CLIOデータの品質評価

Hideyuki Tagoshi (Osaka Univ.)
田越秀行 (大阪大学)

解析ミーティング, 2009/9/29

Introduction: LCGT and CLIO

LCGT (*Large-scale Cryogenic Gravitational wave Telescope)*

Japanese future gravitational wave detector

3km arm length, sensitivity is similar to advanced LIGO

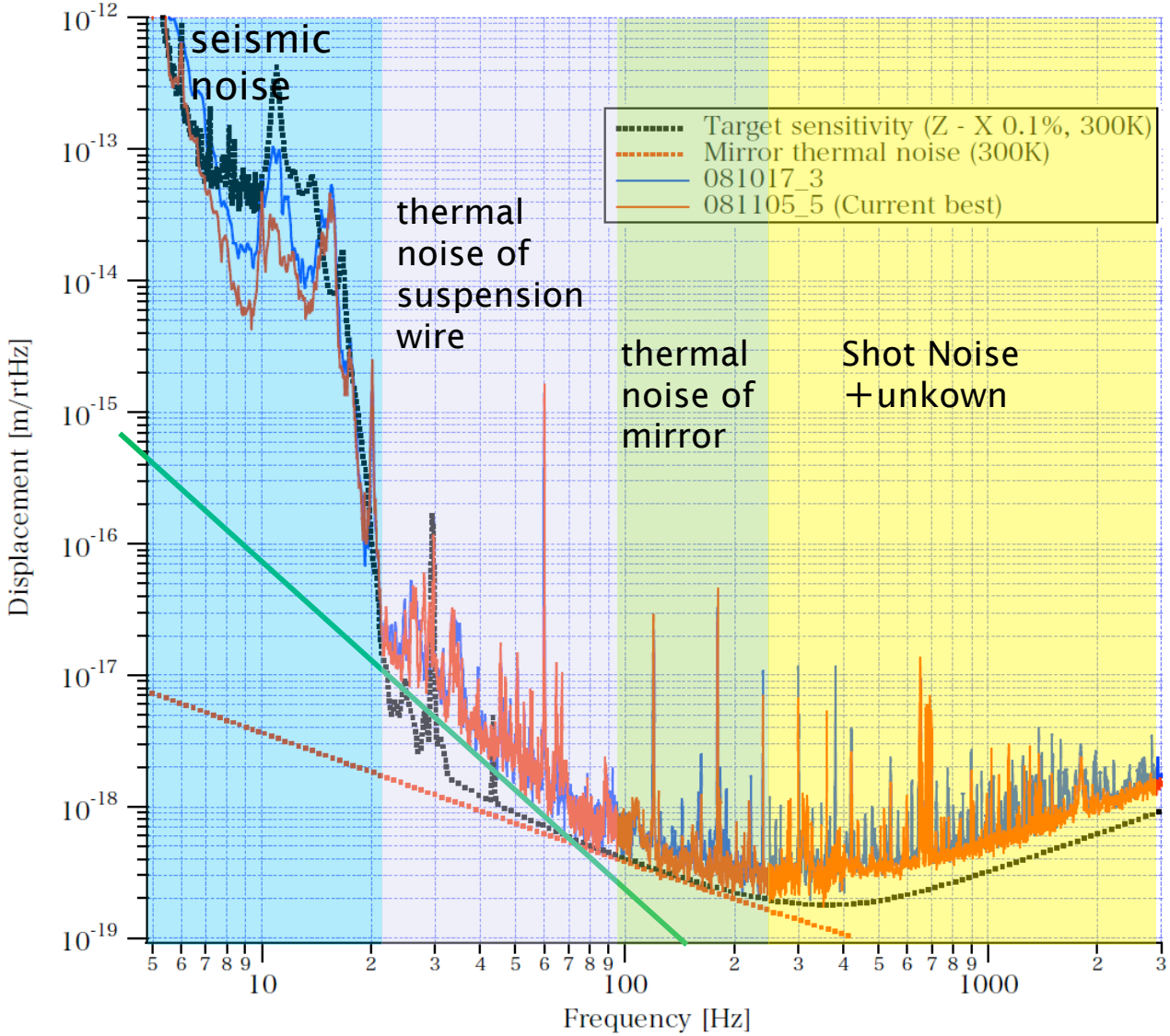
Waiting for the budget approval by government

CLIO is a 100m prototype of LCGT built at the same site of LCGT (in Kamioka mine)

Main purpose : test Cryogenic technology for LCGT

Site of LCGT and CLIO: Kamioka mine

CLIO's sensitivity



red line: current best sensitivity at room temperature (2008/11/5)

CLIO data taking

- CLIO performed test run in April and May, 2009 for 3 days with room temperature. This was the first data taking operation after CLIO achieved current best sensitivity.

- This is a very good chance to look at the data from a laser interferometer located in the underground environment.

- Such a detector is very rare so far. Since the underground environment is also the candidate site of the future, 3rd generation gravitational detector such like Einstein telescope planned in Europe, it is important to investigate the property such data.

- We investigate the gaussianity of data, and compared it with TAMA's data in 2004.

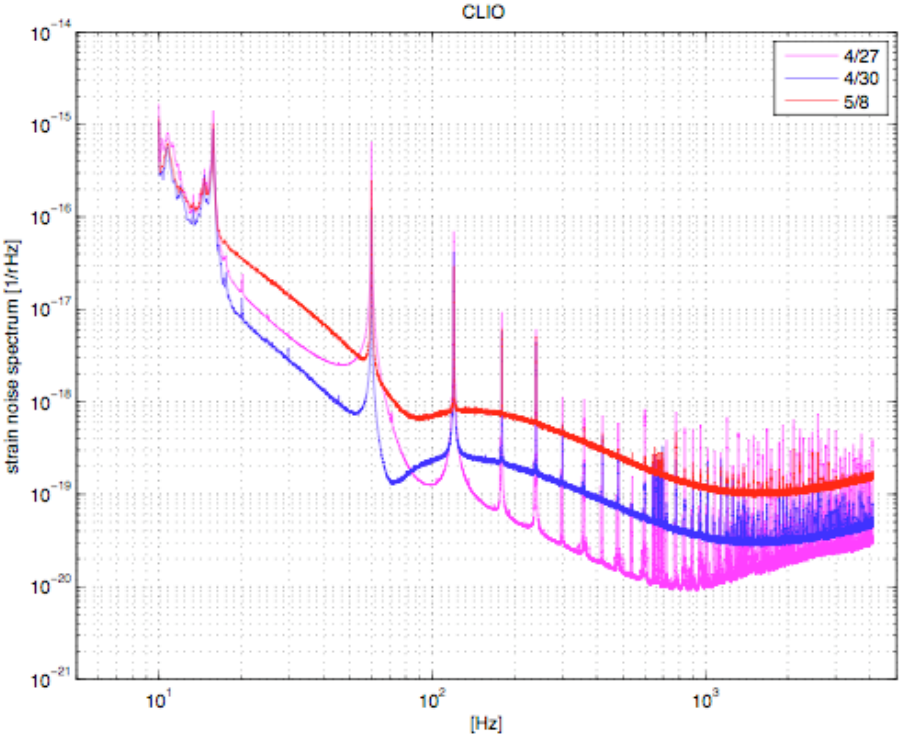
TAMA: 300m detector, Data taking was done during 1999-2004.

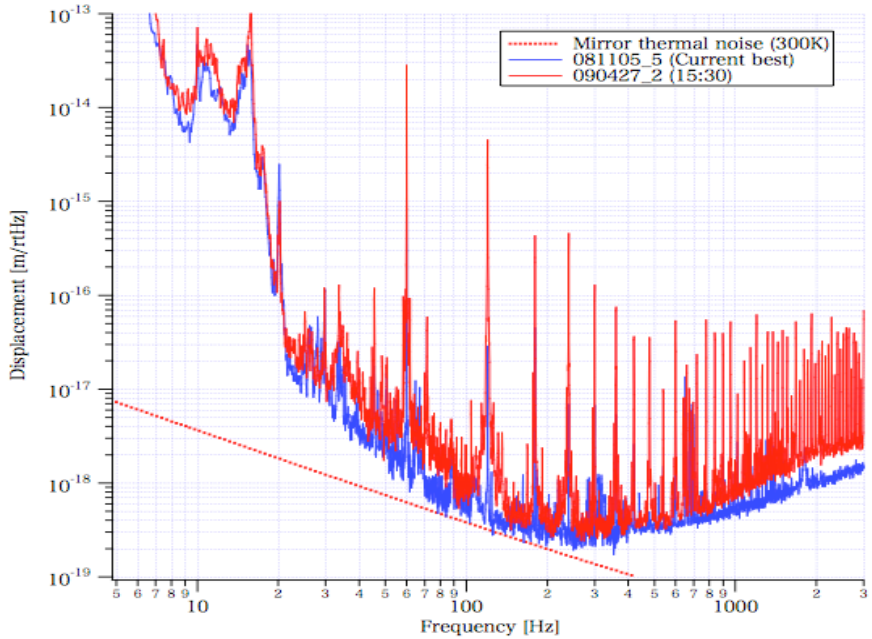
CLIO data

	CLIO 427	CLIO 430	CLIO 508	TAMA run142
Period	start 2009/4/27 15:00 end 2009/4/27 21:40	start 2009/4/30 18:25 end 2009/5/1 0:30	start 2009/5/8 11:35 end 2009/5/8 16:30	Jan. 2004 last part of DT9, which is the best data in the history of TAMA
Data length used here	4.8356 hours	4.3467 hours	1.9733 hours	4.8378 hours 4.8788 hours

DAQ system trouble.
Data was not taken properly

Spectrum

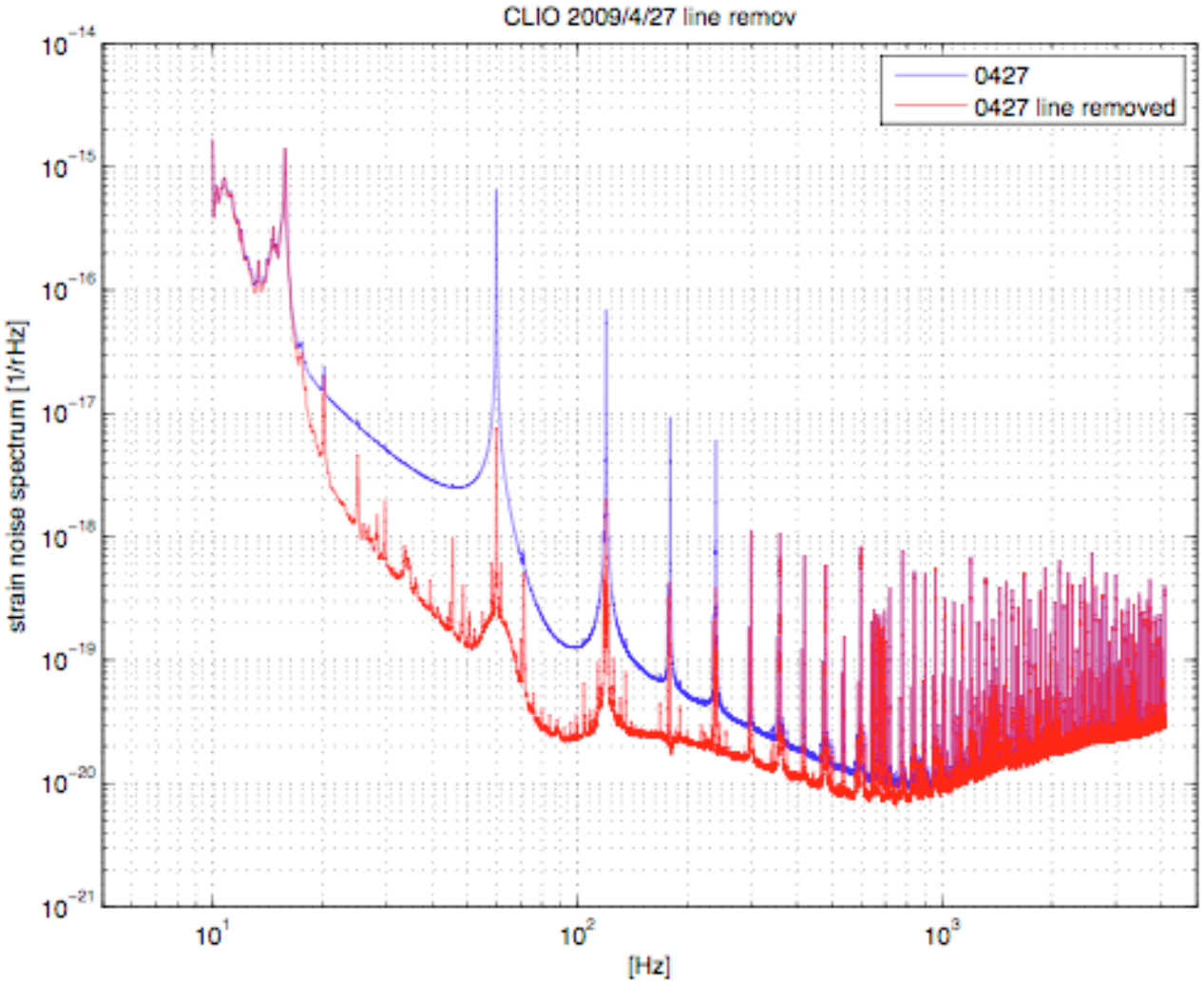




magenta: 427
blue: 430
red: 508

red: 0427

Spectrum (line removed data by Terada)



Gaussianity (1)

- We look at the power spectrum, and select the frequency range where there are no electric lines and violin mode lines.

- Fourier transform each 16 seconds data, and apply the transfer function.

$$v(t) \rightarrow \tilde{v}(f_i) \rightarrow \tilde{x}(f_i)$$

Investigate the statistial property of real and imaginary parts $\tilde{x}(f_i)$

- Skewness b_1, Kurtosis b_2 are computed

Skewness: $b_1 = m_3/(m_2)^{3/2}$

Kurtosis: $b_2 = m_4/(m_2)^2 - 3$

r-th moment $m_r \equiv \sum_i (X_i - \mu)^r / N$

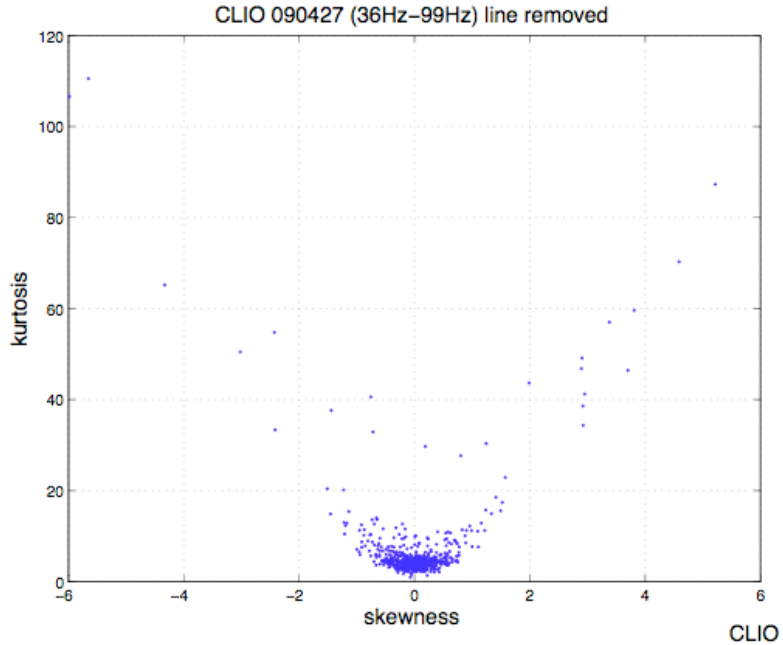
data

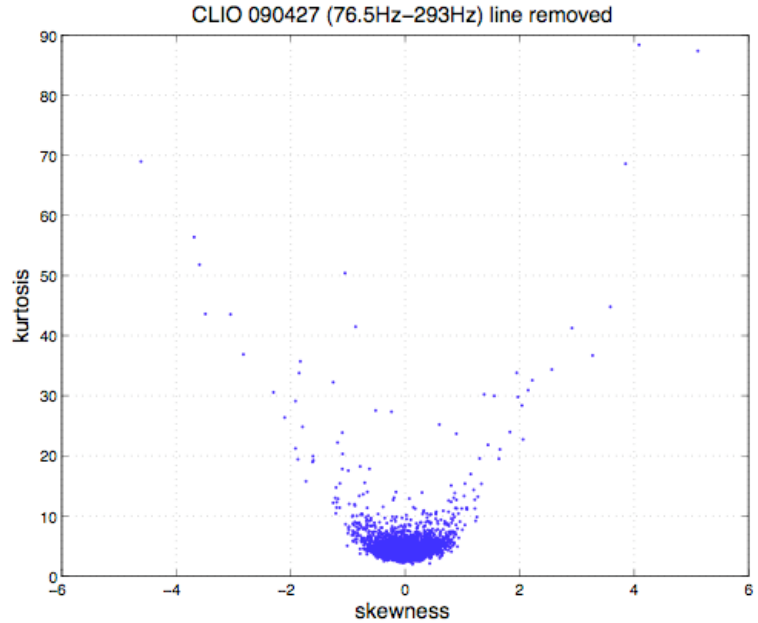
average

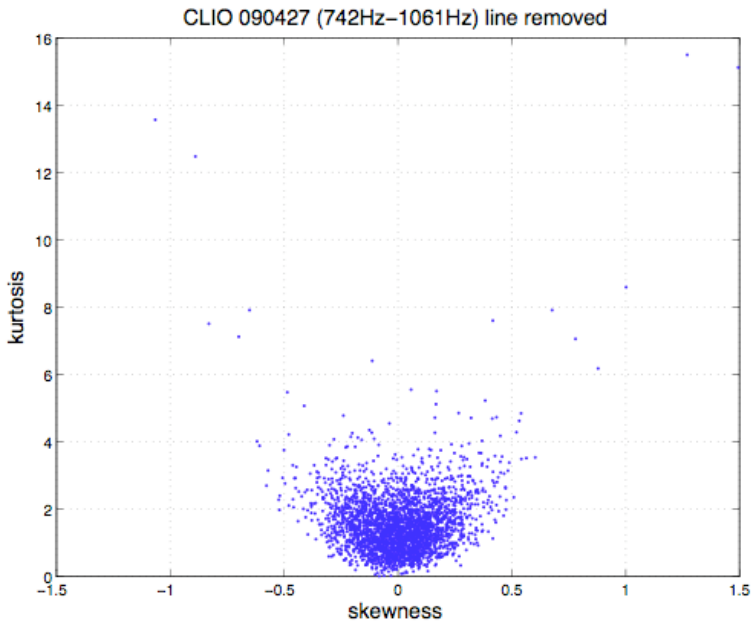
number of data

When data obey Gaussian distribution, skewness and kurtosis become neary zero.

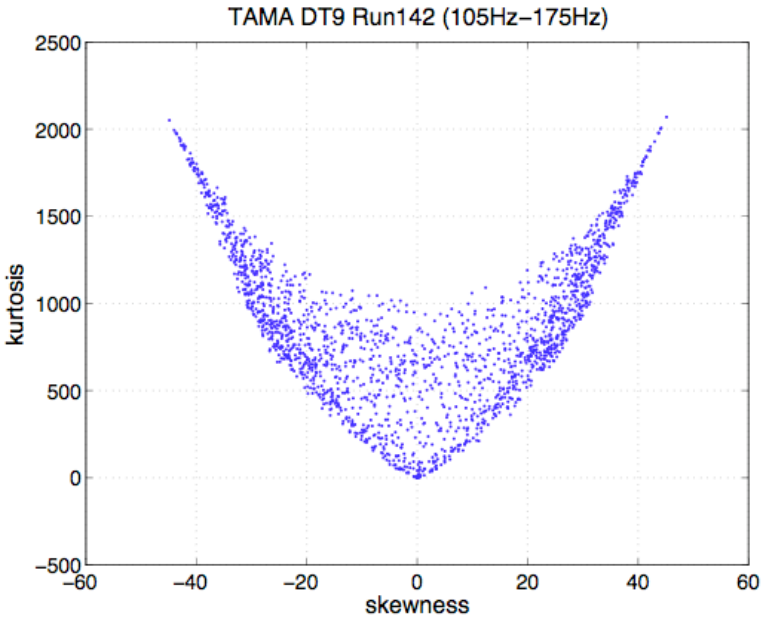
Gaussianity (2) CLIO 427

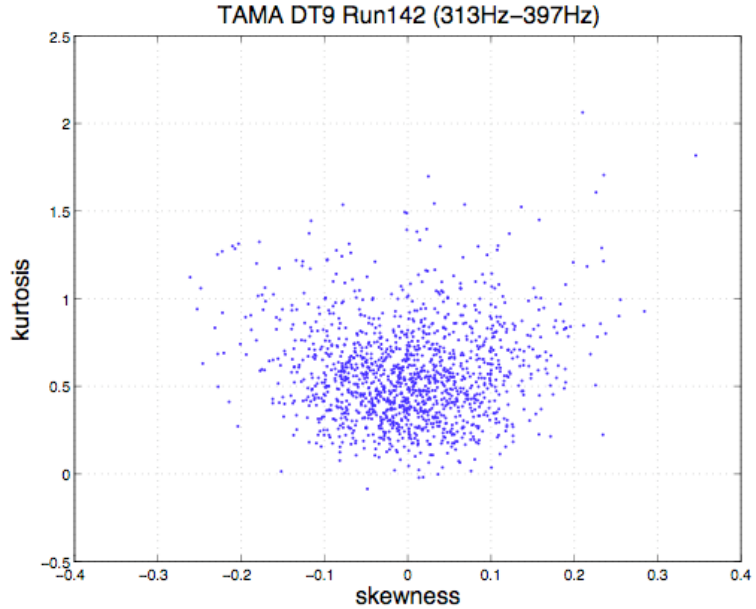


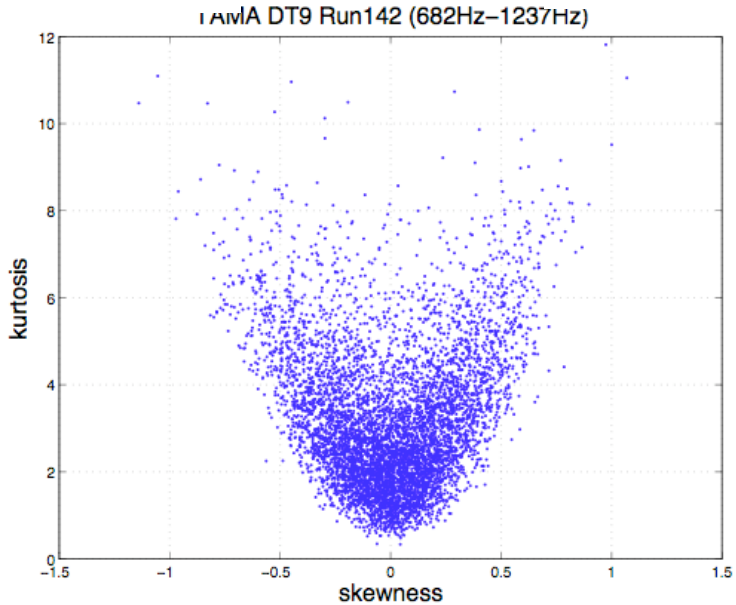




Gaussianity (3) TAMA 142

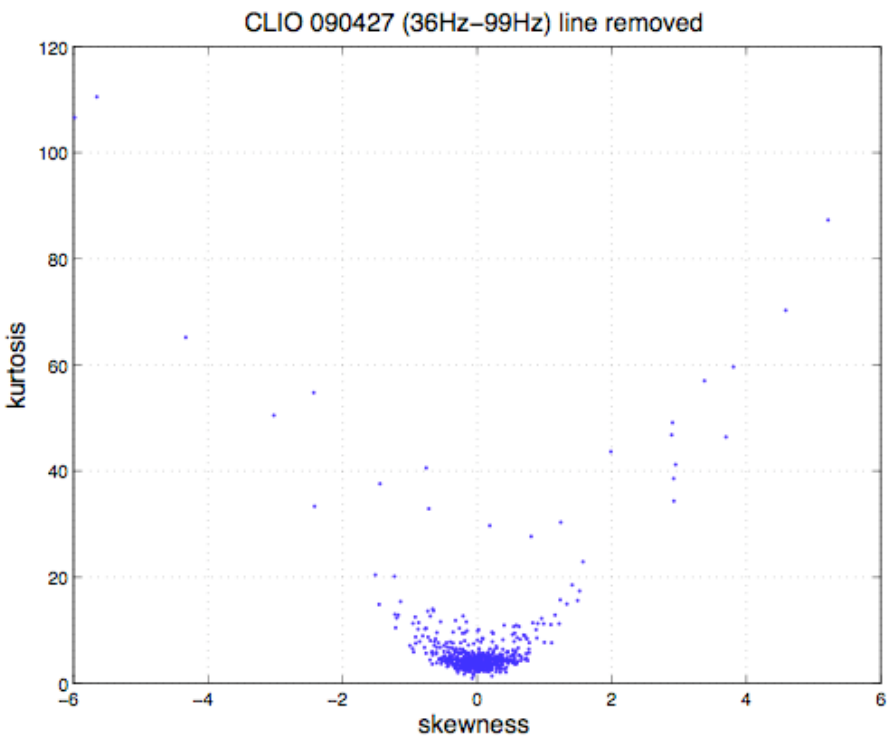


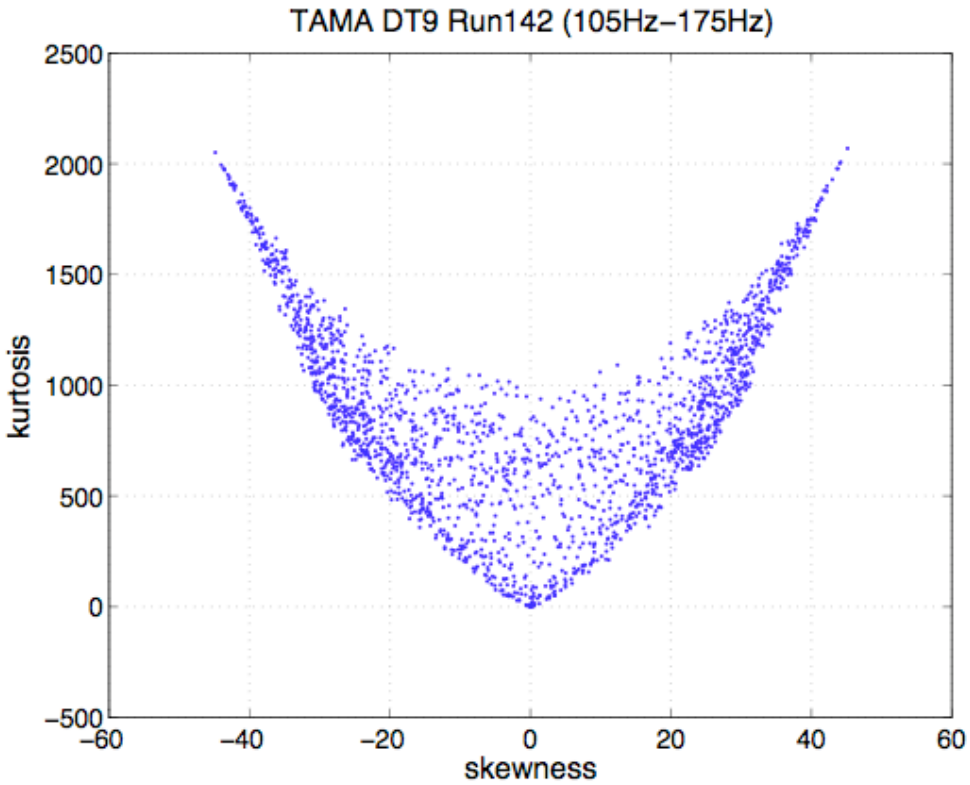




Gaussianity (4)

At low frequency, CLIO's gaussianity is much better than TAMA





scale of two figures are very different

Gaussianity check by matched filtering

Standard method to detect inspiraling compact binaries:

Matched filtering + chi square selection

Normalized signal template:

$$h(f) = s_0(f)\cos\delta_c + s_{\pi/2}(f)\sin\delta_c$$

•Compute cross correlation between data x(f) and template h(f)

$$(x,h) \equiv 2\int_{-\infty}^{\infty} df \frac{x(f)h^*(f)}{S_n(f)}$$

•Maximize with respect to the phase δ_c and obtain matched filter statistic ρ

$$\boxed{\rho^2(t_c, M, \eta) = (s_0, x)^2 + (s_{\pi/2}, x)^2}$$

Signal-to-noise ratio

We also compute chi square as a measure of the deviation of the frequency profile from the binary inspiral signal's profile.

Large chi square is a signature of the existence of non-Gaussian noise.

マッチドフィルターによるガウス性検証 (2)

カイ2乗

周波数積分をp分割．各積分からの寄与の期待値を等分する

(実際の値-期待値)^2の和

$$\chi^2 \equiv p^2 \sum_{i=1}^{p} \left[(\rho_0^{(i)} - \rho_0/p)^2 + (\rho_{\pi/2}^{(i)} - \rho_{\pi/2}/p)^2 \right]$$

$$\rho_{0,\pi/2}^{(i)} \equiv 2 \int_{\Delta f_i} df \frac{x(f) s_{0,\pi/2}^*(f) + x^*(f) s_{0,\pi/2}(f)}{S_n(f)}$$

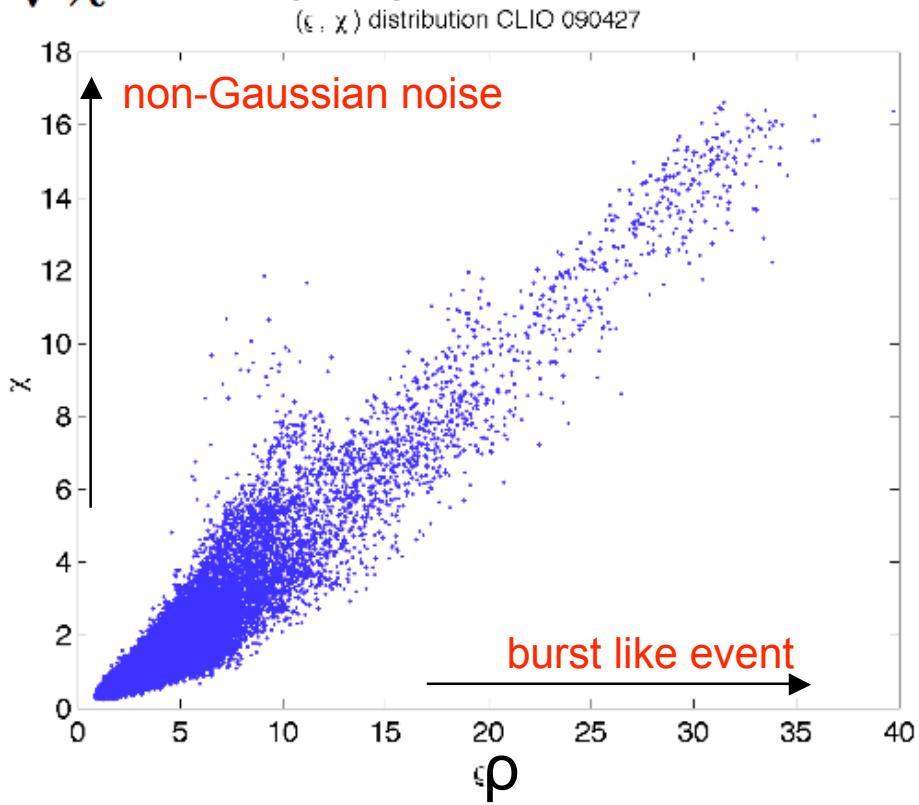
•各周波数帯へのパワー分布が，インスパイラル波形のと矛盾していないか？を見る指標．
•もしデータがガウスノイズなら，このカイ2乗は自由度2p-2のカイ2乗分布に従う統計量となる．(だからカイ2乗と呼ばれる)
•しかし，実際のデータはカイ2乗からはかけはなれた分布となる

Gaussianity check by matched filtering

We consider one template waveform with mass 1.4Msolar x 2.
We look at the distribution of (ρ , χ^2) with respect to different coalescing time of signal.

$\sqrt{\chi^2}$

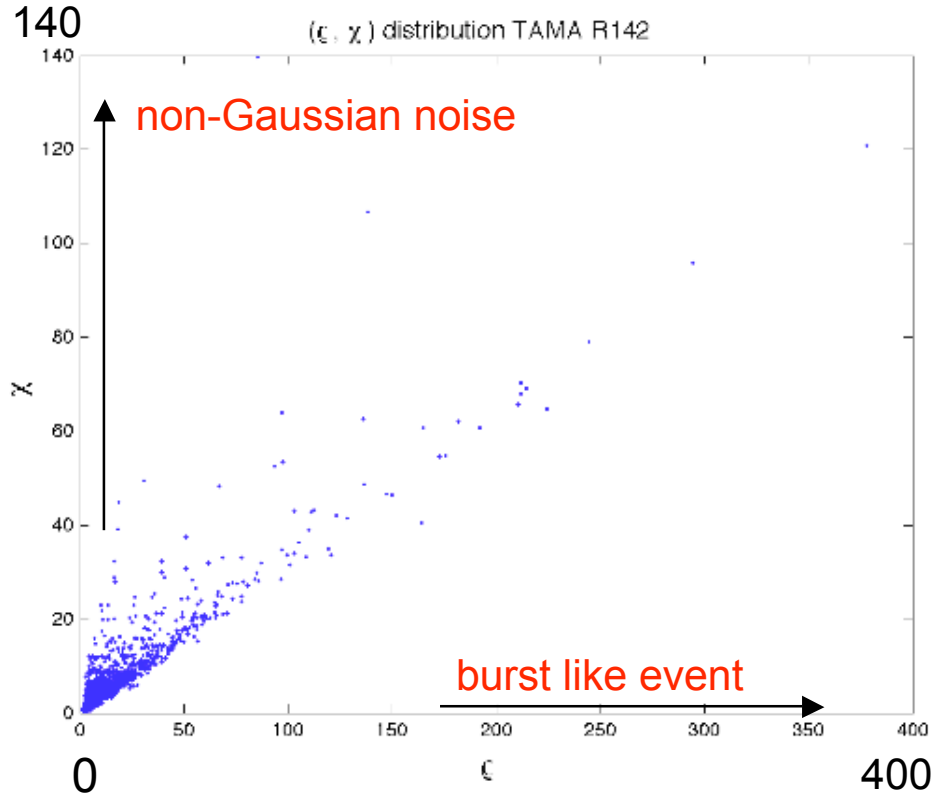
CLIO427



$\sqrt{\chi^2}$

TAMA DT9

140



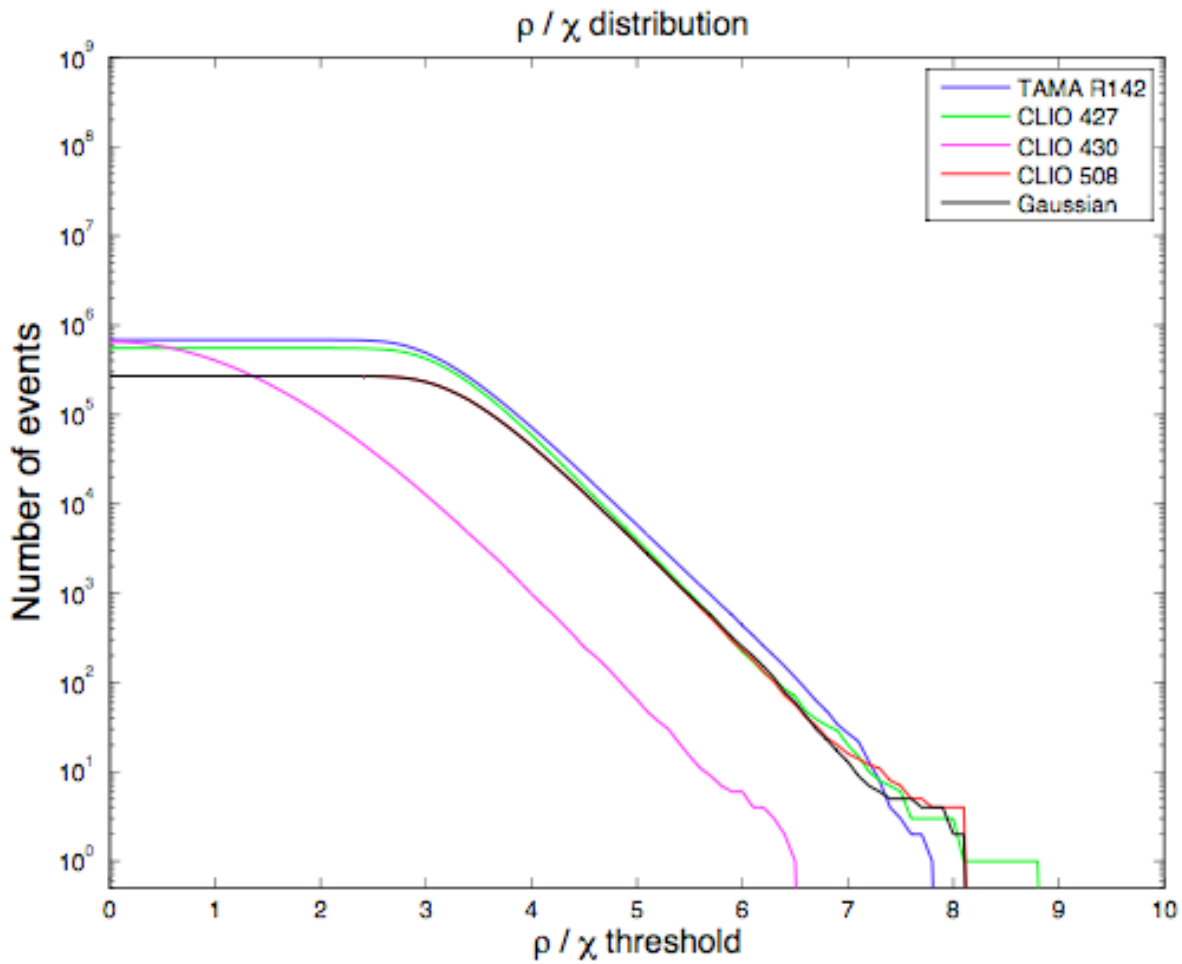
0

400

ρ

scale of two figures are very different

マッチドフィルターによるガウス性検証　参考(2)



TAMA解析で使っていた　$\rho/\sqrt{\chi^2}$ の差は小さい

定常性

連星合体インスパイラル波形のマッチドフィルター解析での規格化因子

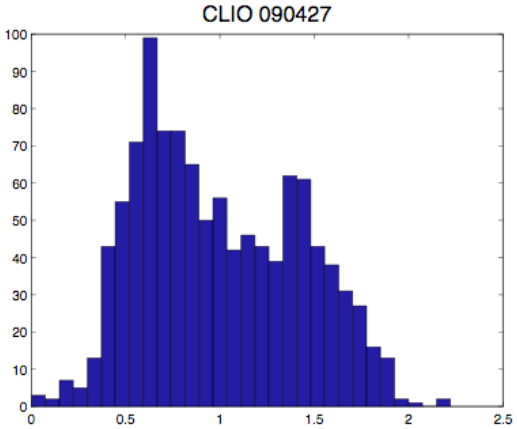
$$N = \left(4 \int_{f_{min}}^{f_{max}} \frac{f^{-7/3}}{S_n(f)} df \right)^{-1/2}$$

をファイル毎に計算し分布を見る.

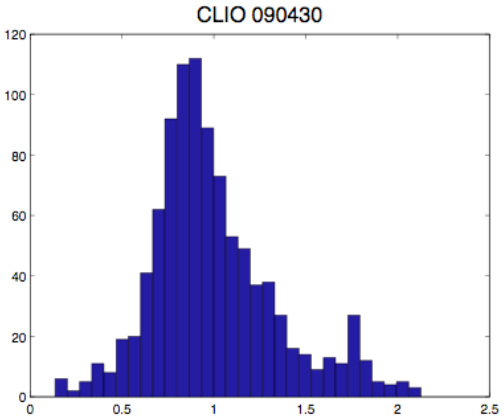
$S_n(f)$ パワースペクトラム密度

定常性 (2)

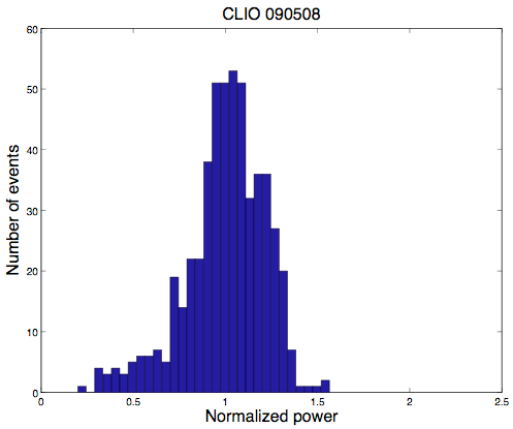
CLIO427



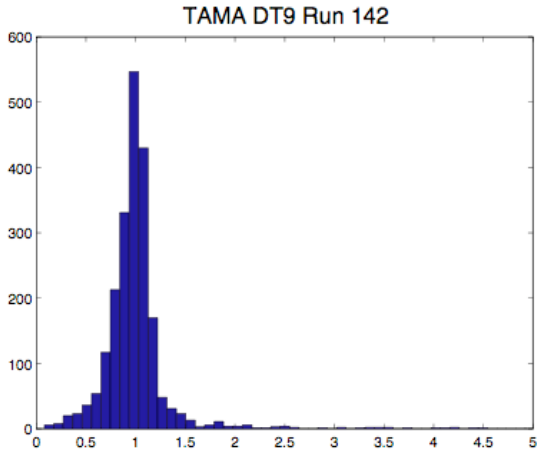
CLIO430



CLIO508



TAMA142



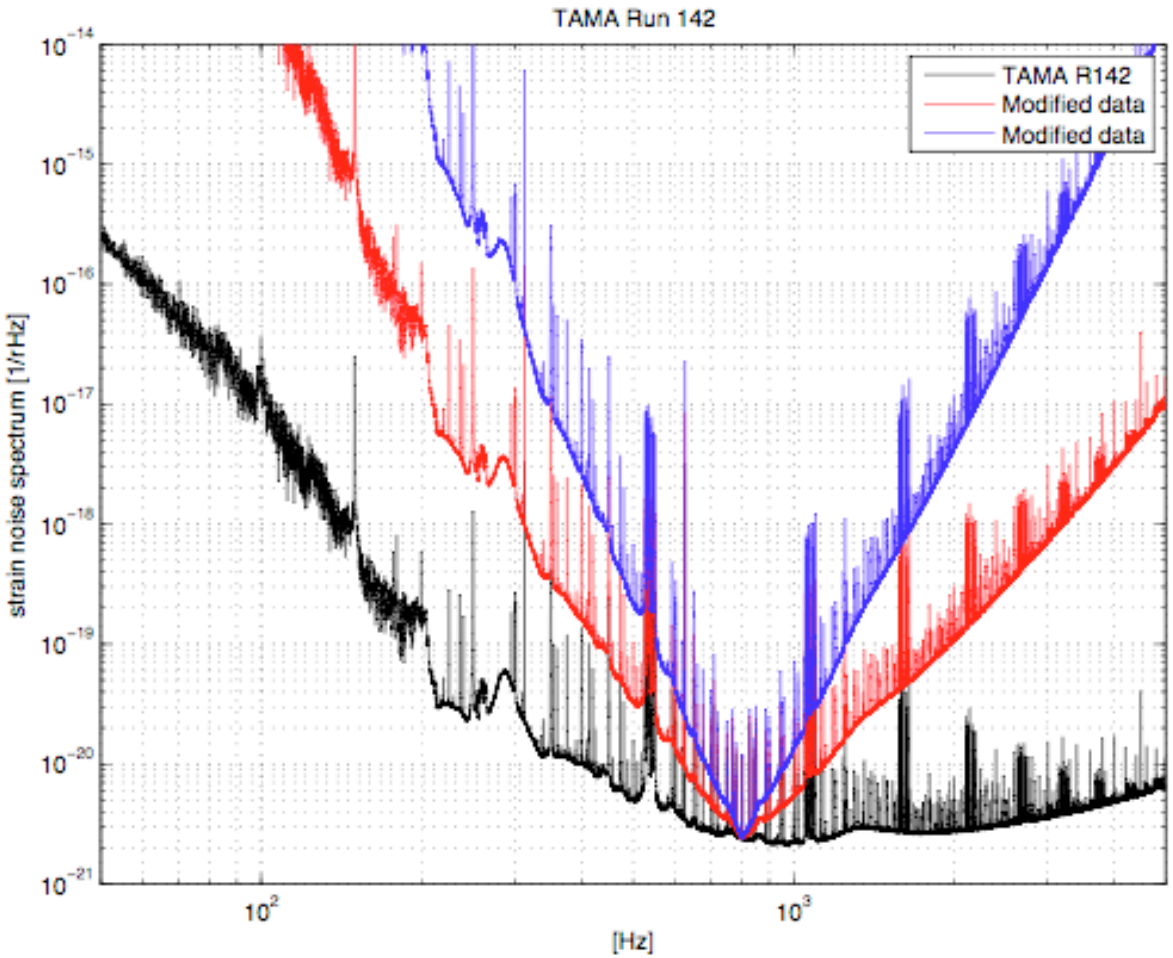
CLIO : 平均の0.5倍から2倍以内に大体収まる.
508が一番良い

TAMA: 平均の0.5倍から1.5倍以内に多くは収まるが, 4倍を超すバーストも現れている.

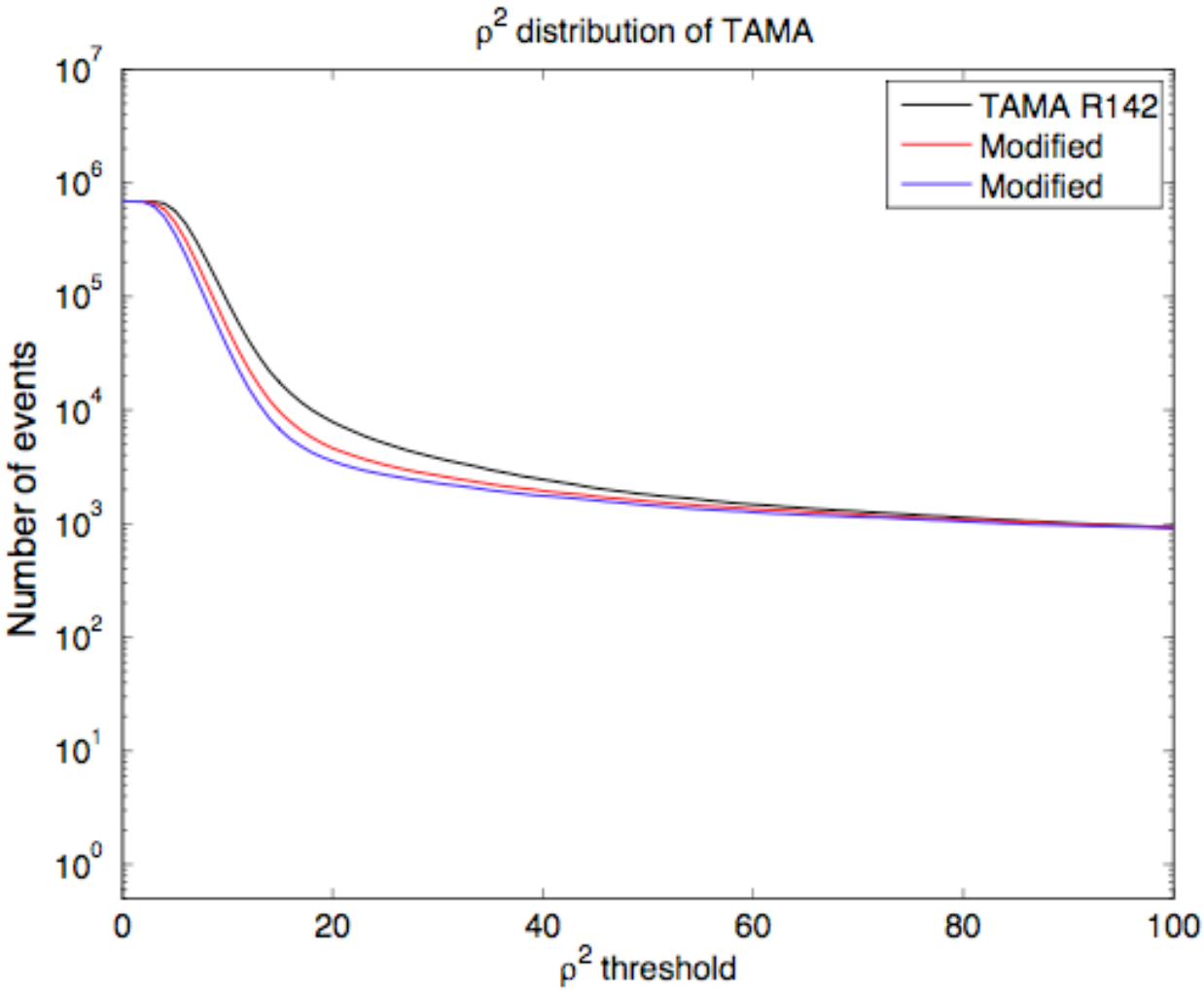
カイ２乗とバンド幅

カイ２乗とバンド幅

TAMAデータのスペクトラムをゆがめて狭帯域データにする
カイ２乗への影響は？ (閾値への影響は？)

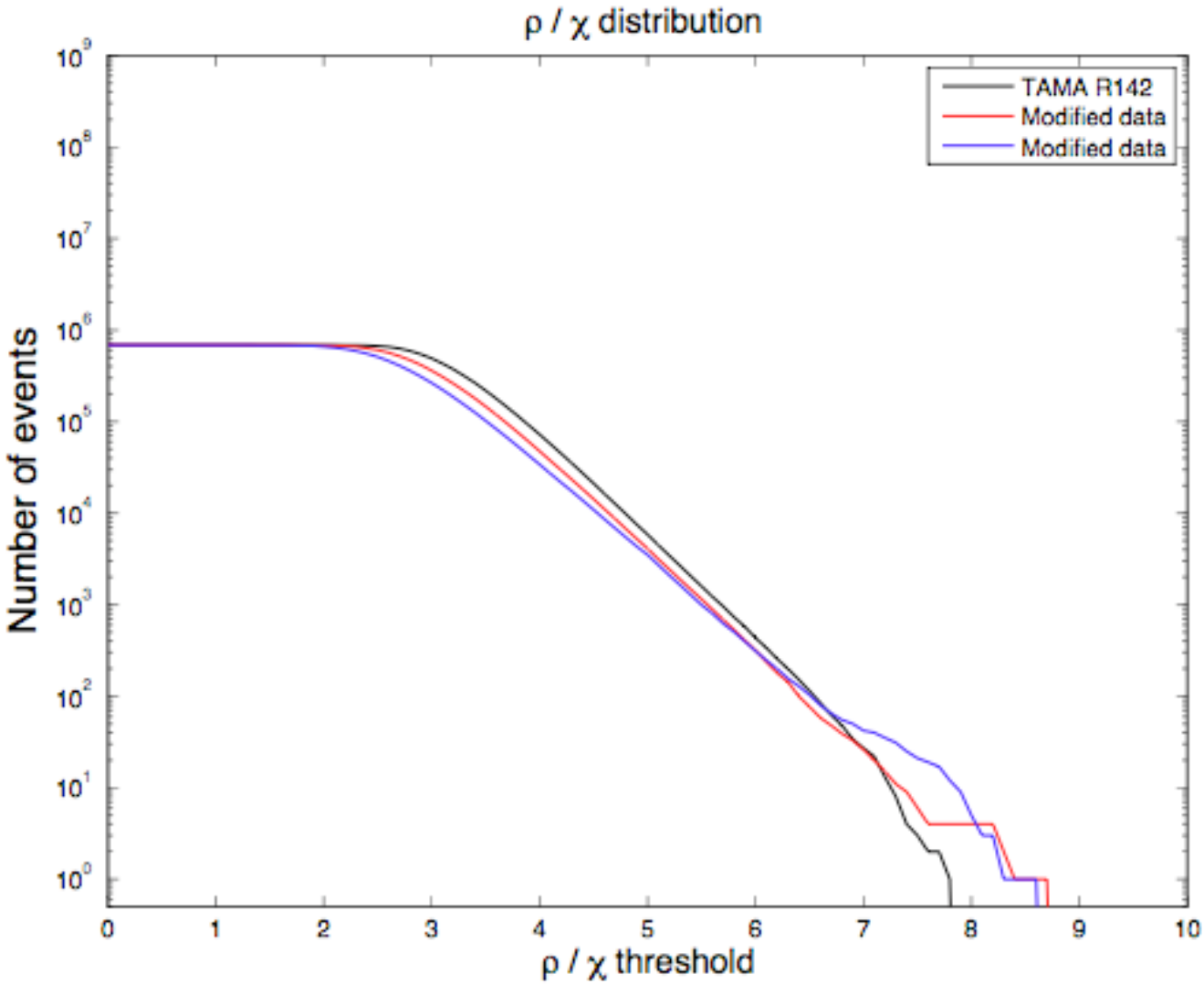


狭帯域データのrho



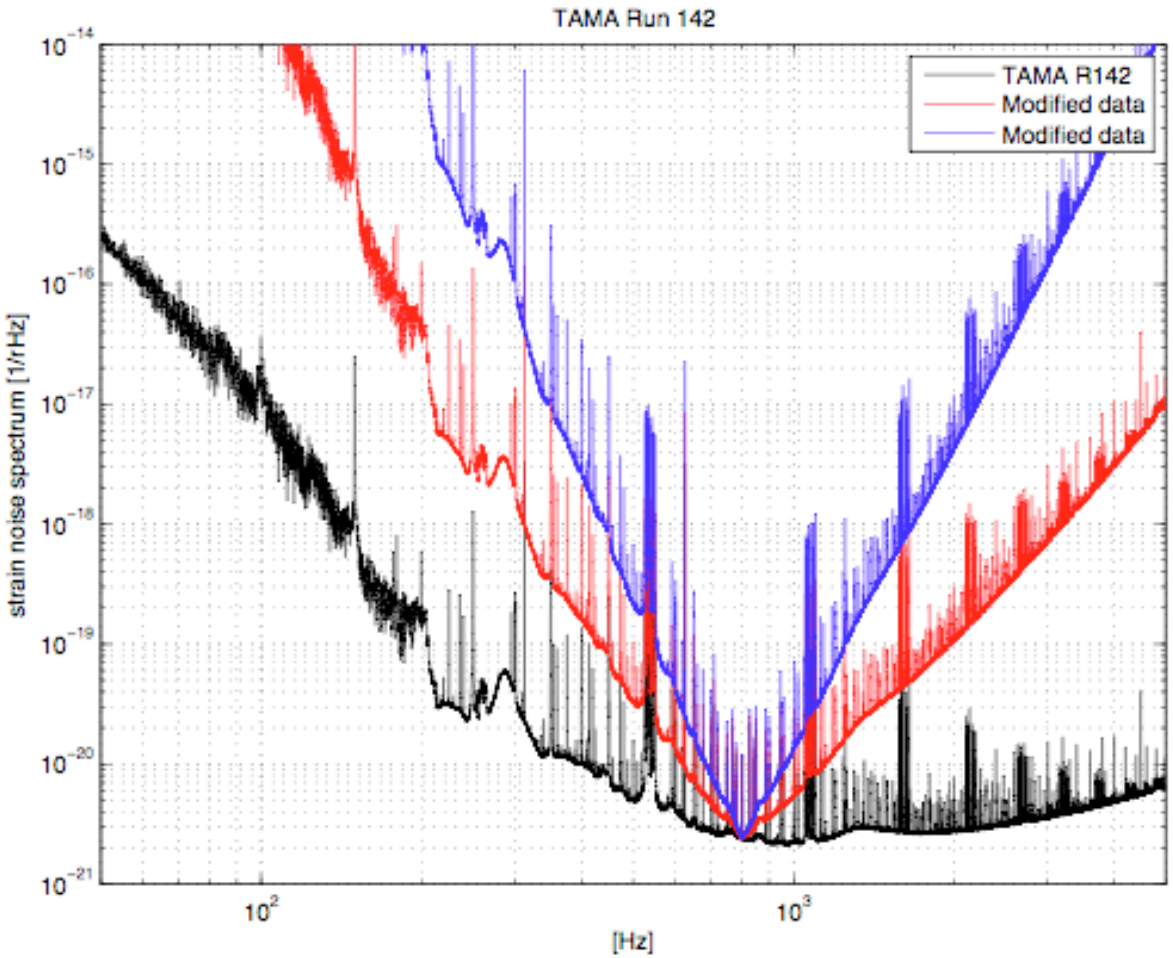
狭帯域データのfalse alarmのrhoは変わらないか確認

閾値への影響


ρ / χ distribution
TAMA R142
Modified data
Modified data
Number of events
ρ / χ threshold
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0
1
2
3
4
5
6
7
8
9
10

カイ２乗とバンド幅

狭帯域にした場合は，その帯域でのカイ２乗の分布だけでchi^2の分布が決まる.



まとめ

- chi^2分布はデータの性質に依存する．狭帯域にした場合は，その帯域でのカイ２乗の分布だけでchi^2の分布が決まる.
- 比rho/chiはデータの非ガウス性に余り依存しないため，閾値への影響は限定的であると思われる.
- TAMA R142の例では，800Hz付近の狭帯域にした場合，rho/chiの分布の傾きは多少なだらかになり，閾値は10%程度大きくなった.