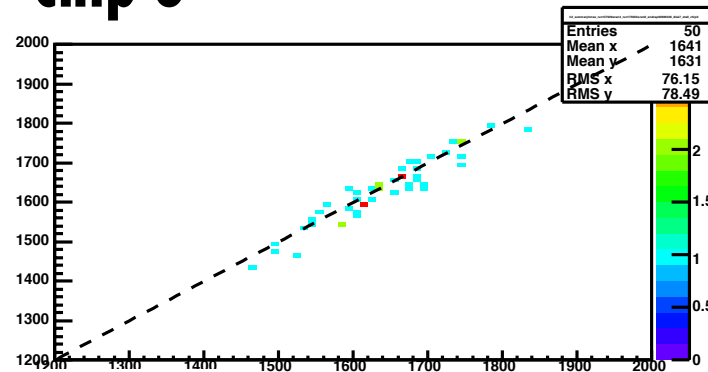
chip 11



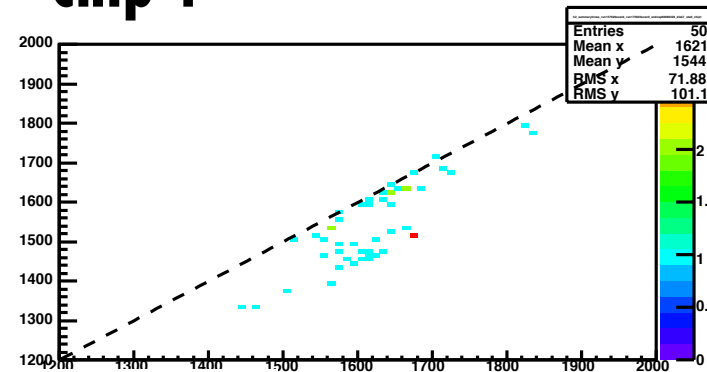
Splitting

- **EndcapC, Disk7, Outer module**

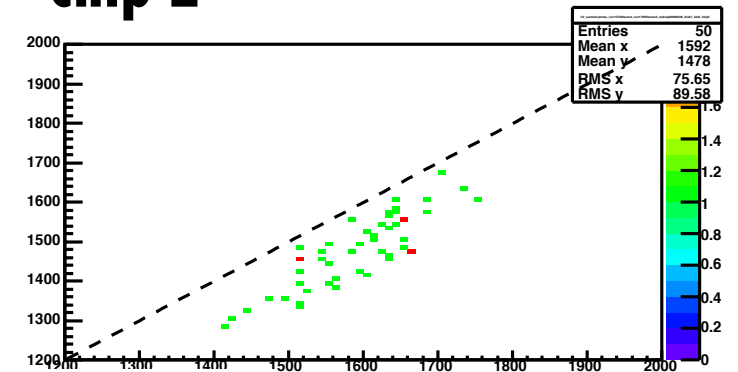
chip 0



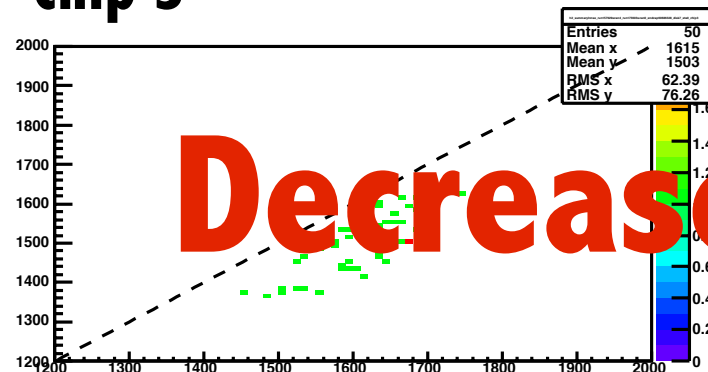
chip 1



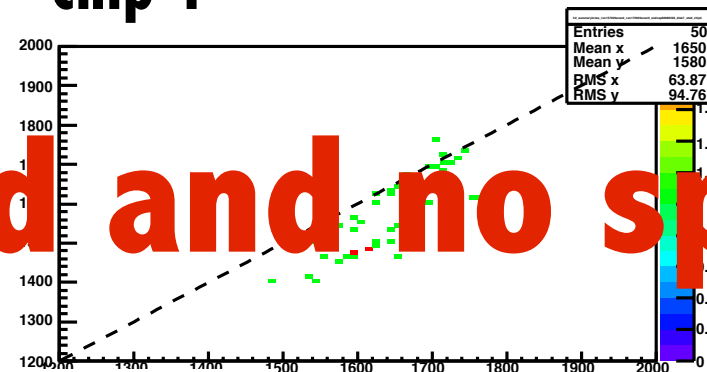
chip 2



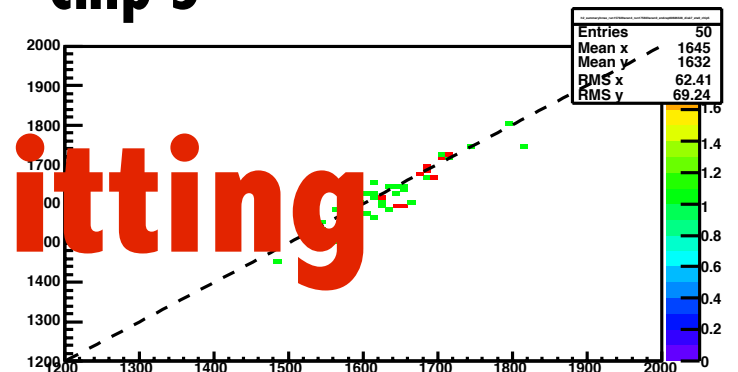
chip 3



chip 4

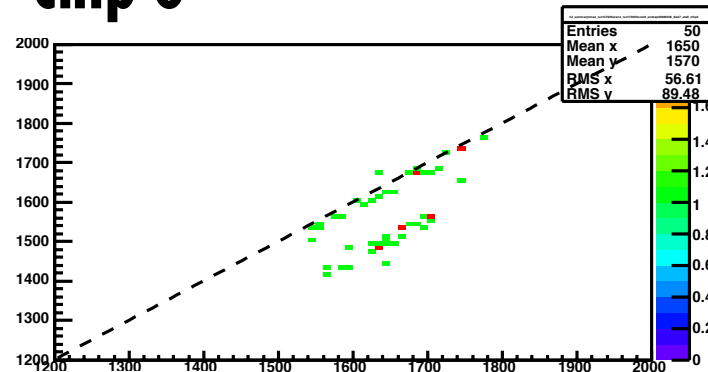


chip 5

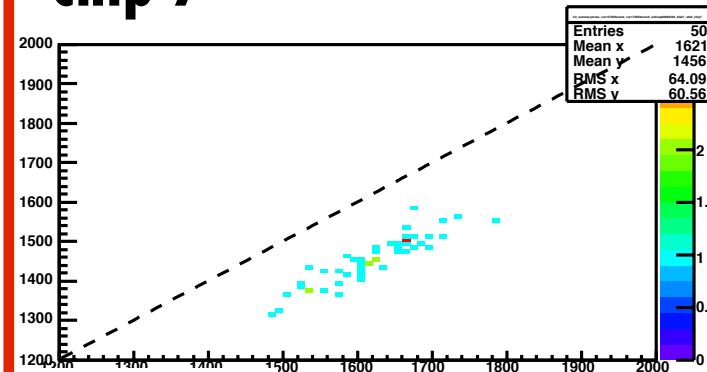


Decreased and no splitting

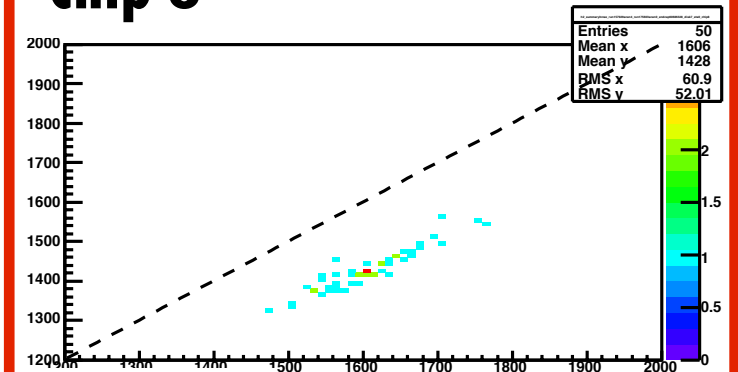
chip 6



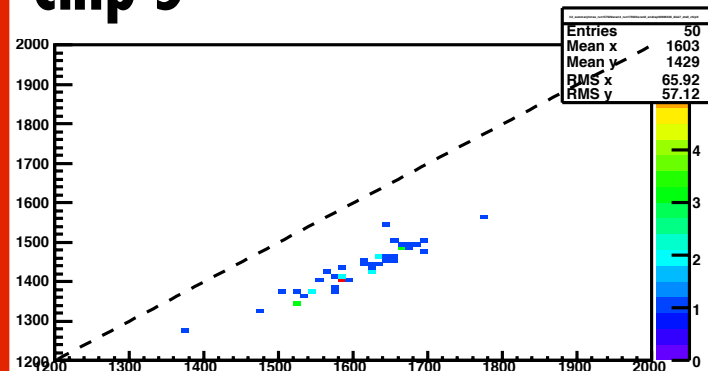
chip 7



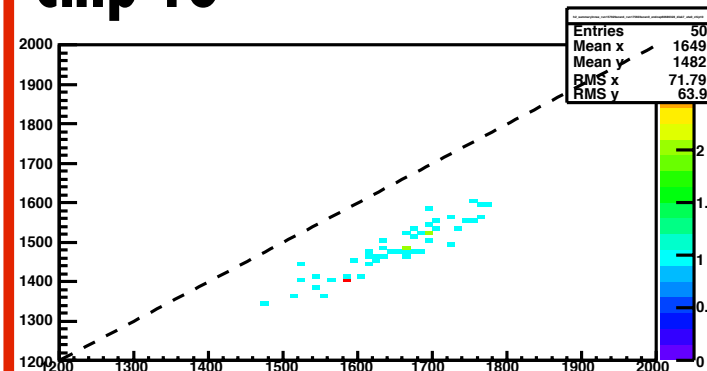
chip 8



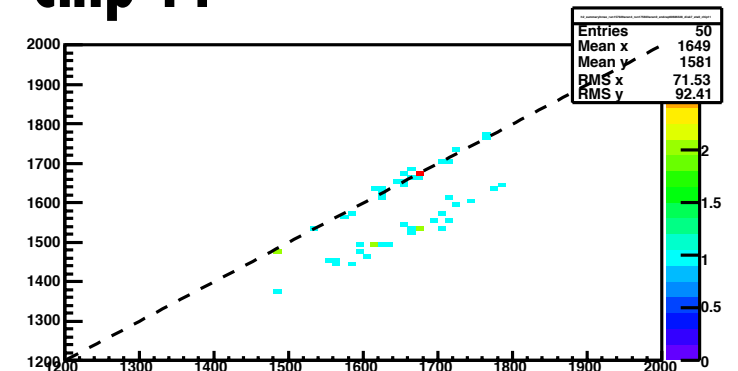
chip 9



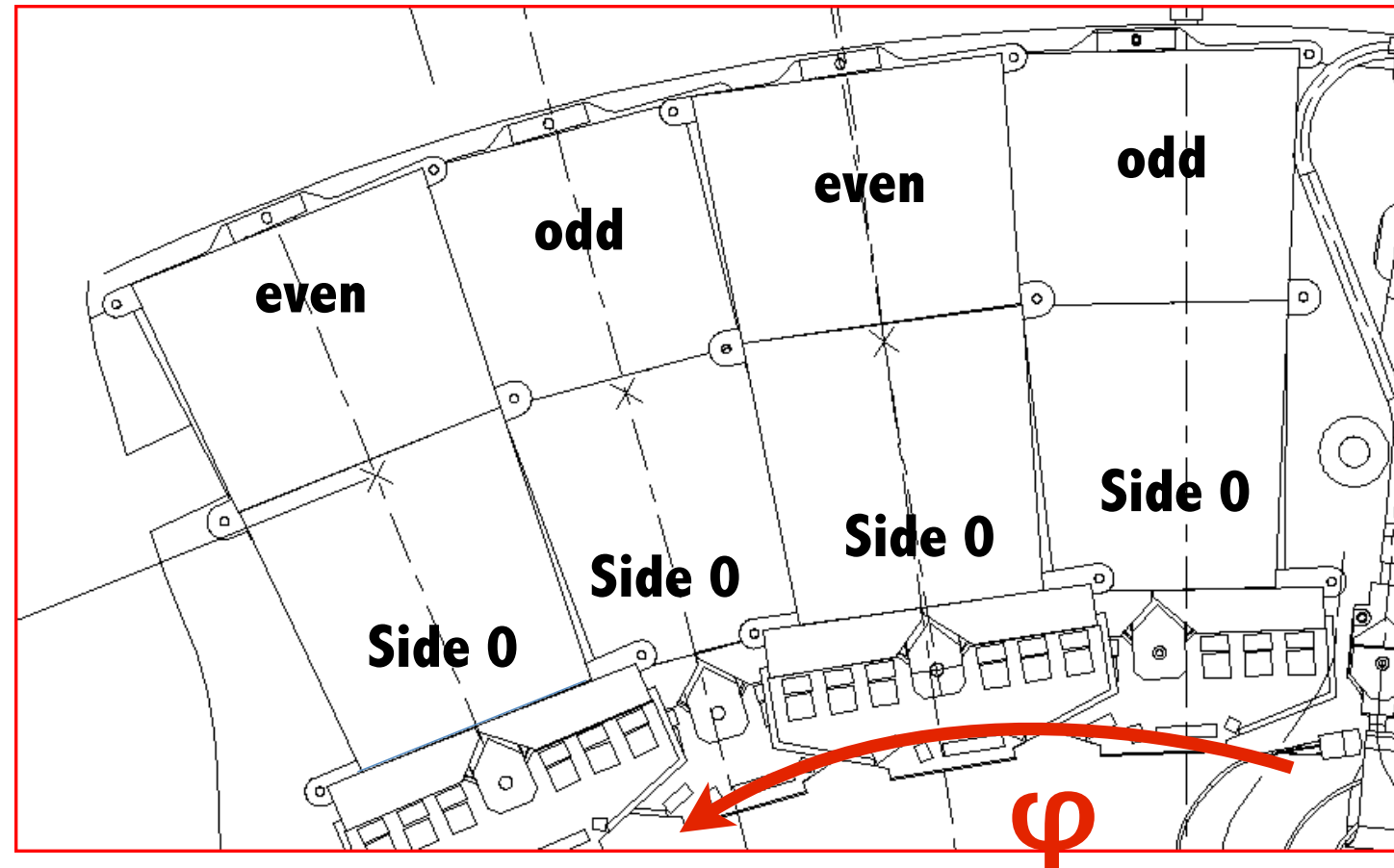
chip 10



chip 11



- **Geometry of Endcap module (from Steve)**
 - e.g. EndcapC, disk7, Outer ring



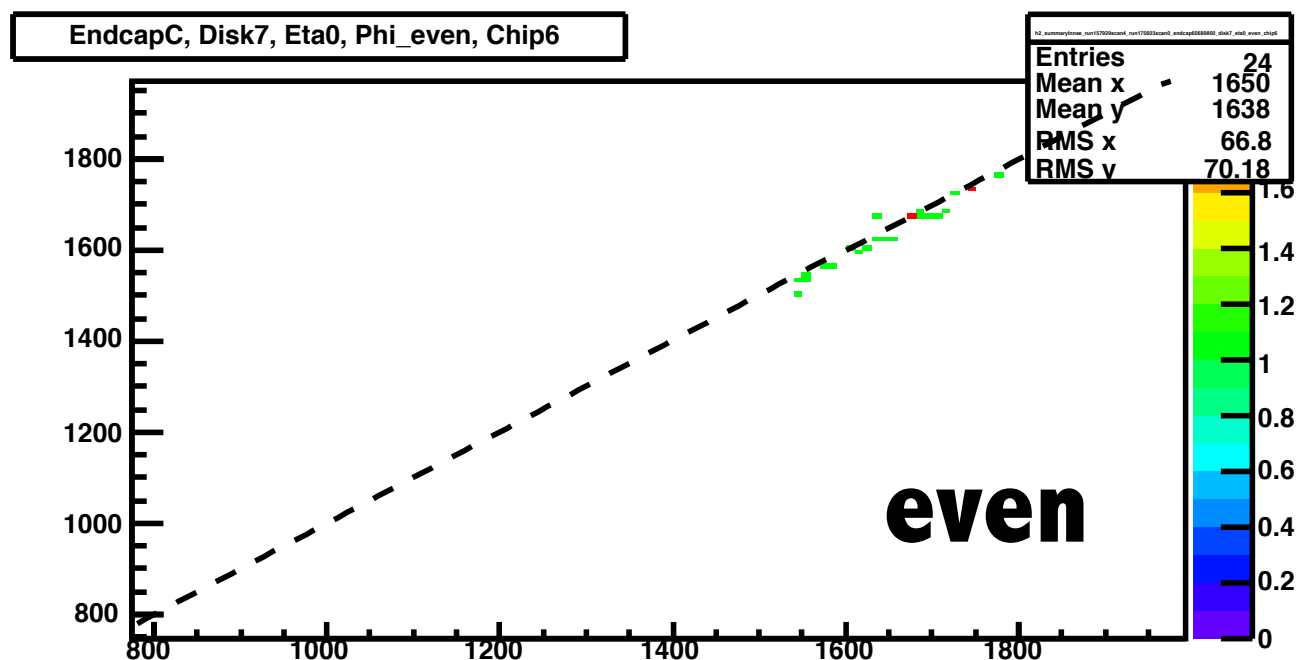
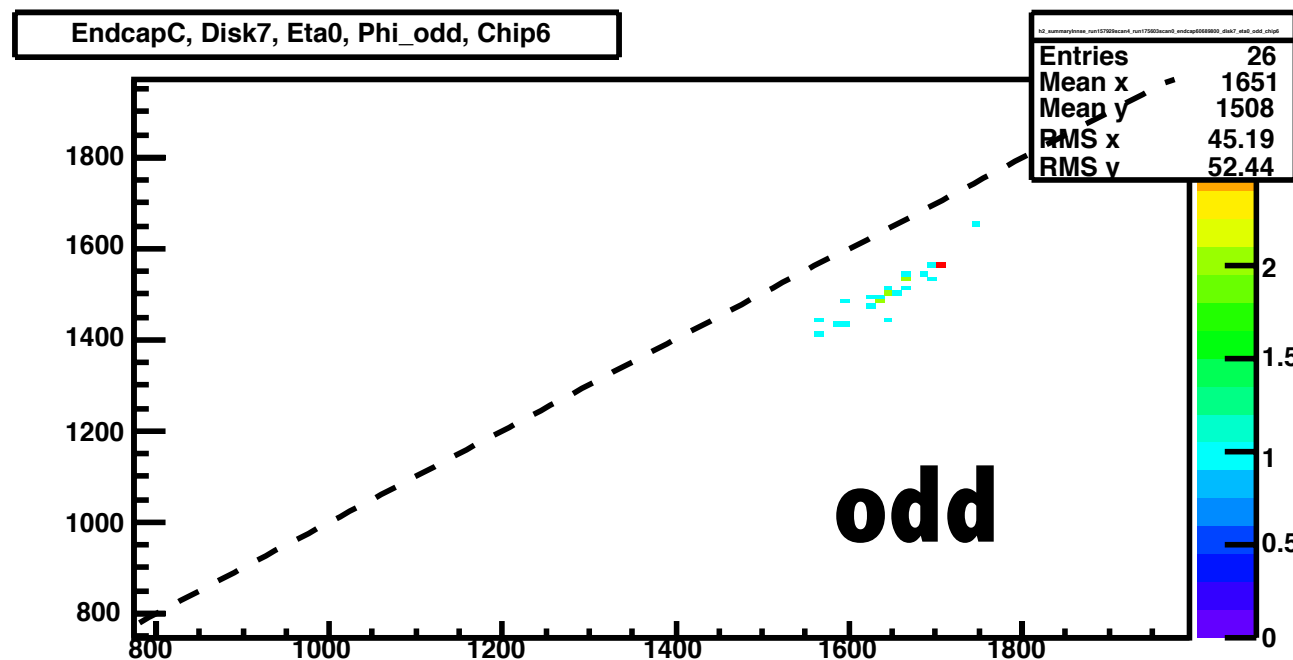
- **Two groups of Endcap module (from Pat)**

even phi module



odd phi module

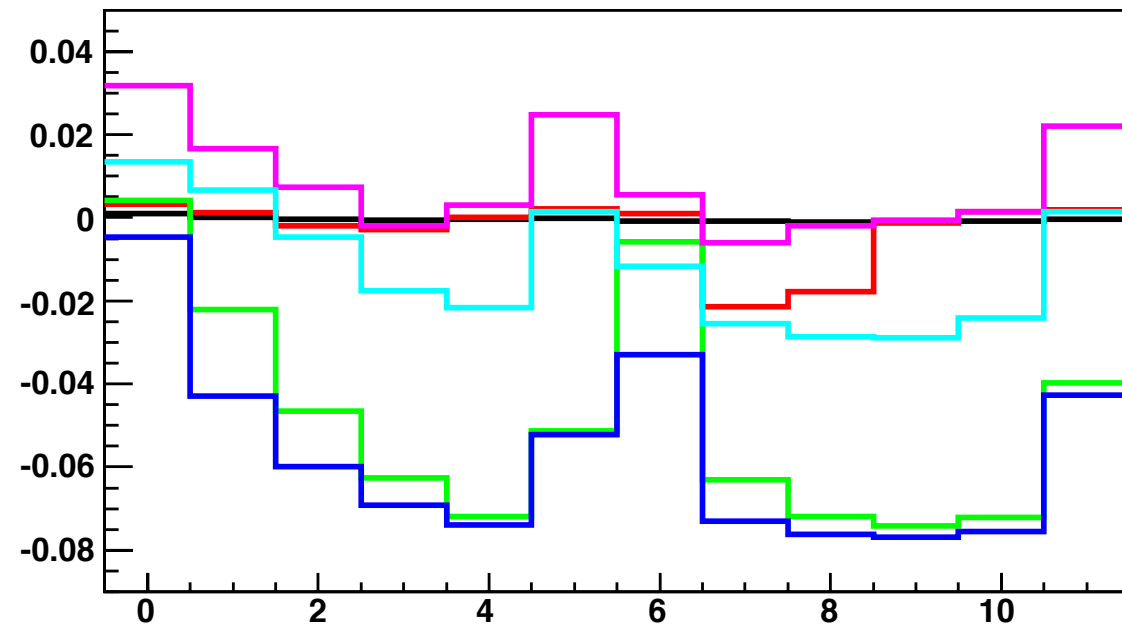
- **EndcapC, Disk7, Outer module, chip 6**



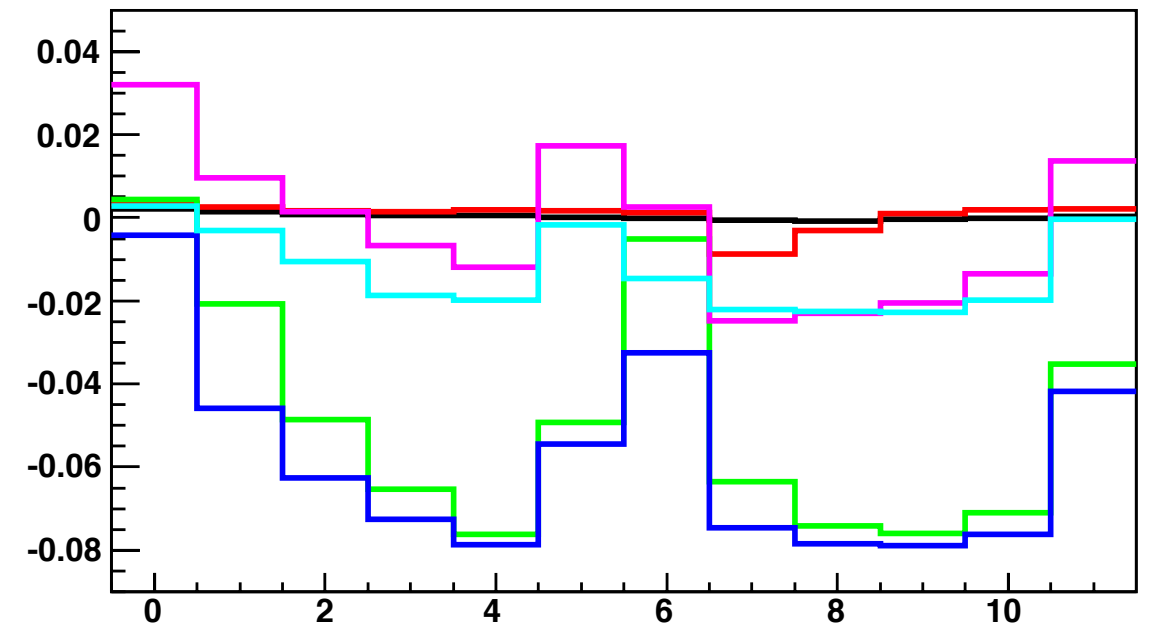
- **X axis : Input noise in run 157929 (Jun. 23, 2010.)**
- **Y axis : Input noise in run 175603 (Feb. 18, 2011.)**
- **Splitting is due to the difference between even/odd-phi modules, pointed out by Steve.**

● Chip position dependence of change in noise

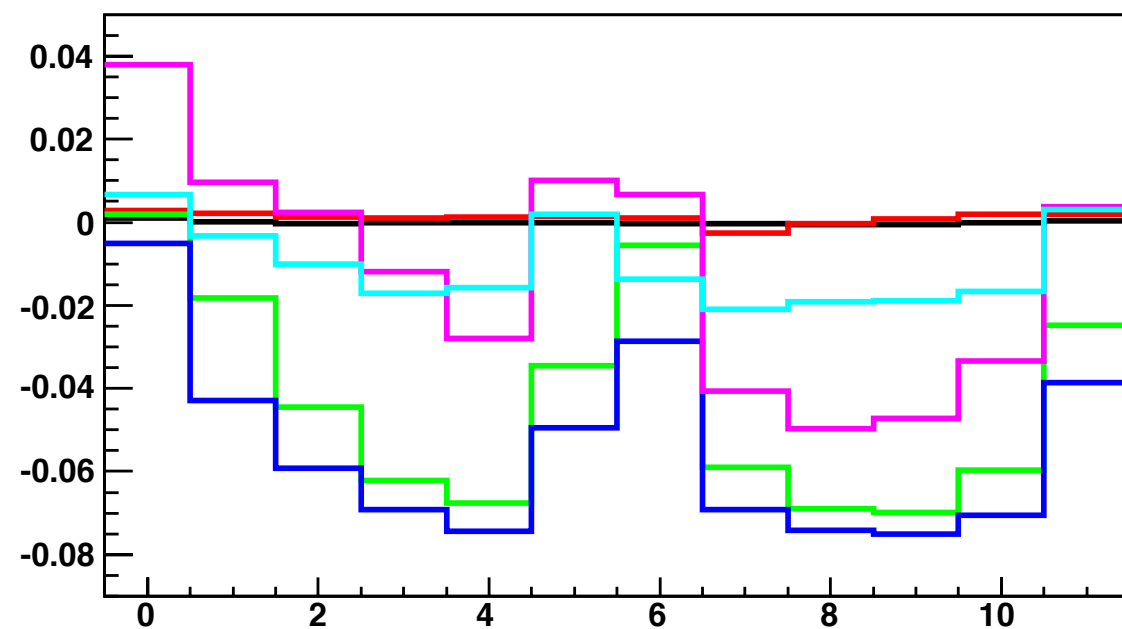
hp1_run145118scan1_run158393scan1_chipdep_B1



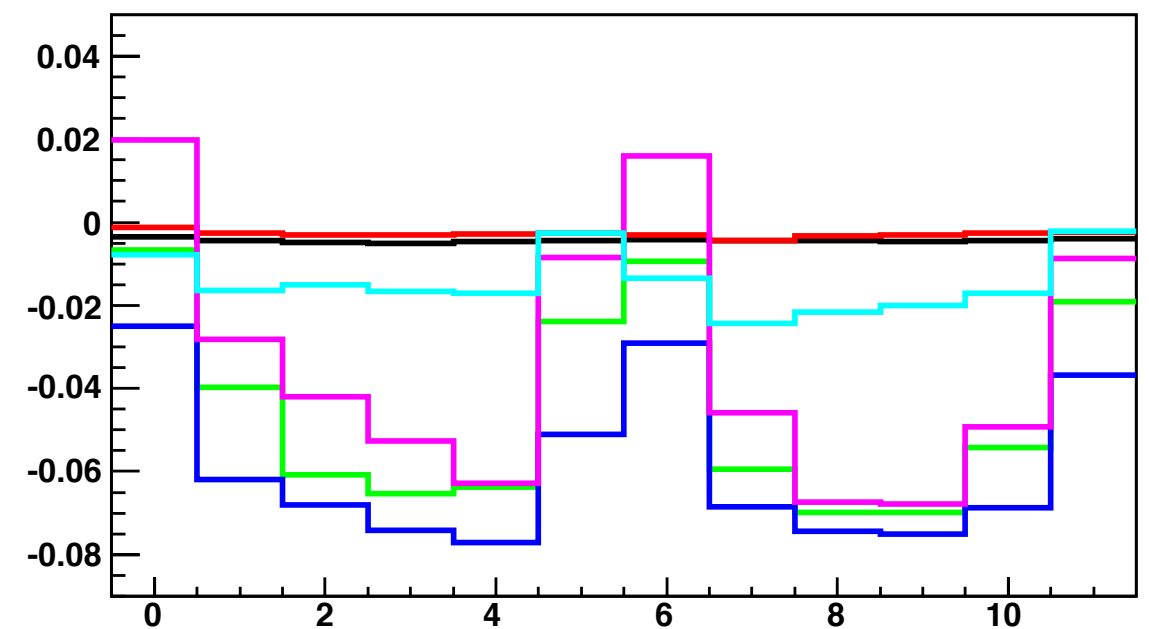
hp1_run145118scan1_run158393scan1_chipdep_B2



hp1_run145118scan1_run158393scan1_chipdep_B3

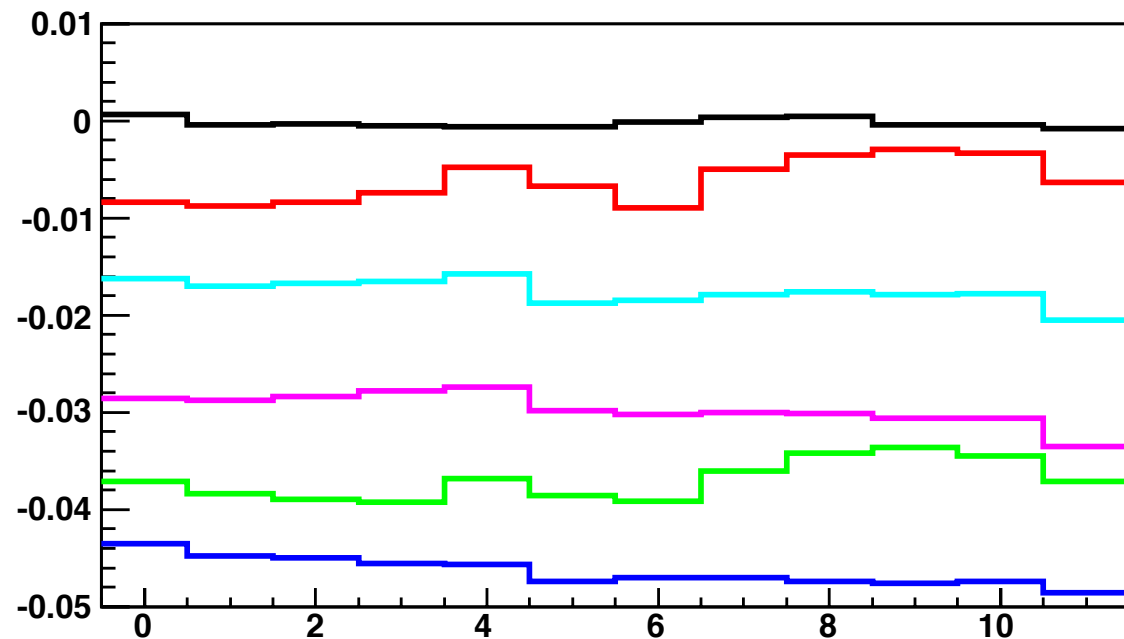


hp1_run145118scan1_run158393scan1_chipdep_B4

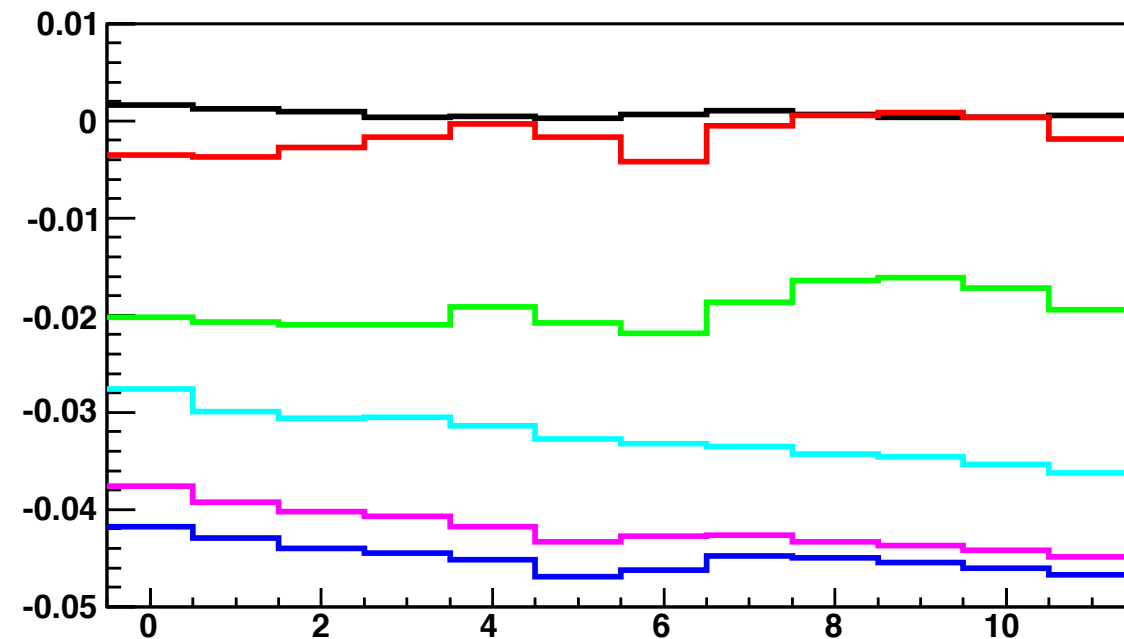


● Chip position dependence of change in gain

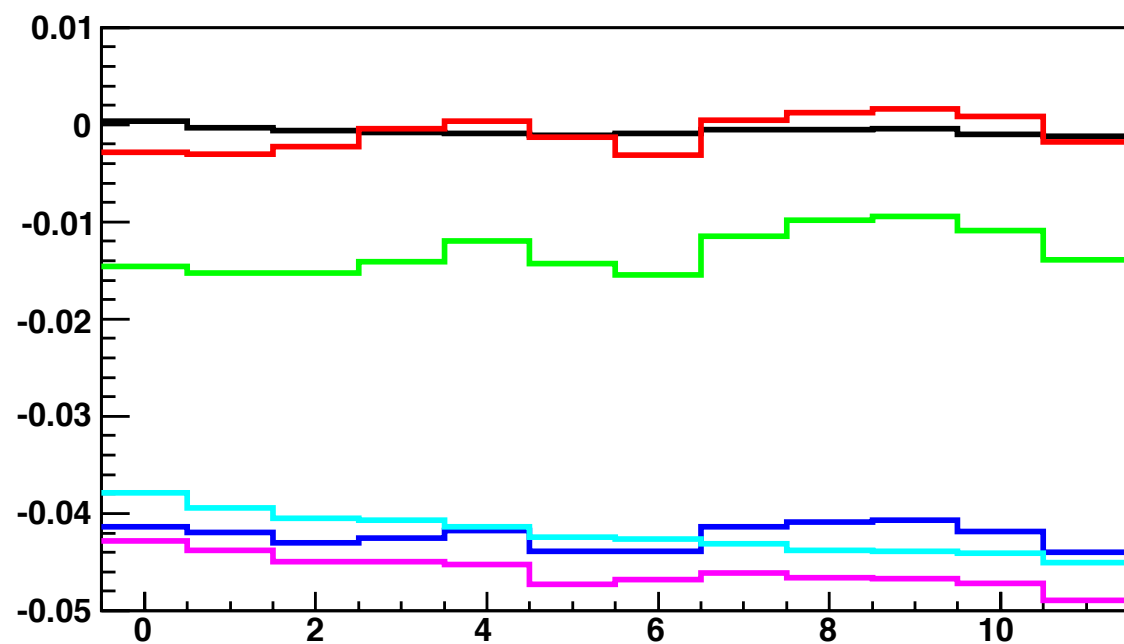
hp1_run145118scan1_run165169scan0_chipdep_B1



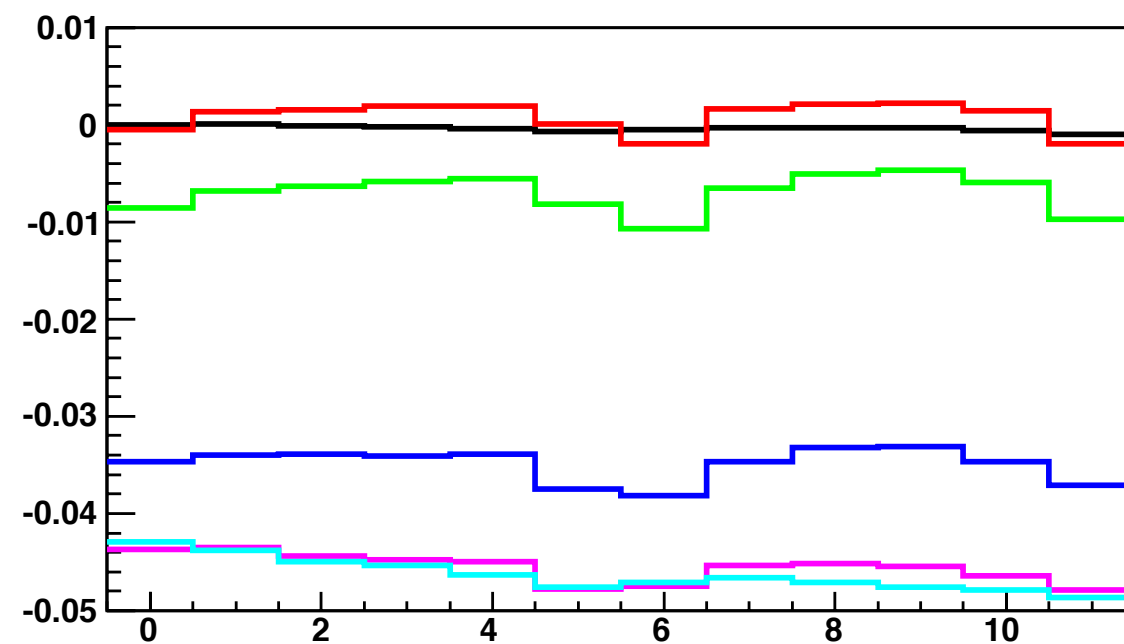
hp1_run145118scan1_run165169scan0_chipdep_B2



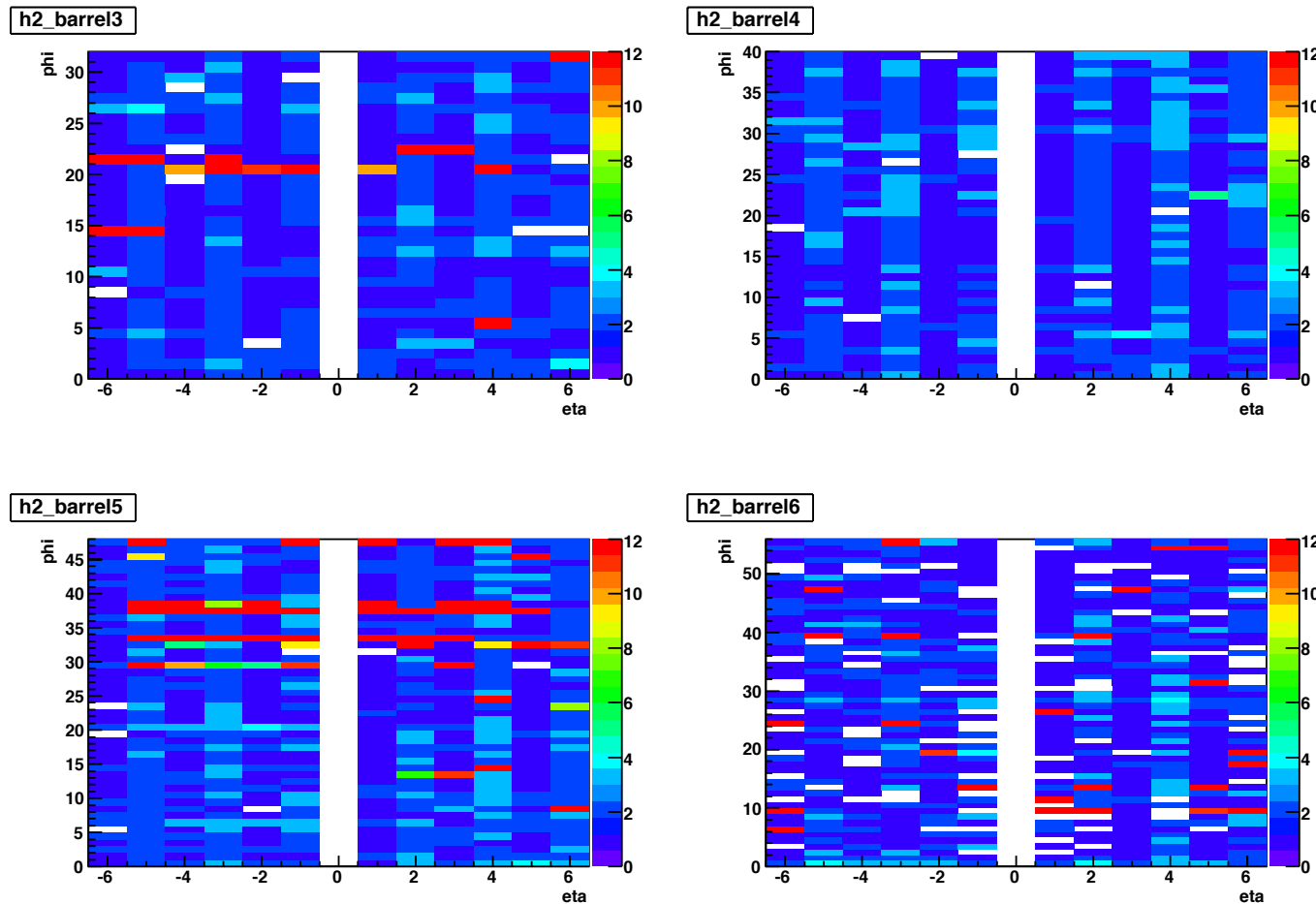
hp1_run145118scan1_run165169scan0_chipdep_B3



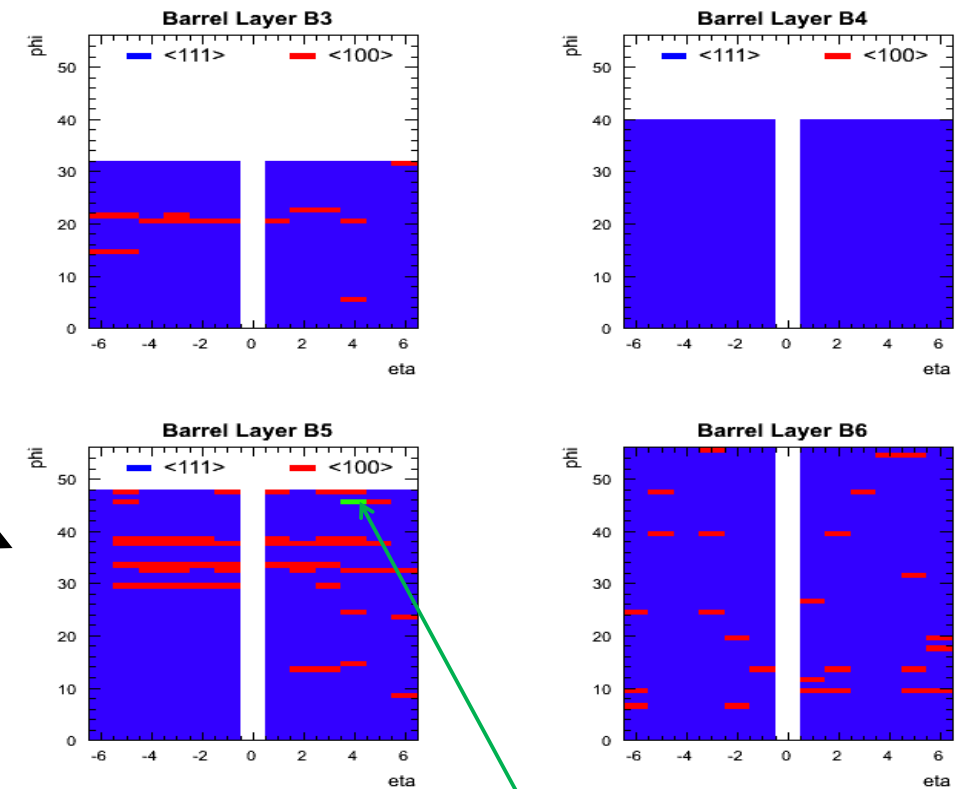
hp1_run145118scan1_run165169scan0_chipdep_B4



- 2D map of module ($|\text{relative difference}| < 0.03$)
 - run 145118 (2010-1) vs run 179871 (2011-4)
 - X axis : eta, Y axis : phi, Z axis : Number of chips



Location of $\langle 100 \rangle$ modules



分布が一致している！

1 sensor of $\langle 100 \rangle$ + 3 sensors of $\langle 111 \rangle$