

# **Acoustic method for the coefficient of restitution measurement**

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# 1. Experimental setup

- Frequency Response 20 – 7,200 Hz
- Sampling rate 5kHz



10/25/2014

# Quiz

We measured the coefficient of restitution for three different materials (steel, glass, and plastic).

Based on your experience, which has a larger coefficient of restitution?

- a) Steel
- b) Glass
- c) Plastic

## 2. Theory

Initial time and speed before first impact

$$t_0 = \sqrt{\frac{2h}{g}}$$

$$v_0 = \sqrt{2gh}$$

Examples

$$h = 5\text{cm} \Rightarrow t_0 = 0.100\text{s}$$

$$v_0 = 0.99 \text{ m/s}$$

$$h = 10\text{cm} \Rightarrow t_0 = 0.143\text{s}$$

$$v_0 = 1.400\text{m/s}$$

$$v_1 = \alpha v_0$$

$$v_2 = \alpha v_1 = \alpha^2 v_0$$

...

$$v_n = \alpha^n v_0$$

The coefficient of restitution

## 2. Theory

$$t_1 = \frac{v_1}{g} = \alpha \frac{v_0}{g} = \alpha t_0$$

Half time between events

$$t_2 = \frac{v_2}{g} = \alpha^2 \frac{v_0}{g} = \alpha^2 t_0$$

...

$$t_n = \alpha^n t_0$$

$$\ln(t_n) = n \ln(\alpha) + \ln(t_0)$$



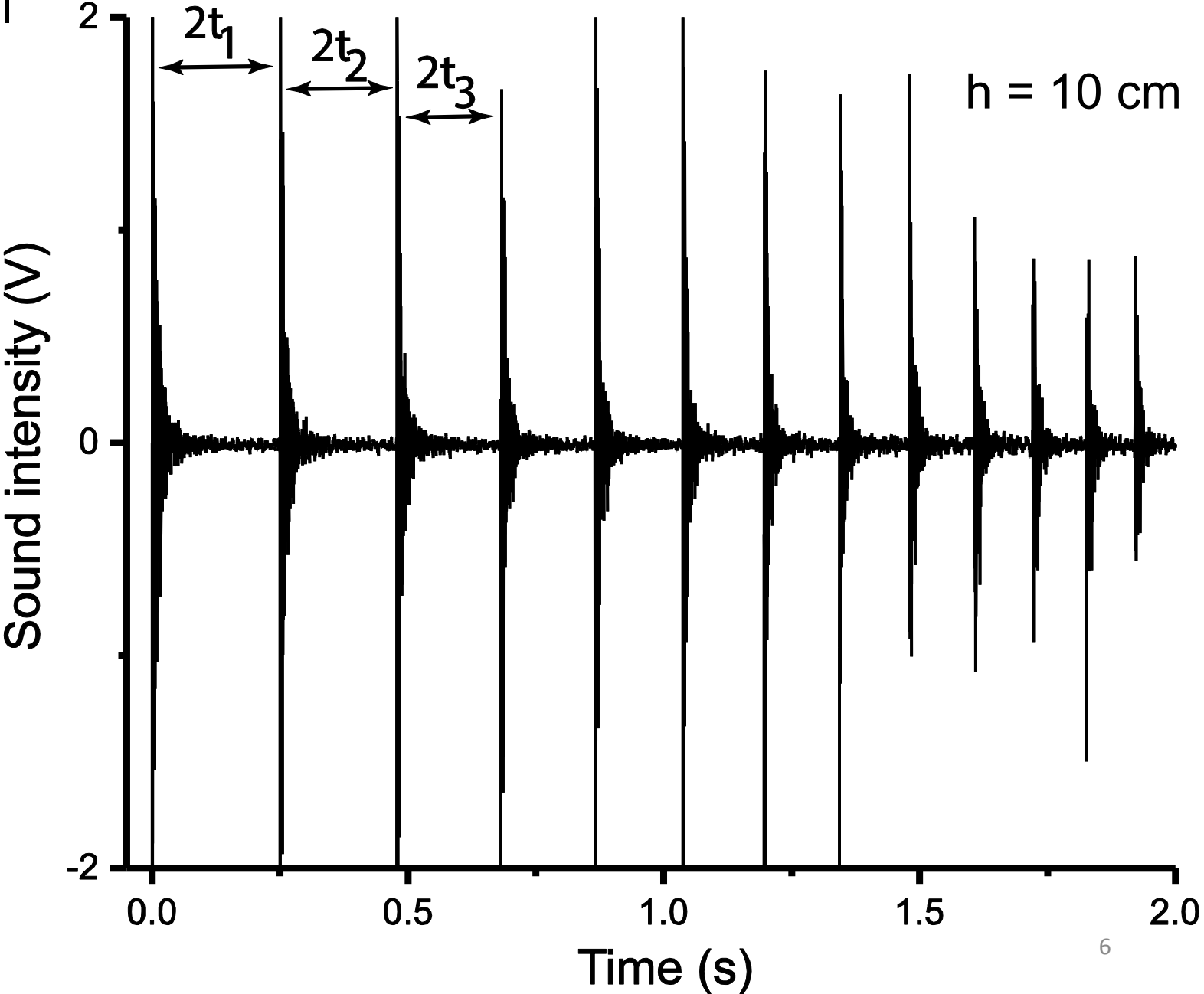
slope



intercept

# 3. Measurements

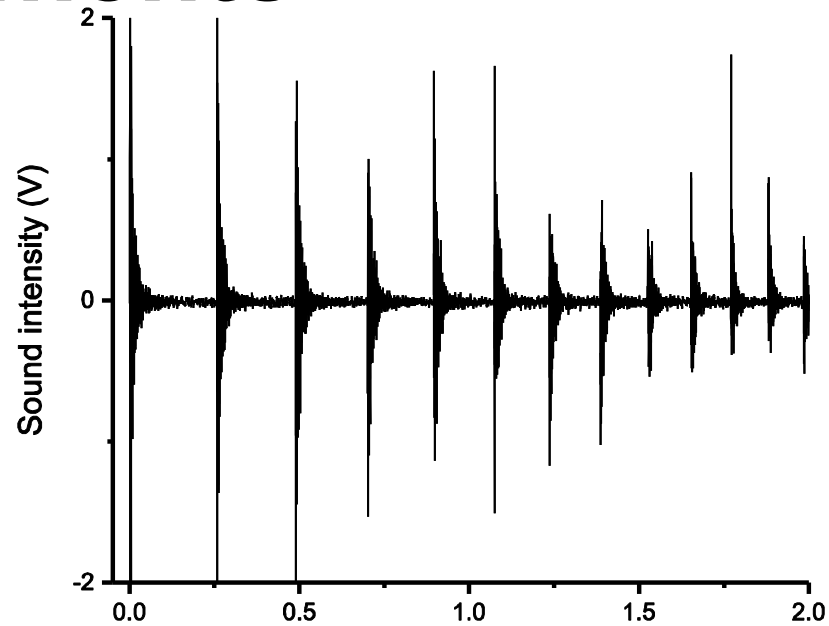
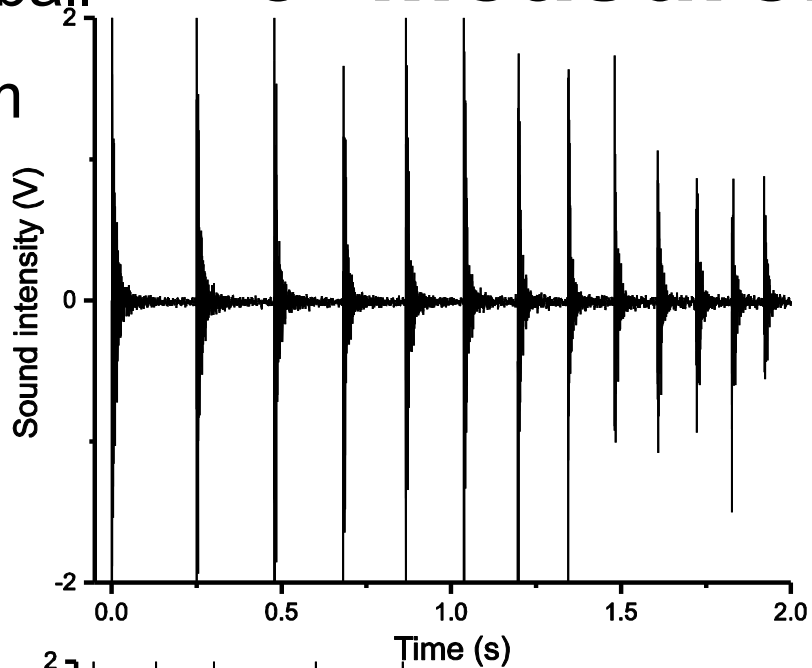
1. Glass ball



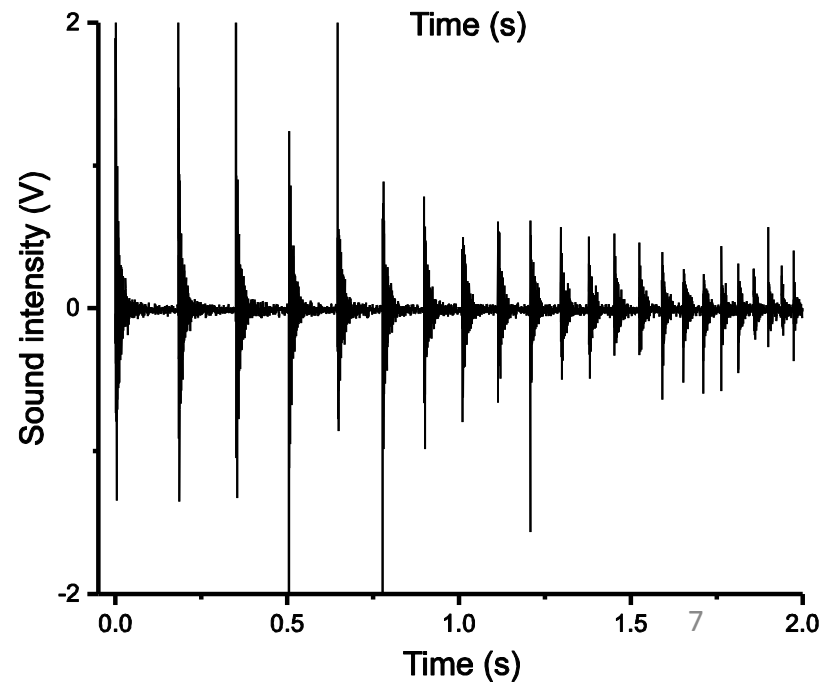
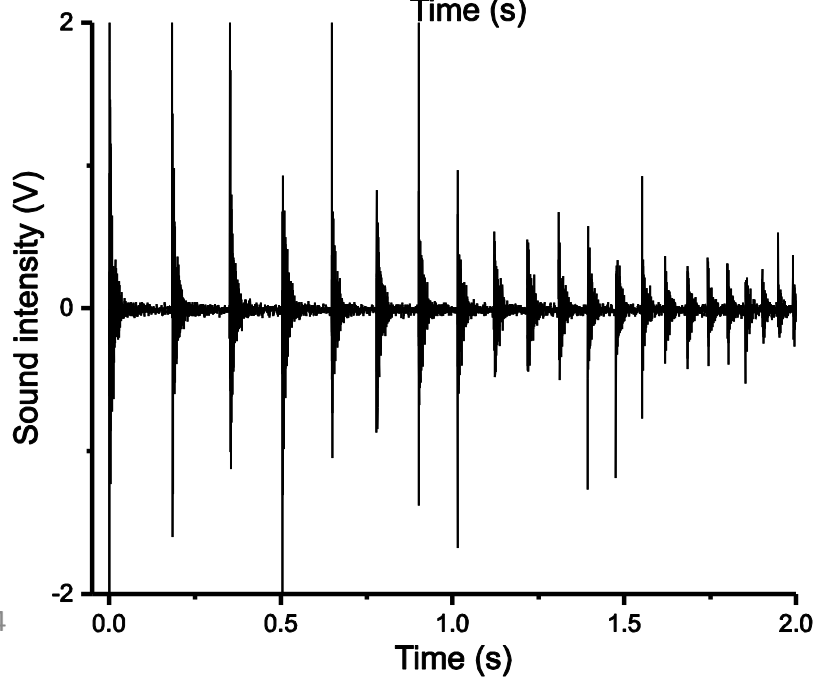
# 3. Measurements

1. Glass ball

$h = 10$  cm



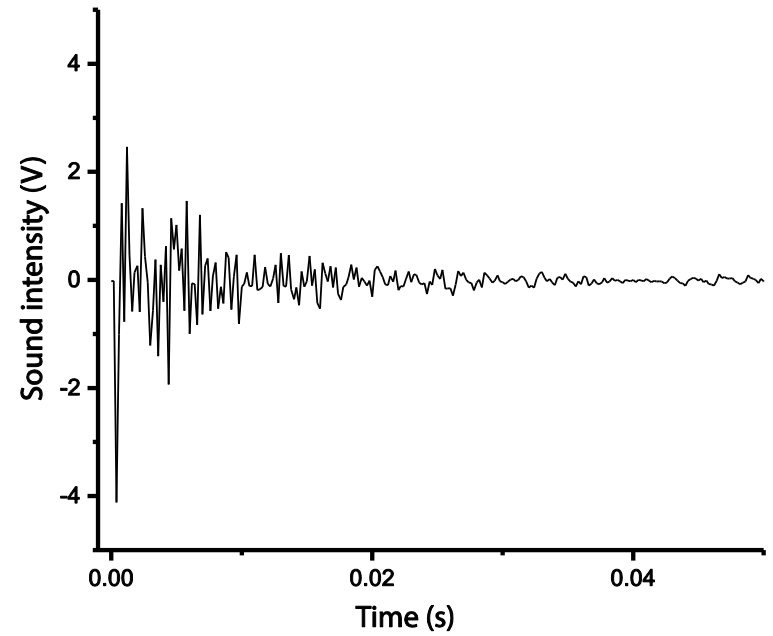
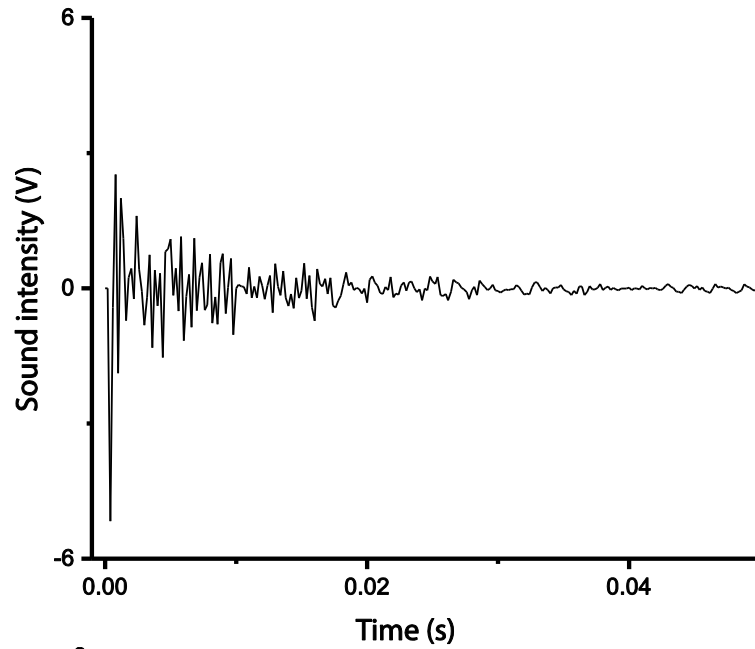
$h = 5$  cm



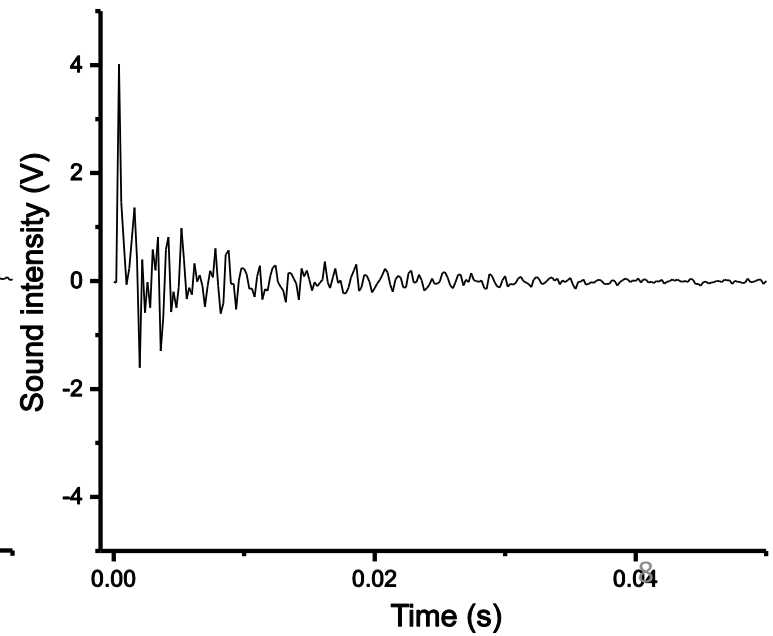
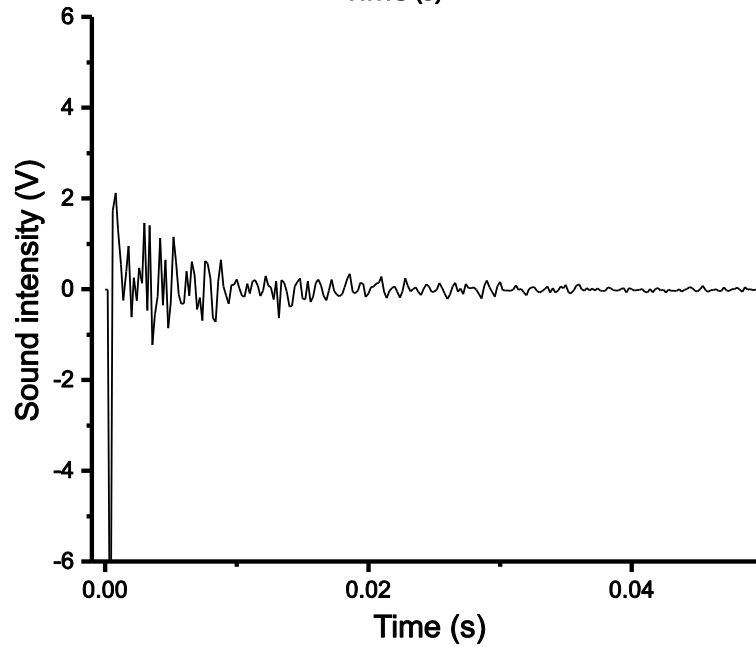
# 3. Measurements

1. Glass ball

$h = 10$  cm



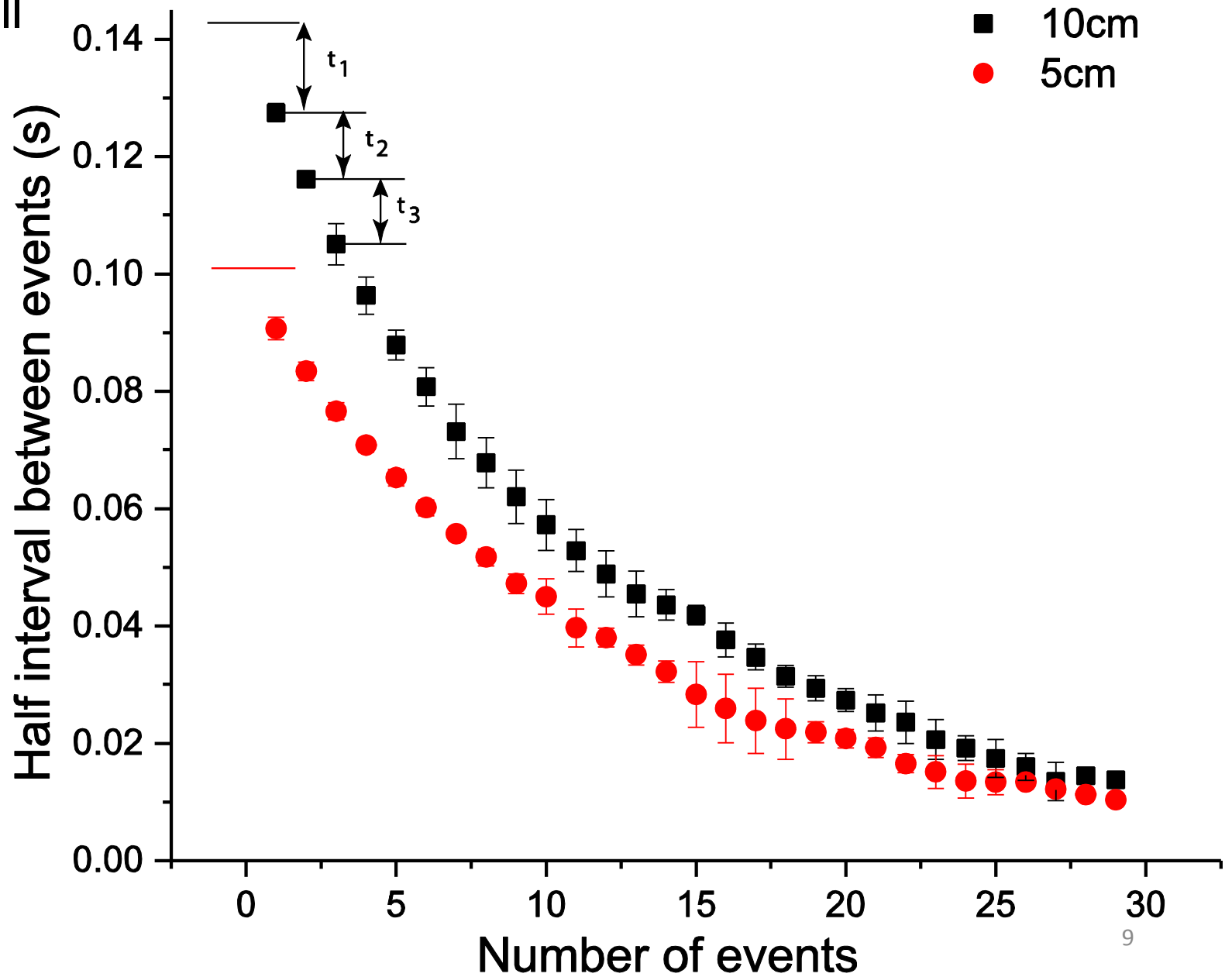
$h = 5$  cm





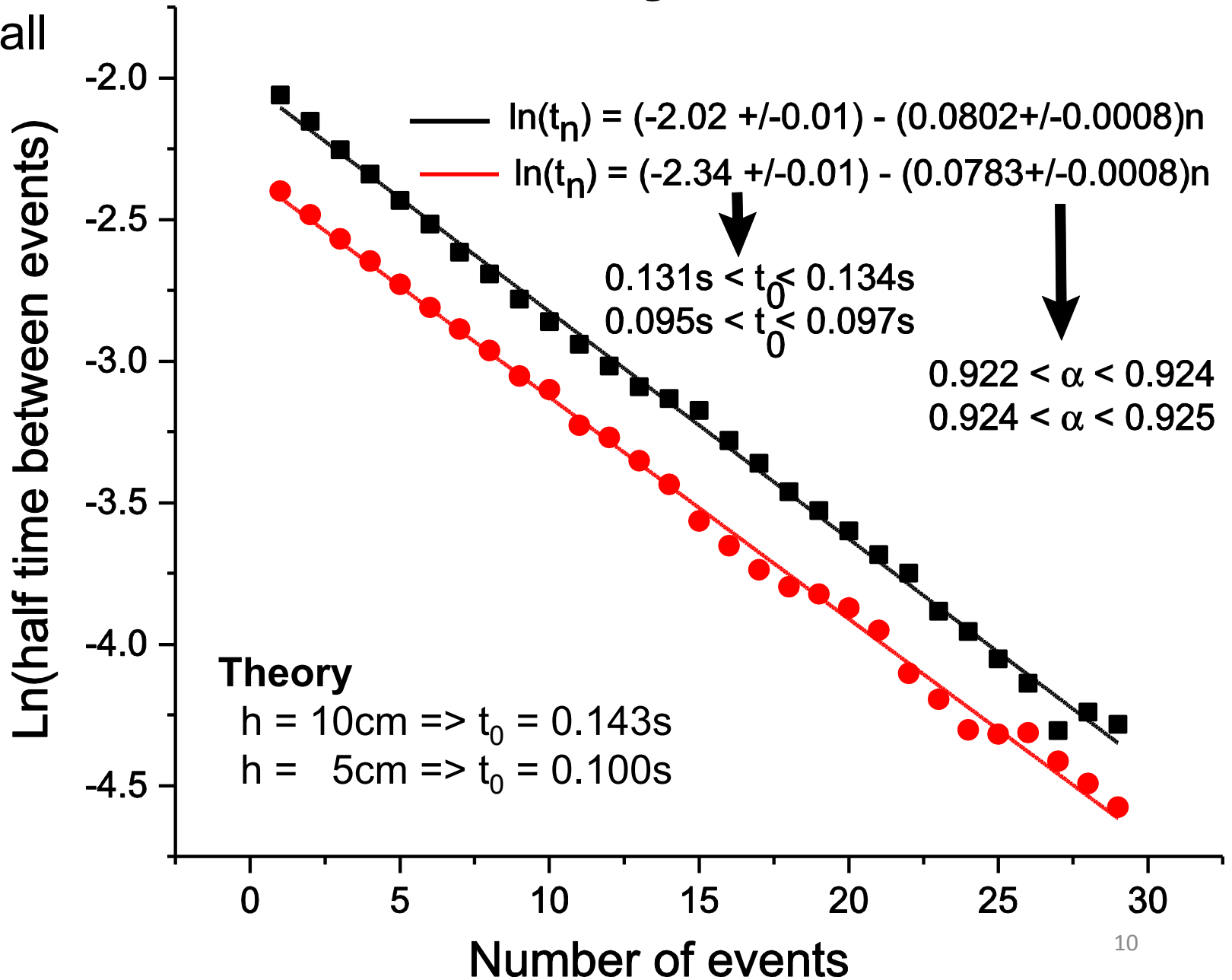
# 4. Data analysis

## 1. Glass ball



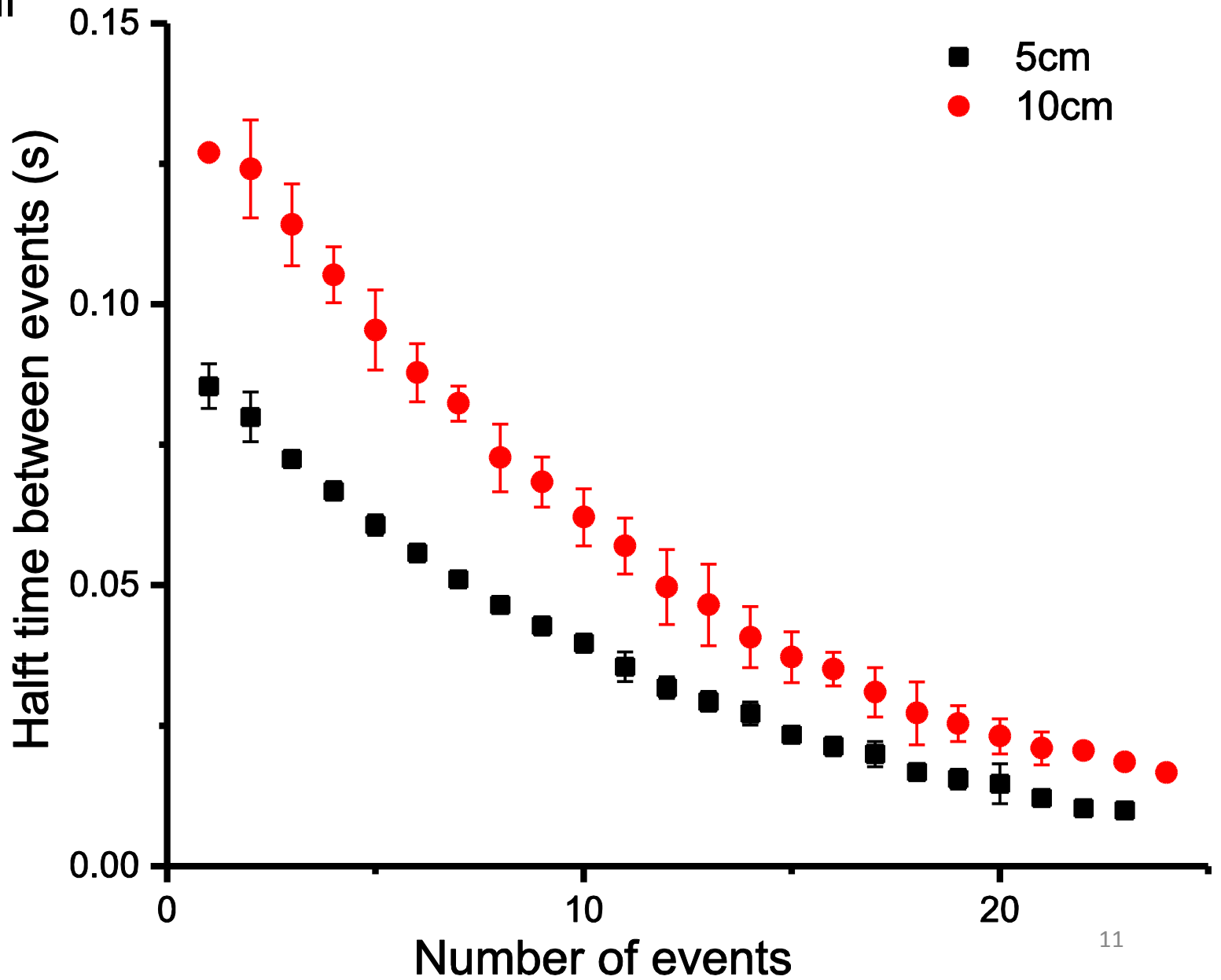
# 4. Data analysis

## 1. Glass ball



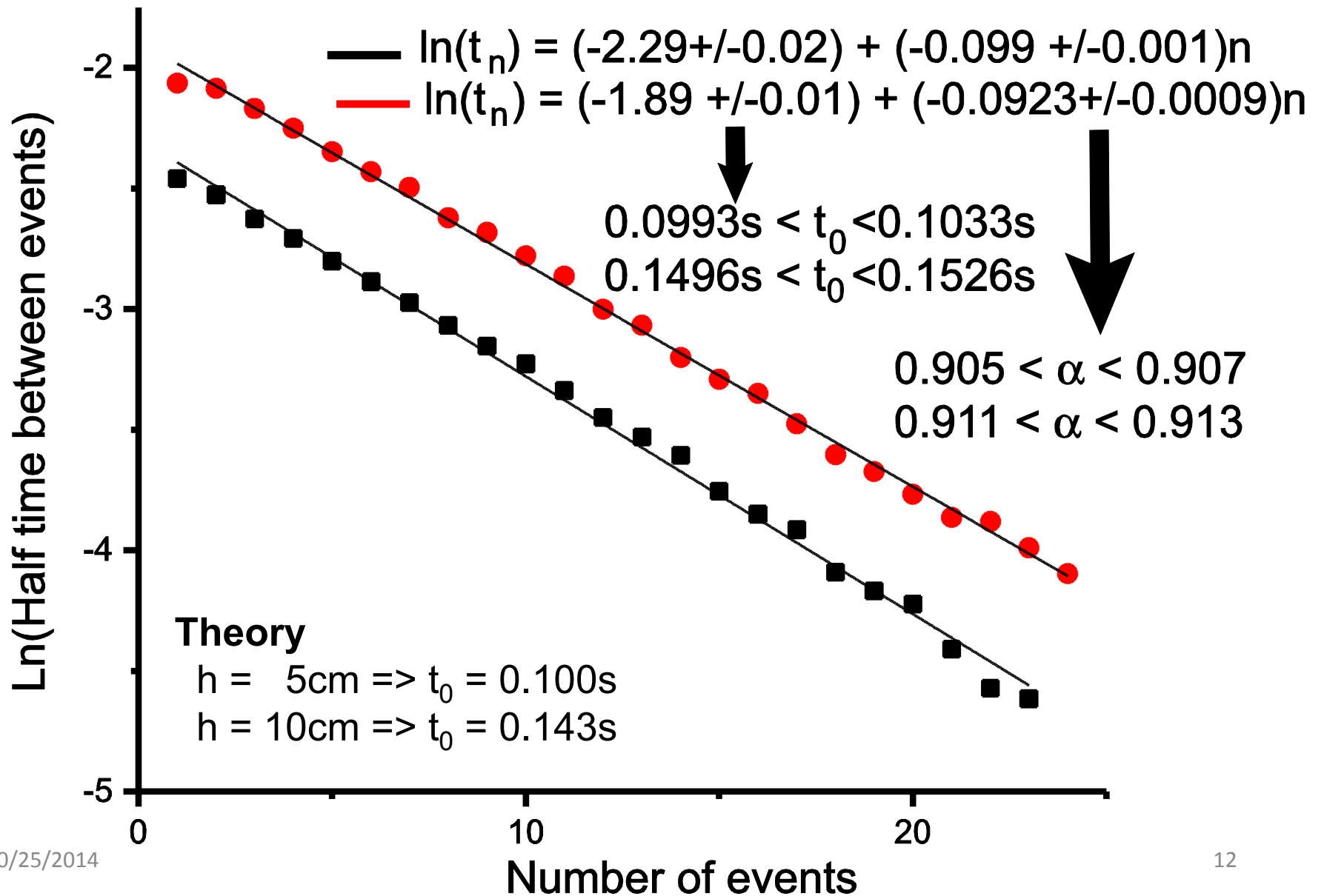
# 4. Data analysis

## 1. Plastic ball



# 4. Data analysis

## 1. Plastic ball



# 5. Conclusions

- PASCO sound sensor records with high enough sampling frequency to allow accurate measurement of fly time between successive collisions.
- At a sampling rate of 5 kHz, the temporal estimation error is 0.2ms => spatial accuracy better than 0.28mm (better than motion sensor measurements).
- The acoustic measurement of fly times allow the determination of both
  - The restitution coefficient
  - The initial height
- The coefficient of restitution (Quiz answer: **B**)
  - Steel  $0.852 < \alpha < 0.858$
  - Plastic  $0.905 < \alpha < 0.913$
  - Glass  $0.922 < \alpha < 0.925$