# Violin Modes

## S2 Line Noise Investigation

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**(thanks to Gaby and Andri for discussions)**

**LIGO-G030130-00-Z**

**presented by S. Klimenko**

- **Outline**
  - **Tracking of violin modes in S2**
  - **Work in progress**
  - **Conclusion**

# VM Monitoring

- Narrow lines are monitored with the LineMonitor

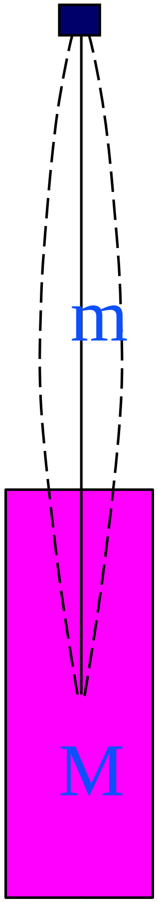
$$I(t) = \sum_n a_n \cdot \cos(\Psi_n(t)) = \sum_n a_n \cdot \cos(2\pi nft + \phi_n)$$

  - Integration time – 1 min
  - we assume that the harmonic's amplitudes do not change much during the integration time ***T*** (line width << ***1/T***)
- The LineMonitor estimates $\boldsymbol{a_n}$, $\boldsymbol{f}$ and $\boldsymbol{\phi_n}$
  - Violin frequencies are known, measure amplitude and phase.
  - Line parameters are constantly measured and stored in trend files
  - Two harmonics for each mode are monitored. Some first harmonics and most of the second harmonics are not visible for 1 min integration time

# Violin Amplitude

- $A$ – pendulum vibration amplitude
- $\boldsymbol{a}$ – mirror motion amplitude ($<<\boldsymbol{A}$)
- $V$ – amplitude measured by LineMonitor in ADC counts, converted to $\boldsymbol{a}$ using calibration
- ν – wire-mirror coupling: $$\nu = \frac{m}{\pi M} \approx 8.3 \cdot 10^{-6}$$
- **Thermal noise:** $$S(\omega) = \frac{4kT}{m\omega_0^2} \cdot \frac{\omega_0^2}{\omega} \cdot \frac{\omega_0^2 \Phi(\omega)}{\left(\omega_0^2 - \omega^2\right)^2 + \omega_0^4 \Phi^2(\omega)}$$
  - **quality factor** $$Q = \Phi^{-1}(\omega_0) = \omega_0 / \Delta\omega$$
- **Wire/Mirror motion:** $$\langle A^2 \rangle = \frac{kT}{m\omega_0^2} \approx (1820\, f)^2$$

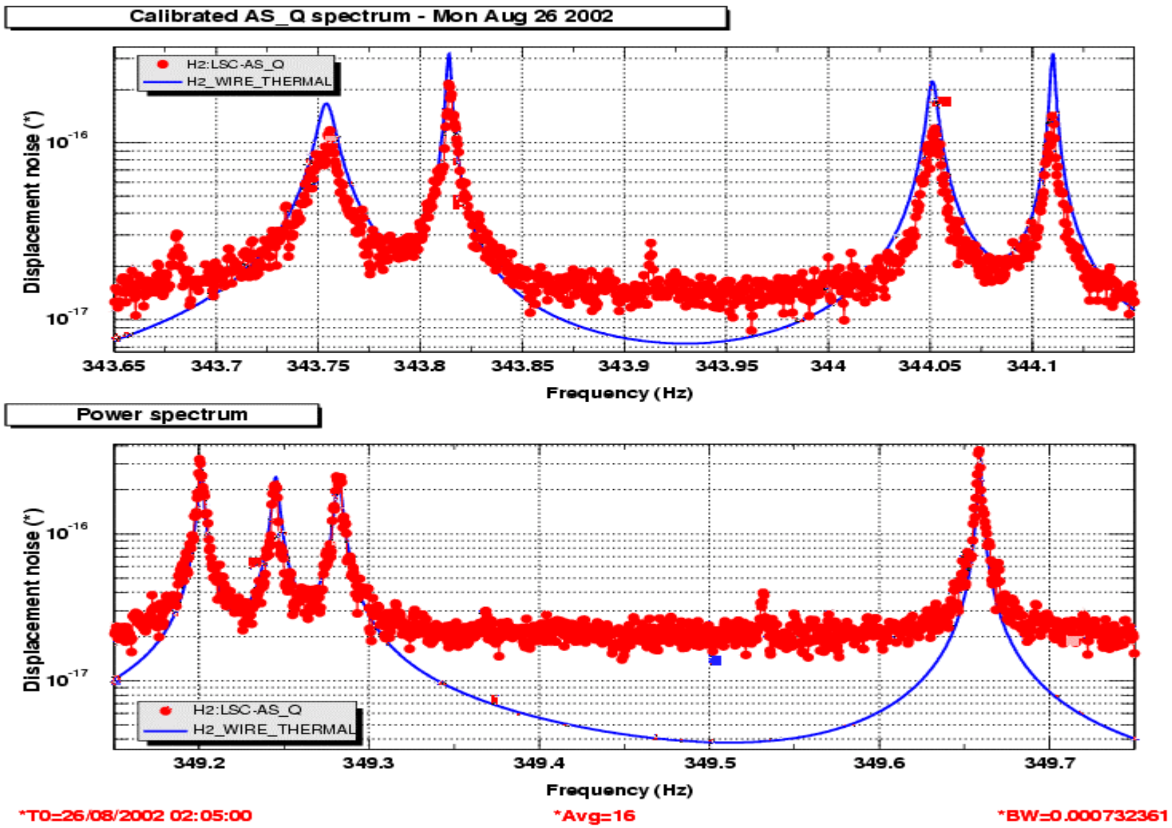
$$\langle a^2 \rangle = \nu^2 \frac{kT}{m\omega_0^2} \approx (15.1 m f)^2$$



# H2 violin modes for S1 run

- **Thermal noise from measured Q's of H2 violin modes**
  - **Fred: e-log 9/8/02**
  - **The raw data (red circles) is compared to the estimated thermal noise (blue curve)**

$$\sqrt{\langle a^2 \rangle} \sim 14 - 20 mf$$

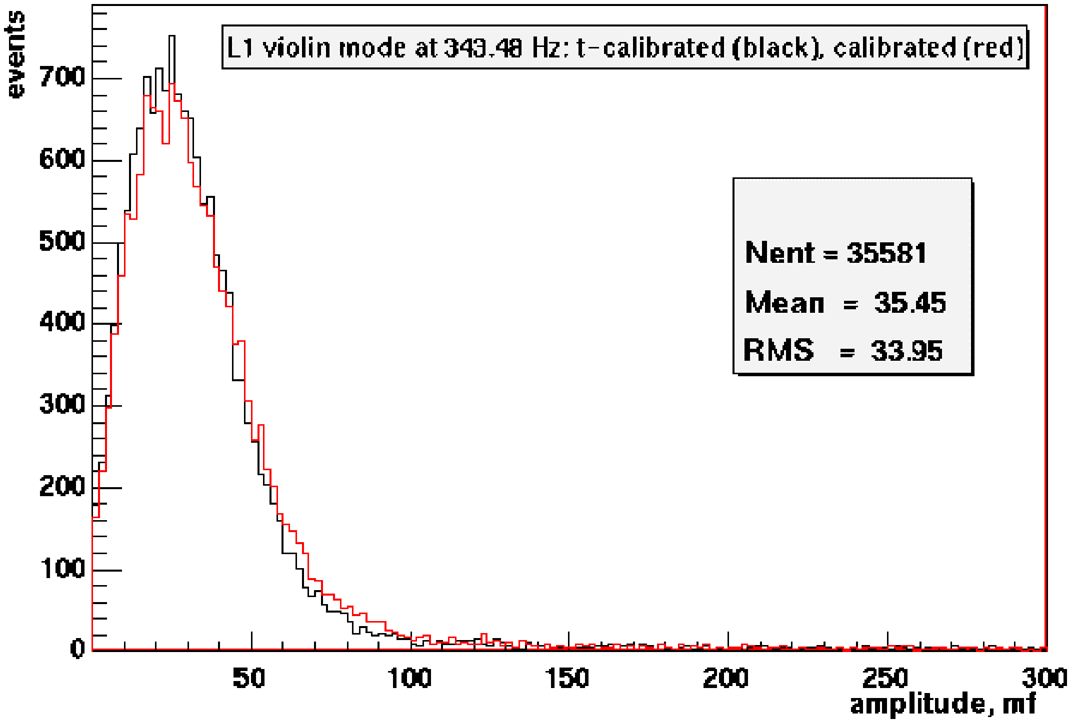



| | | |
|---|---|---|
| 343.754 | 39,000 | |
| 343.814 | 143,000 | ETMX |
| 344.051 | 70,000 | ETMX |
| 344.110 | 143,000 | |
| 349.201 | 116,000 | |
| 349.245 | 90,000 | |
| 349.282 | 90,000 | |
| 349.659 | 175,000 | |

# Calibrated Amplitude

$$a(t) = V(t)\cdot R(t) = V(t)\cdot \frac{1+\gamma(t)\left(C_0(f)R_0(f)-1\right)}{\alpha(t)C_0(f)}$$

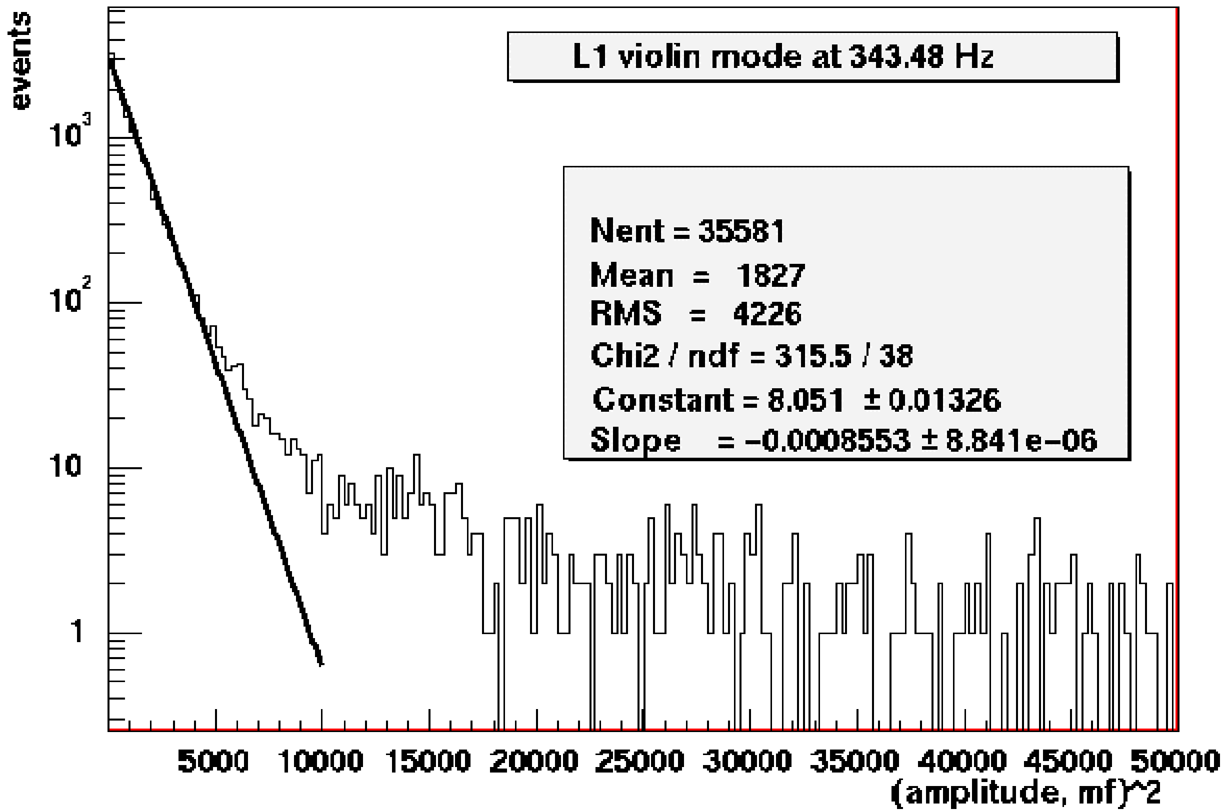
- $R_0$ – response function
- $C_0$ – sensing function
- $H_0$ – open loop gain (0.376 @ 344 Hz)
- $\gamma,\alpha$ – t-calibration



# Average square amplitude

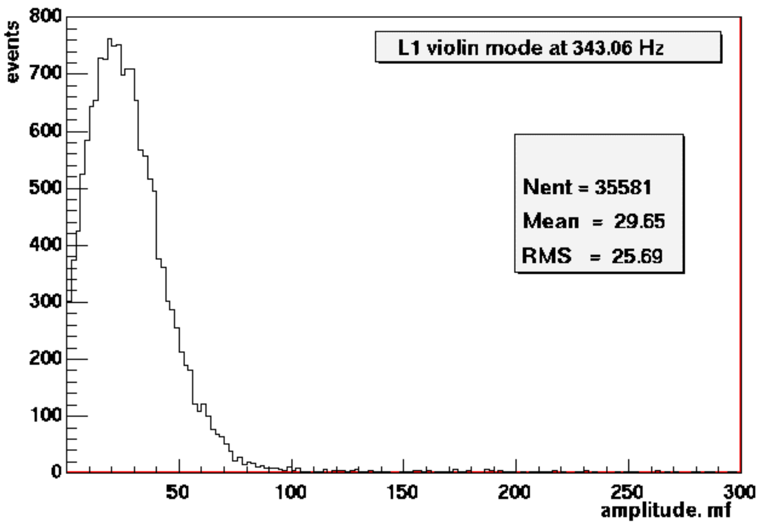
- *P(a)* – Raylegh distribution
- *P(a²)* – exponential
  - slope *s* gives <a²>

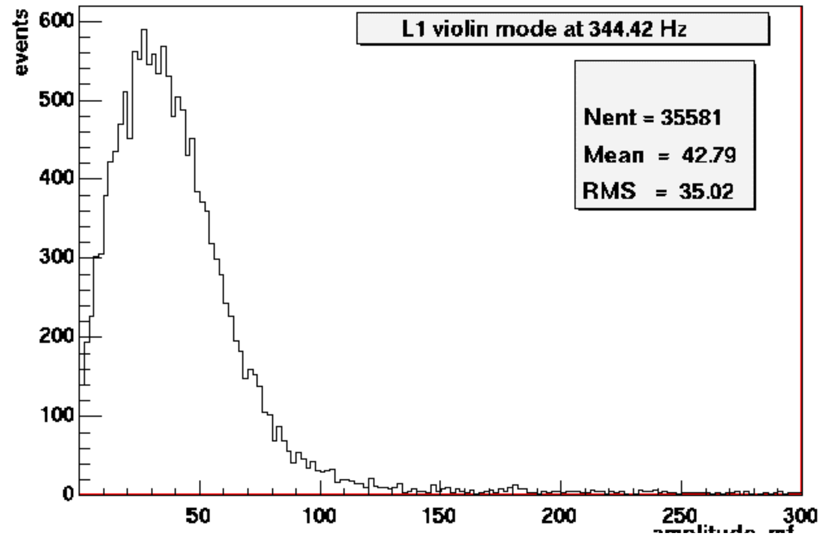
$$\langle a^2 \rangle = s^{-1}\frac{4-\pi}{4}$$

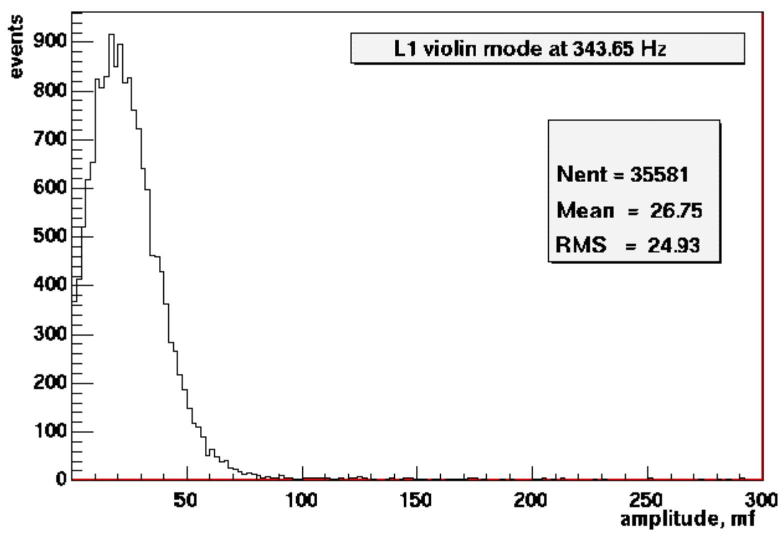


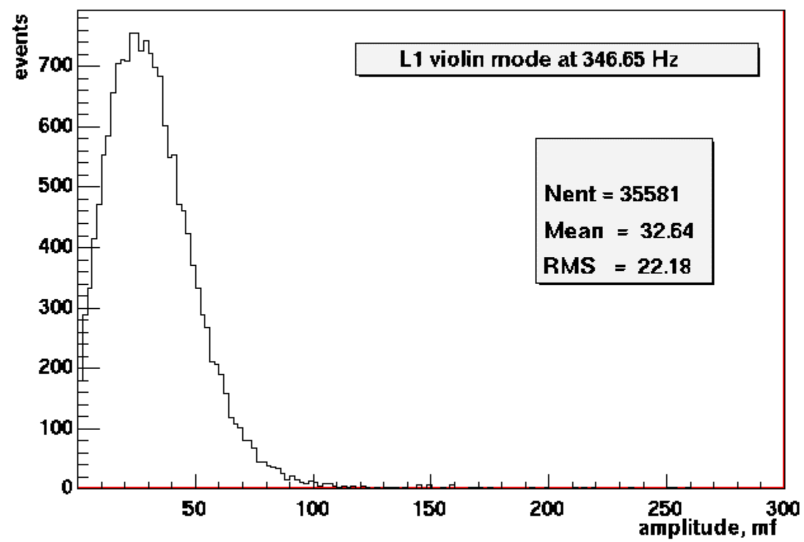

$$\sqrt{\langle a^2 \rangle} = 15.8mf$$

# Amplitude distribution

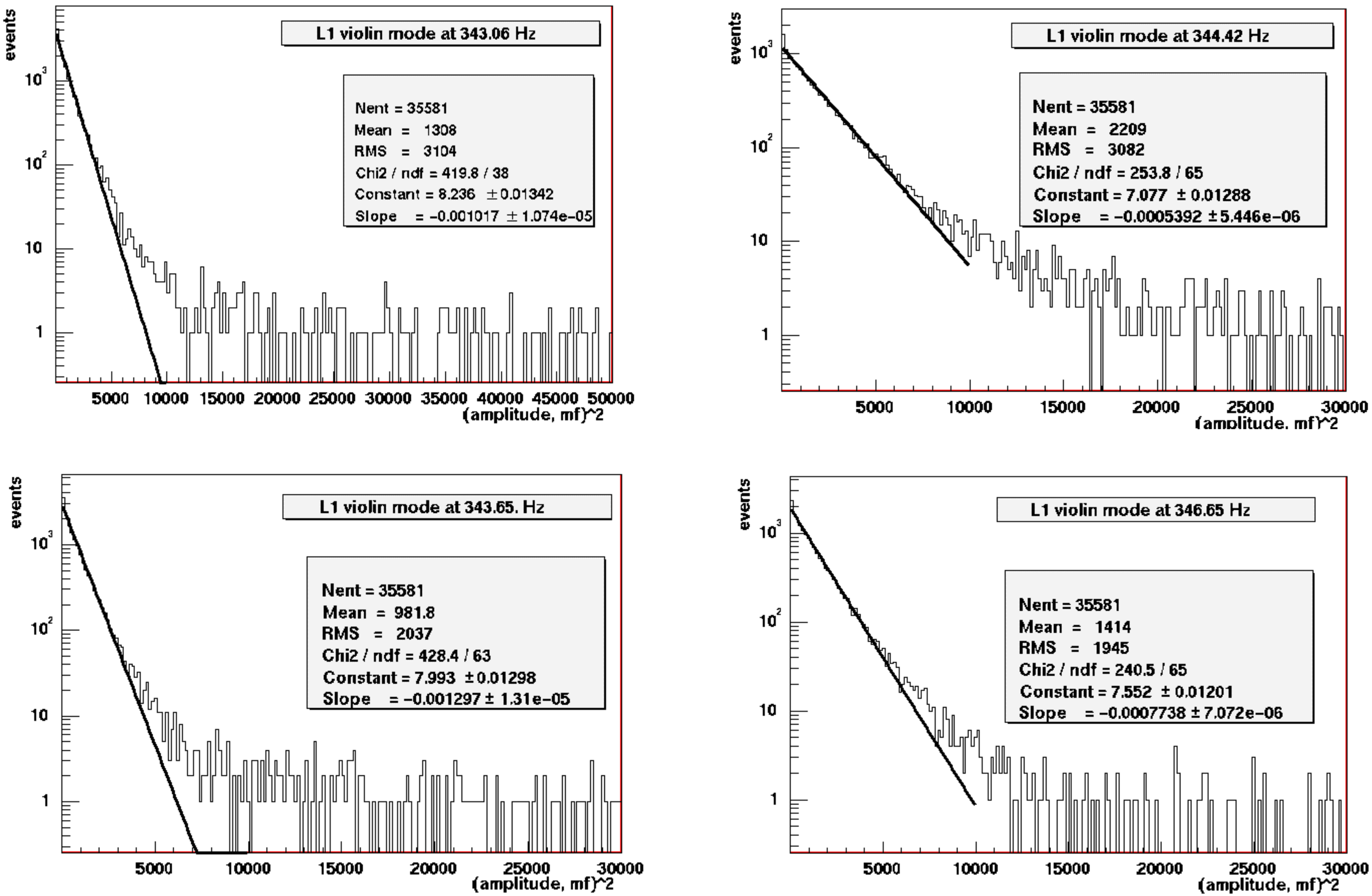


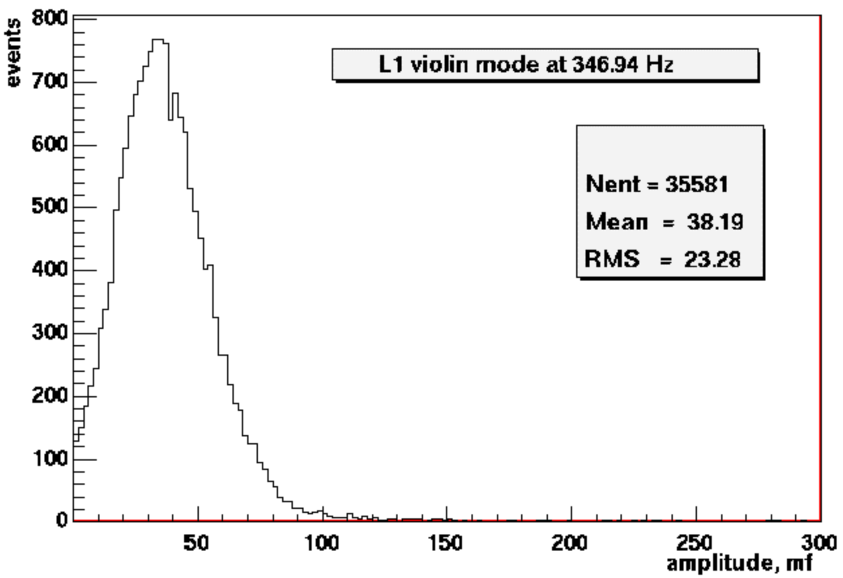



# exponential



# external excitation

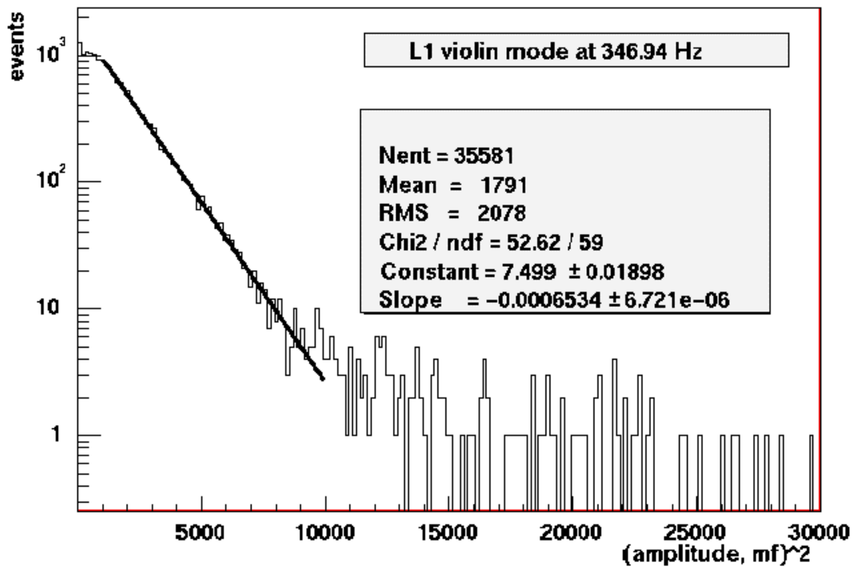
- **non-exponential tail**
  - *can be excluded from the fit*
  - *LineMon outlier triggers could be used as veto for the analysis.*




- **shifted Rayleigh distribution**

$$\log(P(a^2)) = s(a^2 + a_s^2)$$

  - slope is not affected by shift



# L1 Violin thermal noise

very preliminary

| frequency , Hz | displacement noise, mf |
|---|---|
| 343.06 | 14.5 |
| 343.48 | 15.8 |
| 343.65 | 12.9 |
| 344.42 | 19.9 |
| 346.65 | 16.6 |
| 346.94 | 18.1 |

stat. error ~ 1%

expected noise for simple mechanical model:

15.0-15.5 mf (depends on M and $\omega$)

# Conclusion & Plans

- **Thermal excitation of the violin resonances is observed**
  - **measured noise: 13-20 mf**
  - **expected noise: 15.0-15.5 mf**
  - **more accurate mechanical model should be used for better agreement between measured and calculated noise.**
  - **the noise measurement could be affected by servo.**
- **Plans**
  - **do analysis of H1 and H2 modes (Sergey)**
  - **calculate thermal noise from measured Q-factors and compare with the LineMonitor results (Fred)**