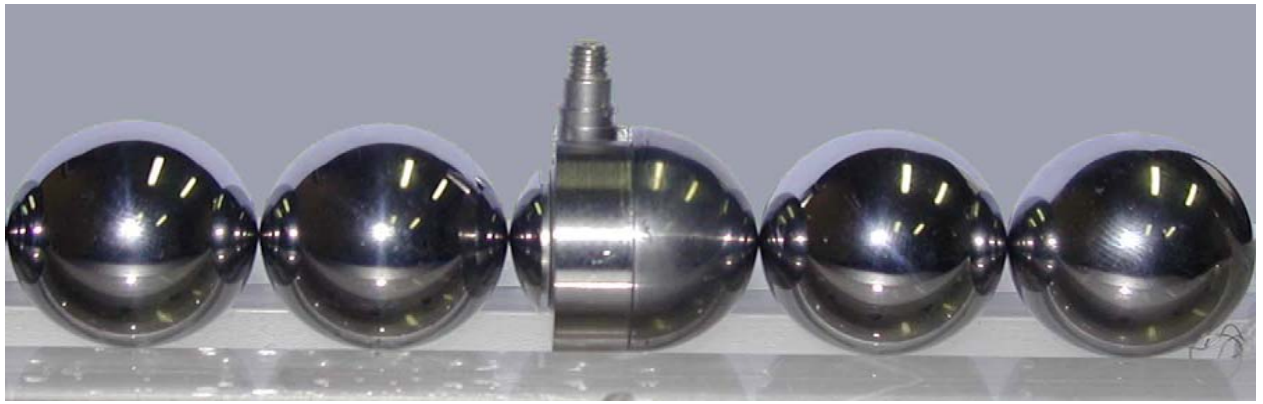
# Nonlinear waves in dry and wet Hertzian granular chains



INSTABILITIES AND NONEQUILIBRIUM STRUCTURES XI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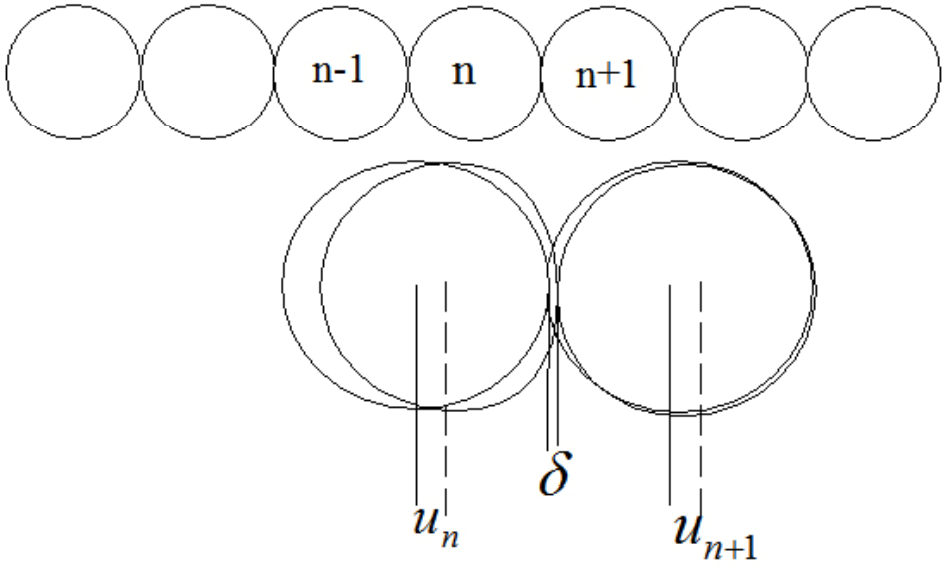
# 1.- One-dimensional Hertzian granular chain




$$\frac{\partial^2 u_i}{\partial^2 t} = \frac{k}{m}\left[(\delta_0 - (u_i - u_{i-1}))^{3/2} - (\delta_0 - (u_{i+1} - u_i)^{3/2})\right]$$

**Phys. Rev. Lett. 94, 178002 (2005)**

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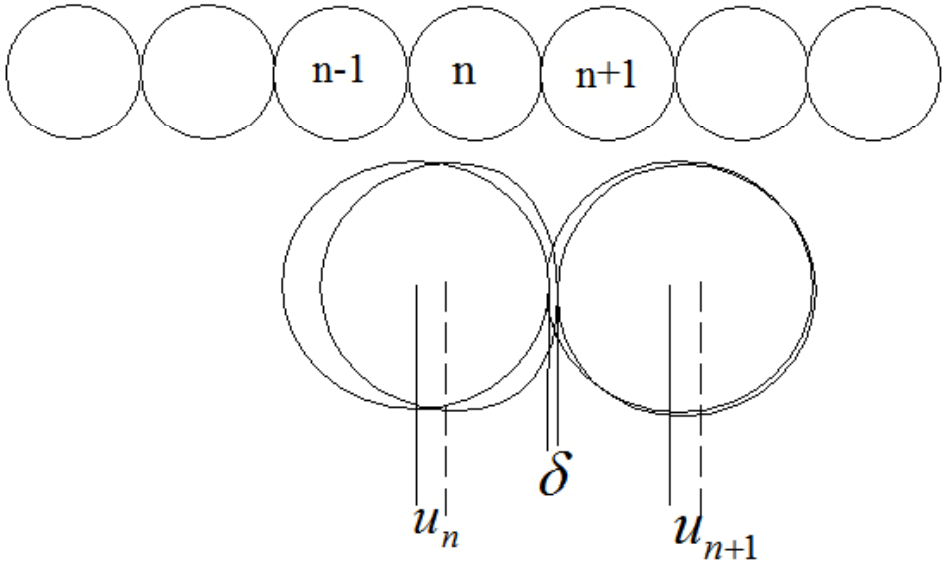


Long wavelength approximation :

$$\frac{2R}{\lambda} << 1$$

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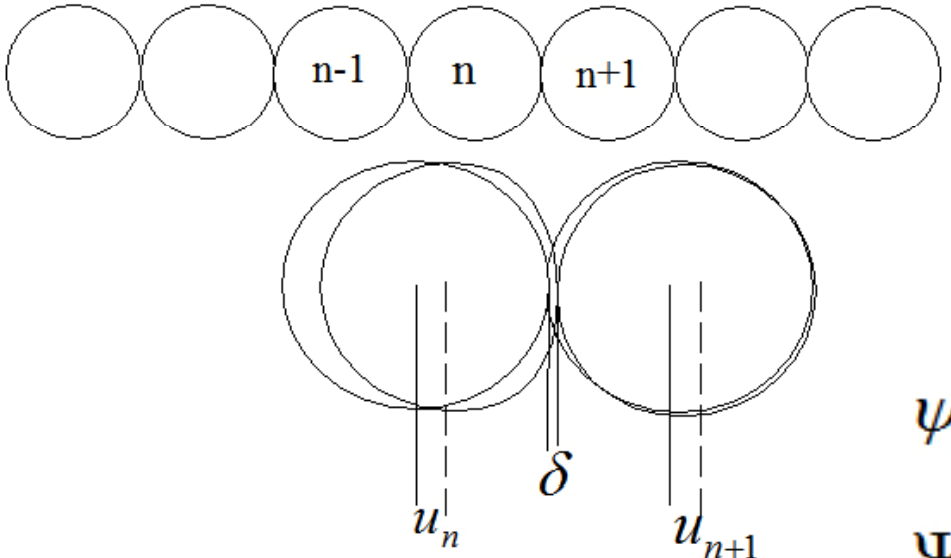



$$\psi(x,t) = -\partial_x u(x,t)$$

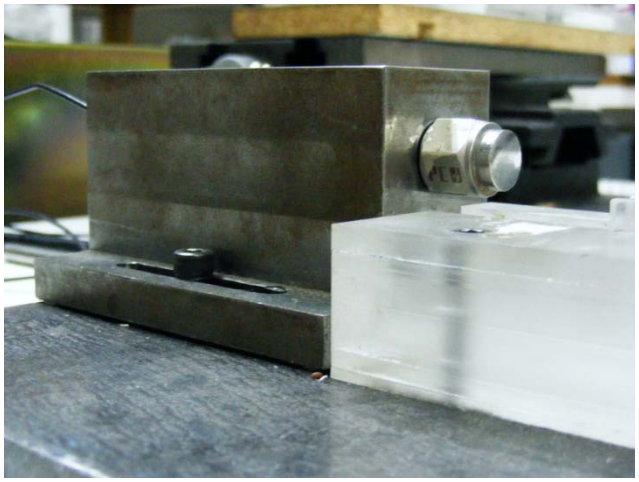
$$\Psi = \Psi_m \cos^4(\xi) \;\; ; \xi = \frac{x - vt}{R\sqrt{10}}$$

$$v = \sqrt{\frac{6}{5\pi\rho\theta}}\Psi^{1/4}$$

**Phys. Rev. Lett. 94, 178002 (2005)**

# Experimental setup

Wall Sensor : pcb piezo  10471



Bead Sensor : pcb piezo 200B02

Plexiglass track

**Phys.  Rev. Lett. 94, 178002 (2005)**

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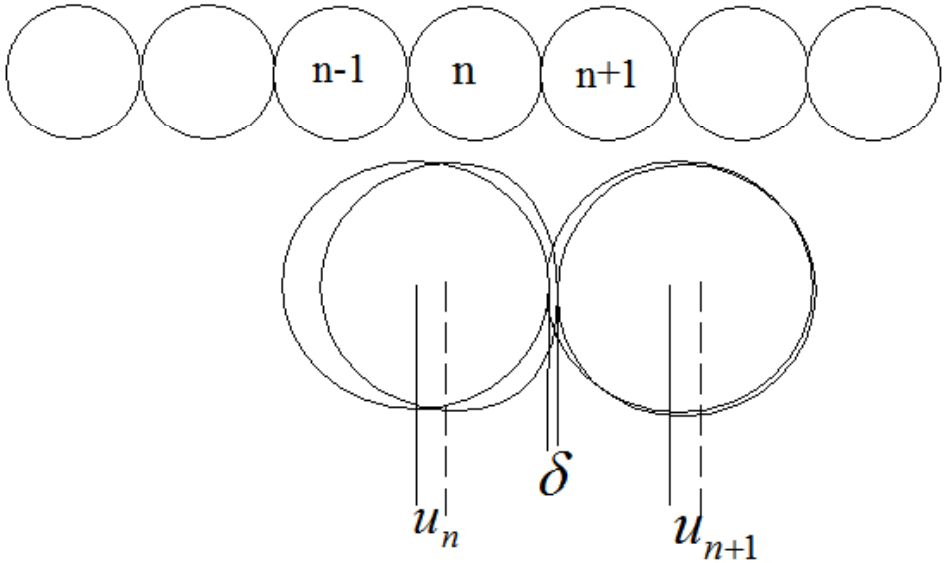


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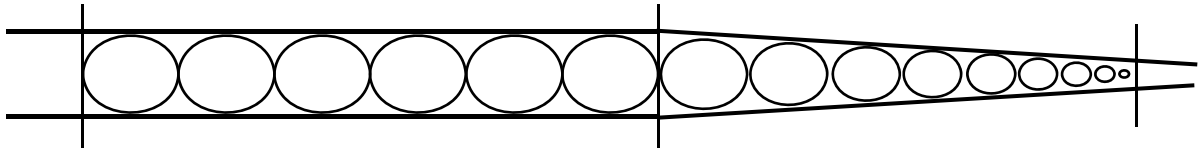
**Phys. Rev. Lett. 94, 178002 (2005)**

# Simulation Results

**Phys. Rev. Lett. 94, 178002 (2005)**

# 2.- Experimental evidence of shock mitigation in hertzian tapered chains



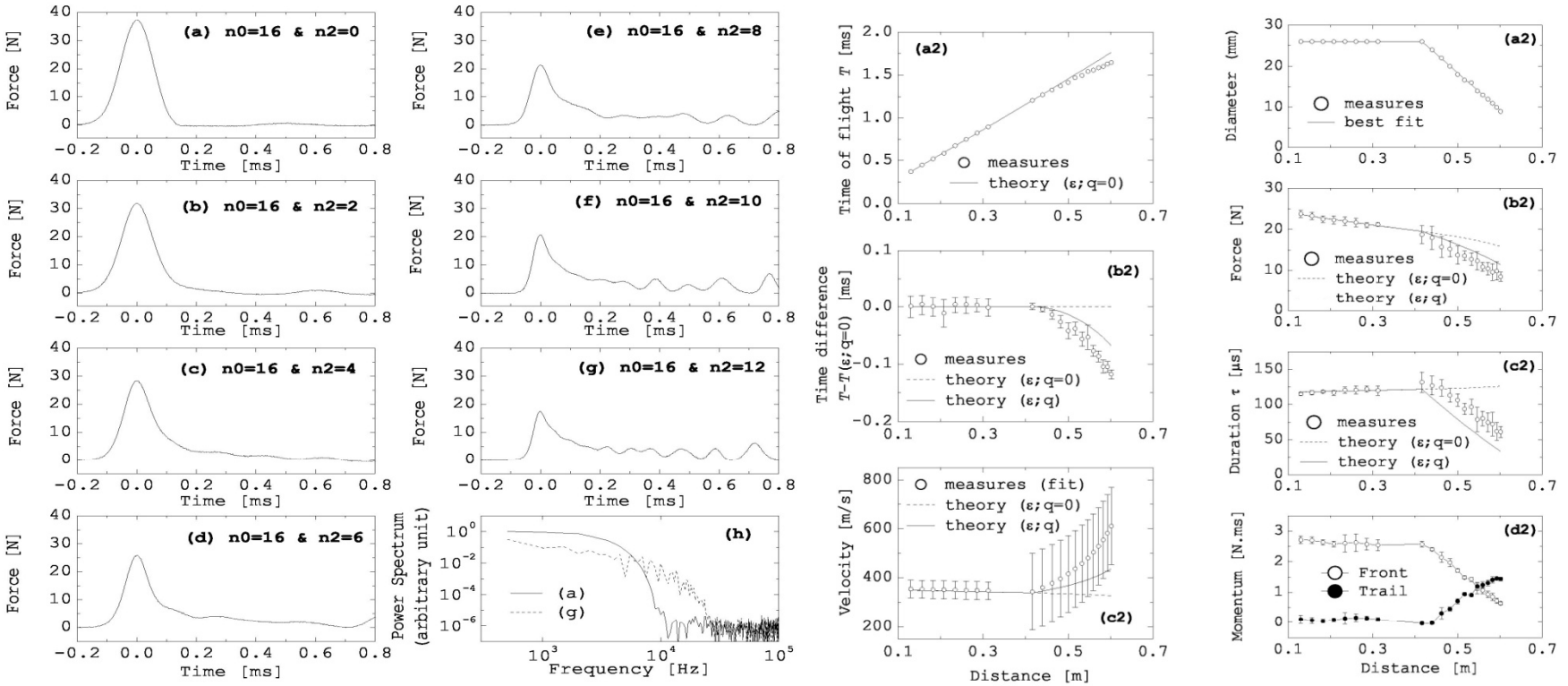
- Mitigation and strong non-linear effects
- Tapping factor plays a significant role
- Possibility to build more efficient shock absorbers

**Phys. Rev. E, 73, 041305 (2006)**

# …Some simulations

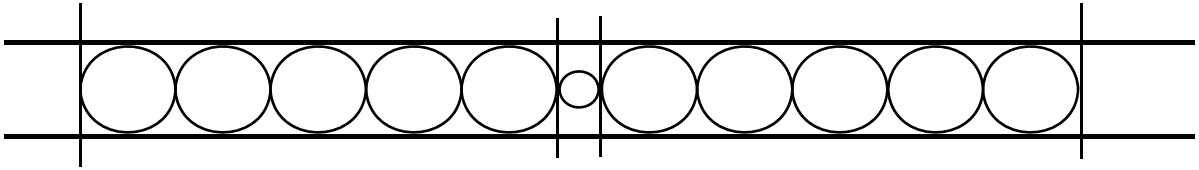
**Phys. Rev. E, 73, 041305 (2006)**

# Experimental results




**Phys. Rev. E, 73, 041305 (2006)**

# 2.- Experimental evidence on localization in hertzian chains containing a small intruder



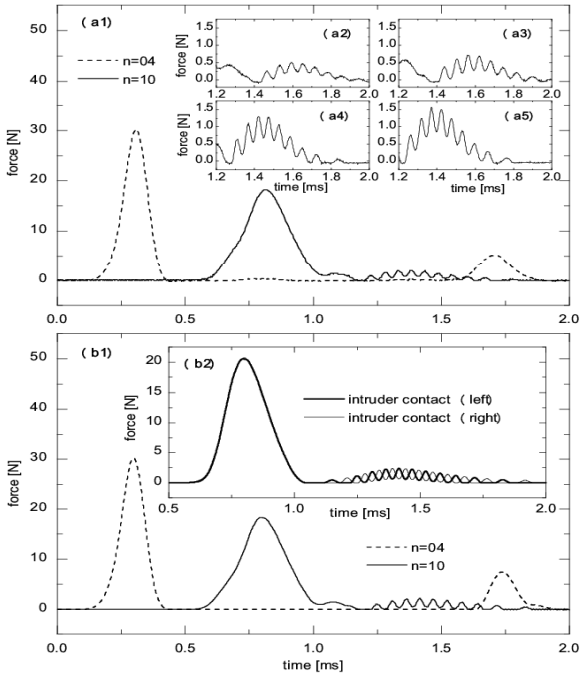
- Energy localization and distance gap formation

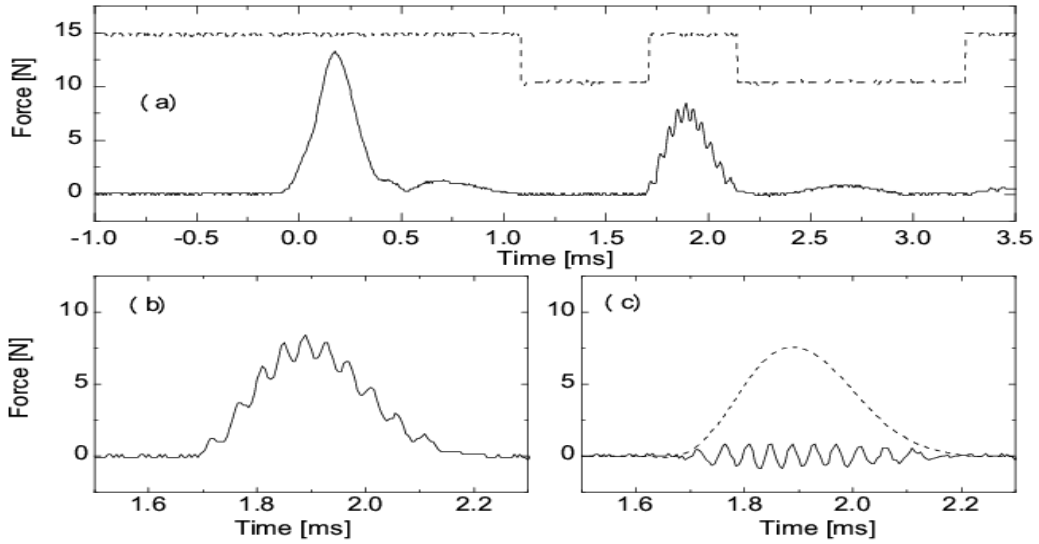
**To be submited to Phys. Rev. Lett.**

# Some simulations…

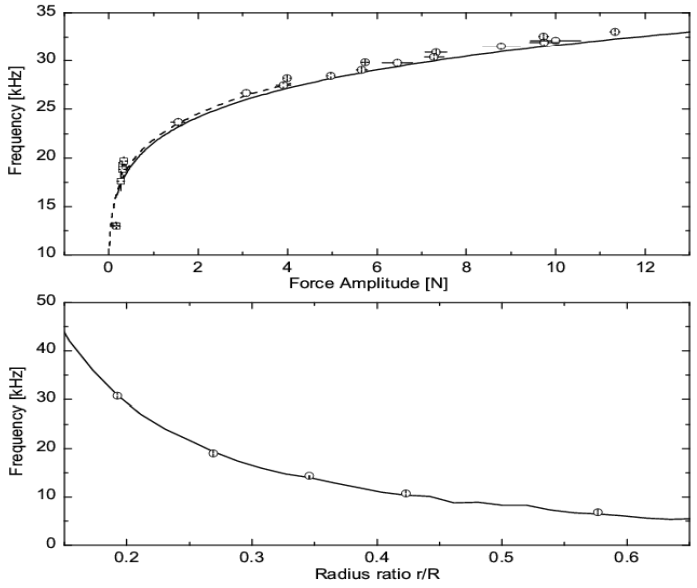
**To be submited to Phys. Rev. Lett.**

# ...Experimental results




$$f_m \approx \frac{\sqrt{3}}{2\pi}\frac{\kappa^{1/3}F_m^{1/6}}{m^{1/2}} \propto \left(\frac{r}{R}\right)^{-4/3}\left(1+\frac{r}{R}\right)^{-1/6} F_m^{1/6}$$




**To be submited to Phys. Rev. Lett.**

# Effects of an interstitial fluid on grain interaction

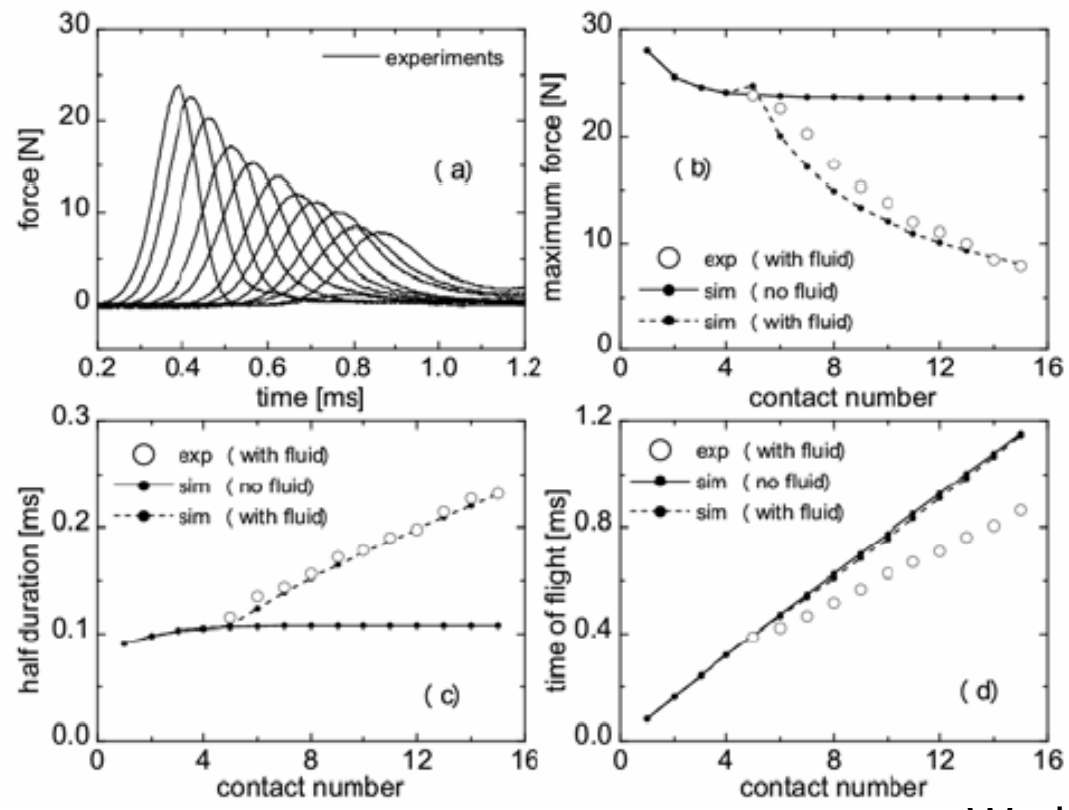
**“Nonlinear waves in dry and wet Hertzian granular chains”**

Stephane Job , *Francisco Santibanez, Franco Tapia, Francisco Melo*

*submitted to Elsevier on November 2007*

Work in progress…

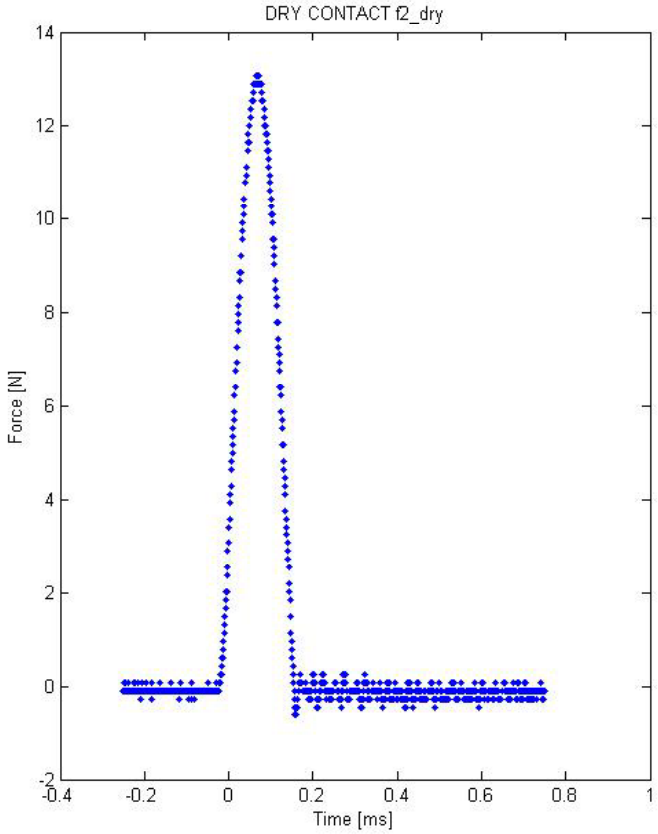
# Full chain experiment

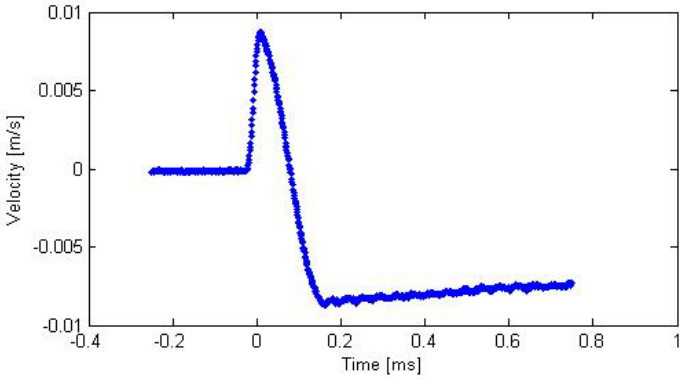


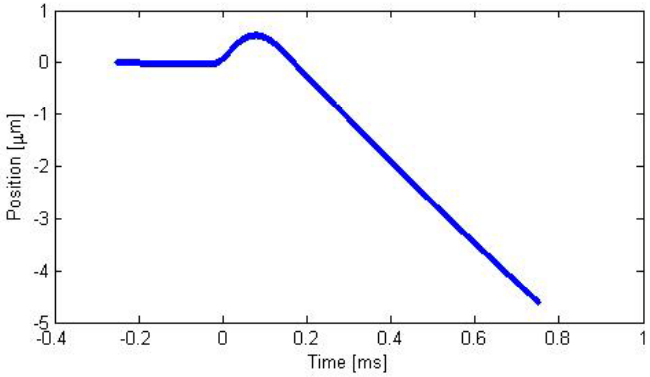

Work in progress…

# Single contact experiment

Dry Contact

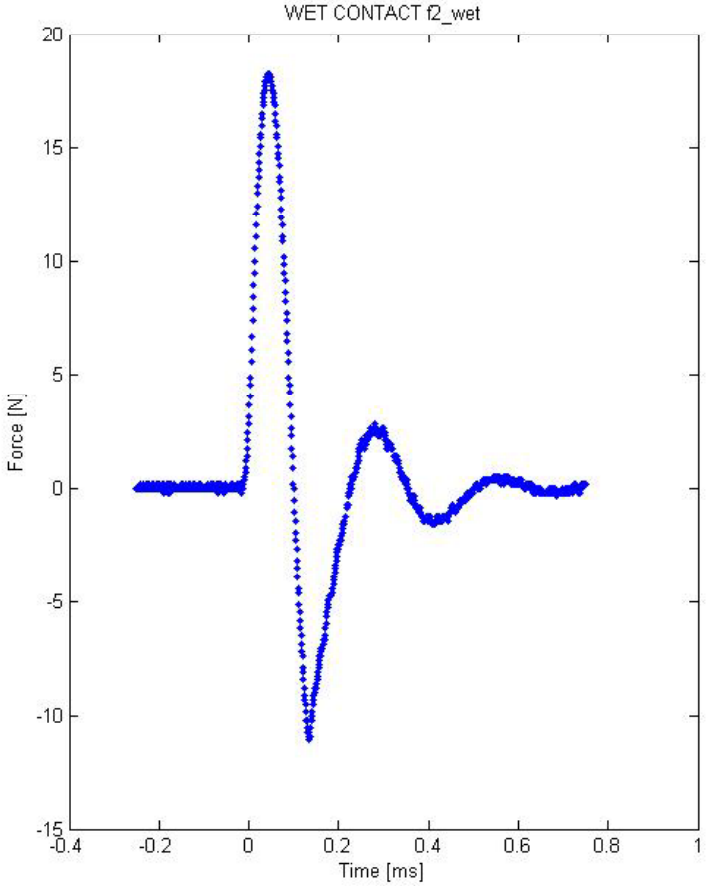


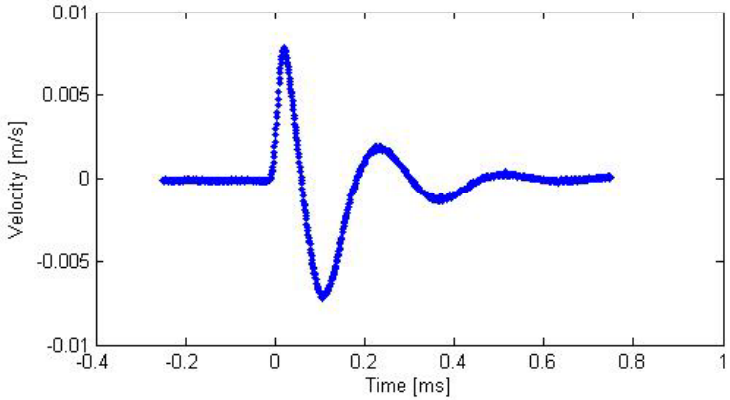



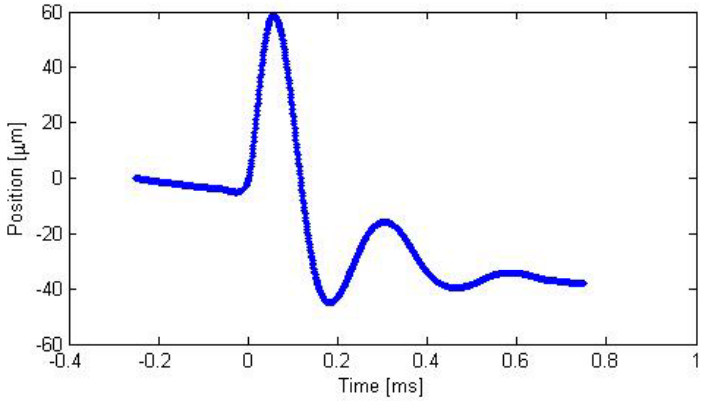



# Single contact experiment

Wet Contact



# Final coments

- It is possible to study the propagation of Nonlinear waves by means of in-situ force measurements and numerical analysis.
- Nonlinear waves are affected by  difference in contact properties (stiffness and inertial) .
- Important applications can be developed starting from this simple systems :
  - » Measuring the young modulus of a solid sample.
  - » Measuring the Viscosity of a fluid.