RAP-Rivelazione Acustica di Particelle

Present Status and First Results

Laboratori
Nazionali
di Frascati

RAP Collaboration

S. Bertolucci, E. Coccia, S. D'Antonio, A.C. Fauth, A. de Waard,G. Delle Monache, D. Di Gioacchino, V. Fafone, A.C.Fauth, G. Frossati,C.Ligi,A. Marini, G. Mazzitelli, G. Modestino, G. Pizzella, L. Quintieri, F. Ronga, P. Tripodi, P. Valente

SIF 2004-Brescia

Lina Quintieri, 23 Settembre 2004

Nautilus Cosmic Ray veto system

In 1992 NAUTILUS was equipped with a cosmic ray veto system

Nucl.Instrum.Meth.A355:624-631,1995

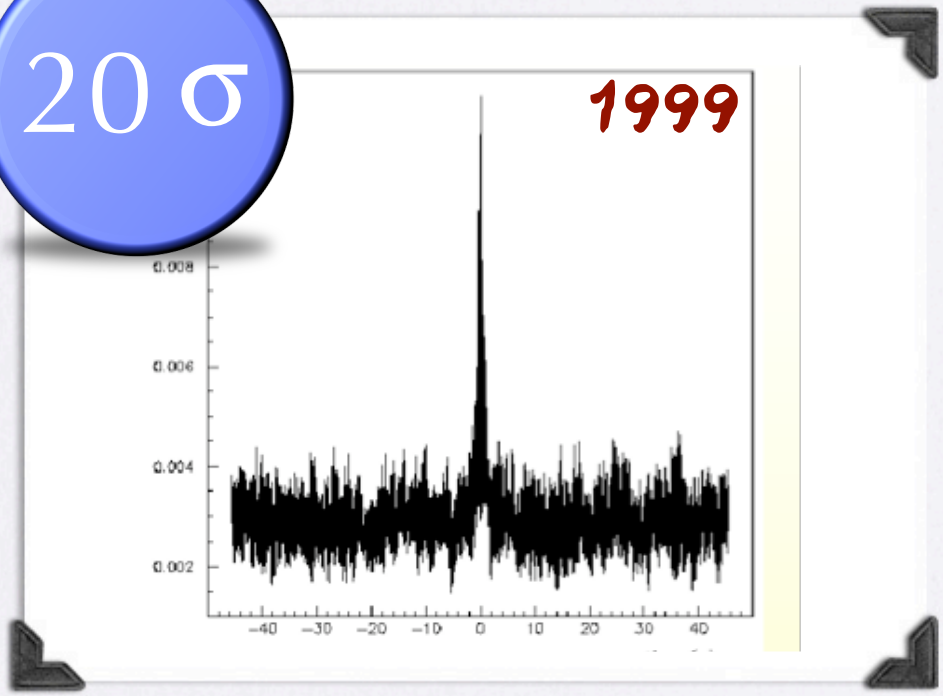
Streamer Tubes

- PVC-rectangular cells (8 per tube) with cross section 3X3 cm2
- Cu-Be 100μm diameter anode
- ΔV=5550 V
- Gas mixture:40%Ar+60% Isobuthane

The NAUTILUS G.W detector has recorded signals due to the passage of cosmic rays.

Thermo-acoustic Model

20 σ



RAP

Scientific Motivation

Phys. Rev. Lett. **84** (2000) 14.

Nautilus answer to 46 Showers with multiplicity

$M \geq 15 \cdot 10^3$ vs time

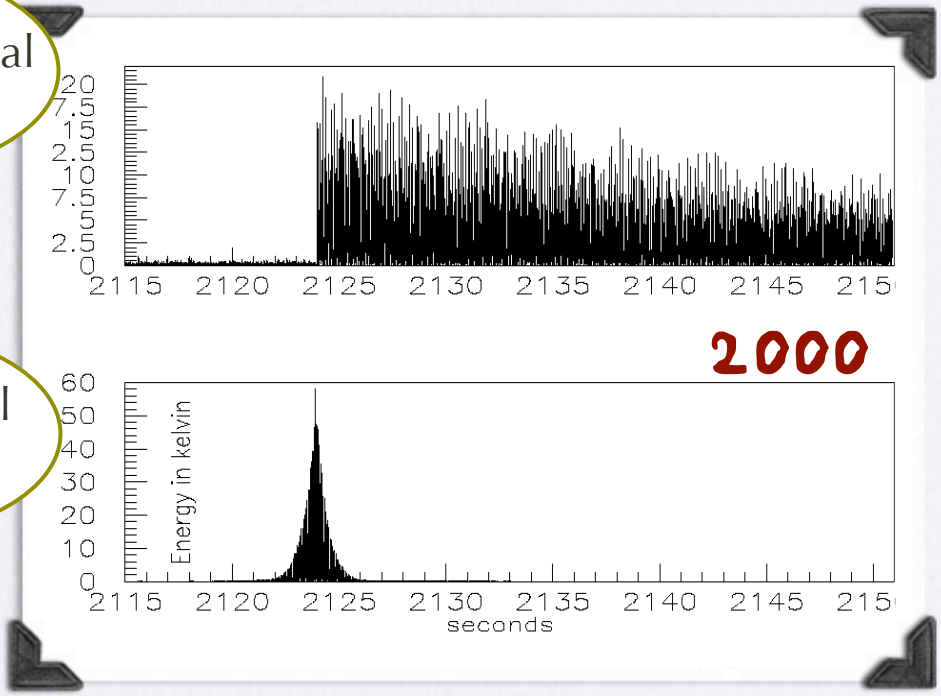
(zero @ time arriving of cosmic showers)

Large signals at higher rate than expected has been observed

~~Thermo-acoustic Model~~

Unfiltered Signal (V^2)

Filtered Signal (K)

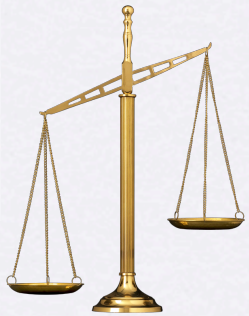


RAP

Scientific Motivation

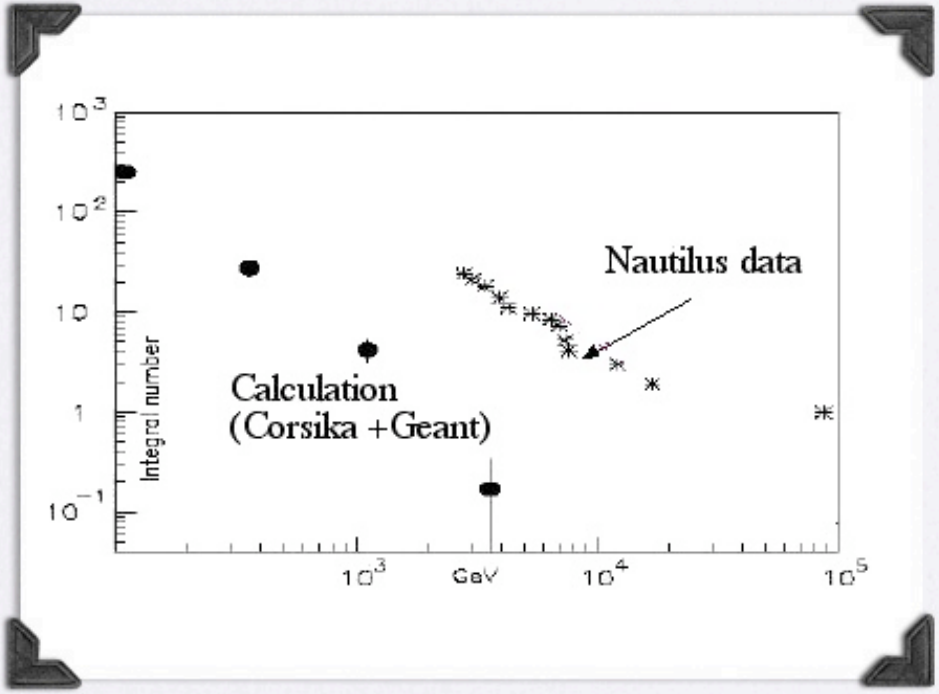
Phys. Lett. **B499** (2001) 16.

Time behaviour of the largest coincident Nautilus event



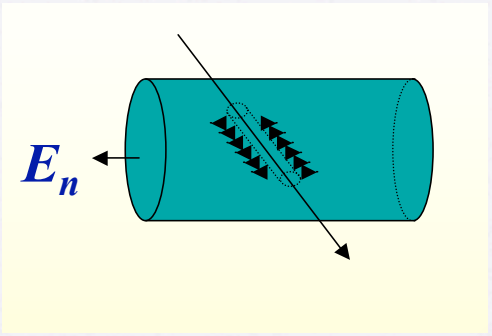
Anomalous Signals

Comparison between calculations and measurements



Hadrons + T.A.M unable to explain the data

Thermo-acoustic model



$$E \propto \left(\frac{dE}{dx}\right) \cdot G^2$$

Energy lost for ionization

Local Heating along the trajectory

$$dT = \frac{dE}{\rho C_V}$$

Local impulse of pression

$$dp = \gamma \frac{dE}{V}$$

Eccitation of natural modes

$$E_n = \frac{1}{2} \cdot \frac{l^2}{V} \cdot \frac{G_n}{\rho c_l^2} . \Sigma^2$$

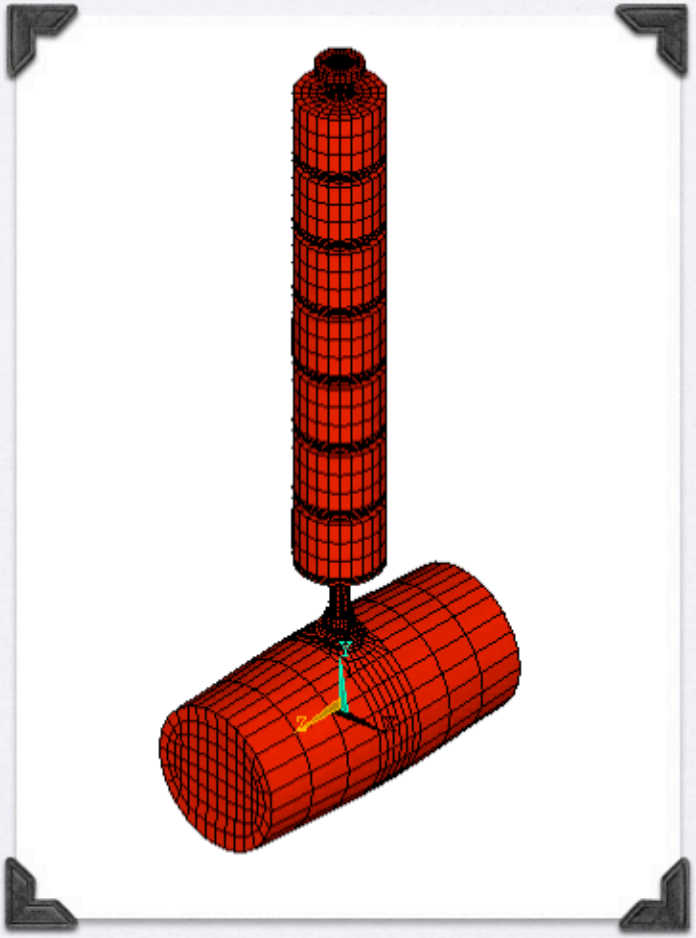
Thermo-acoustic model(2)

$$E_n = \frac{1}{2} \cdot \frac{l^2}{V} \cdot \frac{G_n}{\rho c_l^2} . \Sigma^2$$

$$\Sigma = \gamma \cdot \frac{dE}{dx}$$ → Source Term

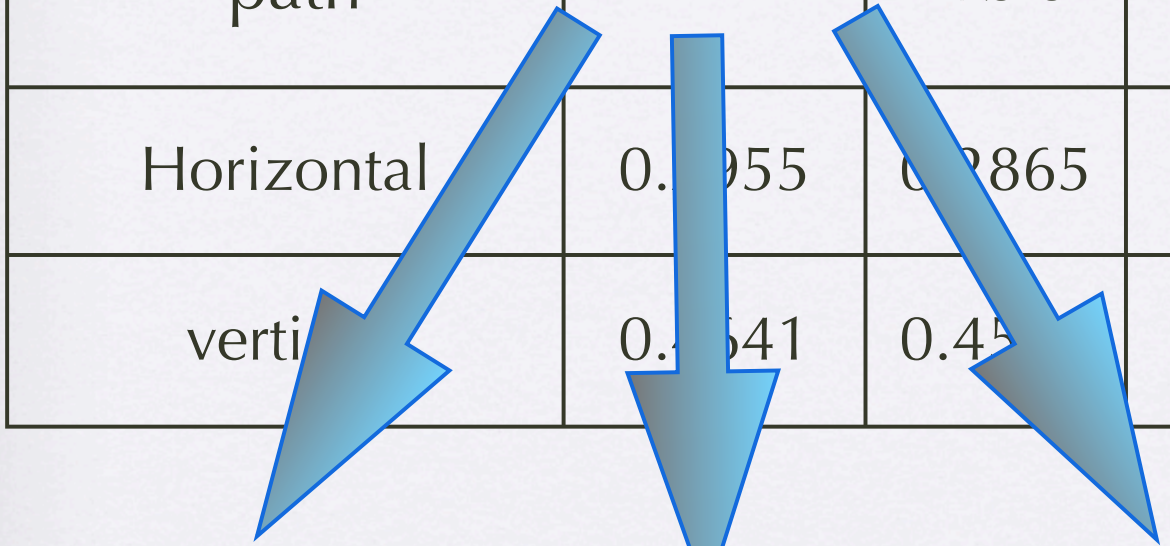
$$G_n \propto \int_l (\nabla \cdot \underline{u}) \; dl$$ → Shape Factor

$$\gamma = \frac{\beta \cdot k_t}{\rho \cdot C_V}$$ → Gruneisen Factor



The Shape Factor G_n: analytic and numerical estimation

First Longitudinal Mode			
path	ANALITIC	ANSYS	RATIO
Horizontal	0.[illegible]955	0.[illegible]8865	1.0314
verti	0.[illegible]541	0.45	1.0268



Torsional

$\nabla . u = 0$

Flexural

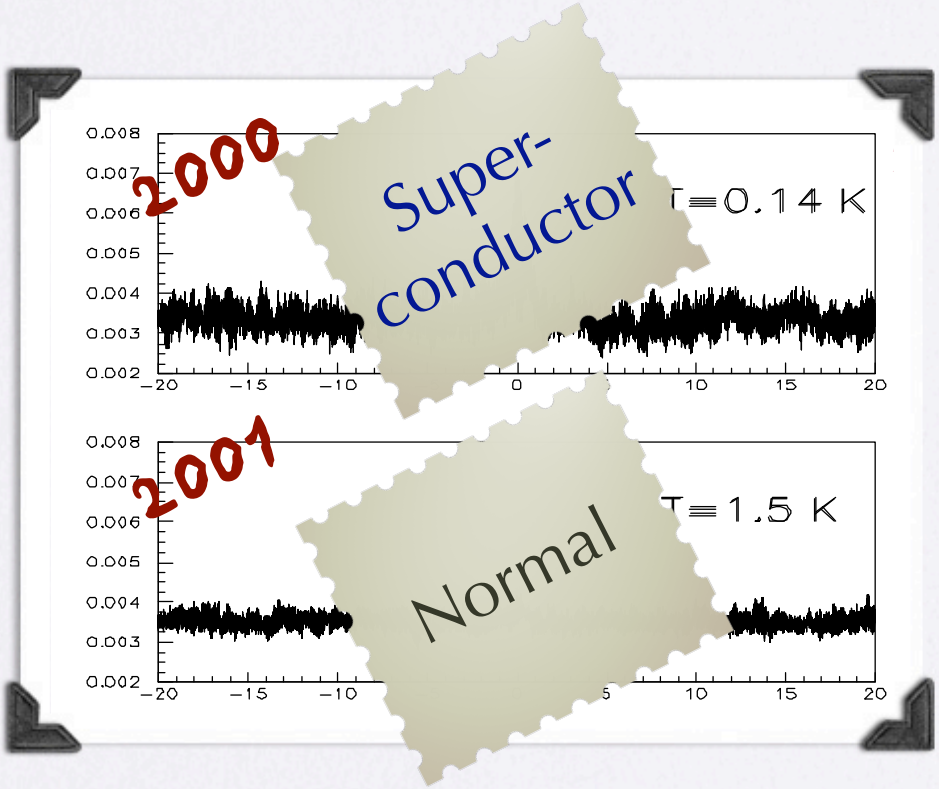
$\nabla u = B_n J_1(K_l r)\, cos\vartheta\, e^{i\gamma z}$

Longitudinal

$\nabla u = A_n J_0(K_l r)\, e^{i\gamma z}$

Why T.M.A doesn't work with 2000 data

Data vs Thermodynamic temperature



2001

Data collected again in agreement with T.M.A.

Why 2000 so special?

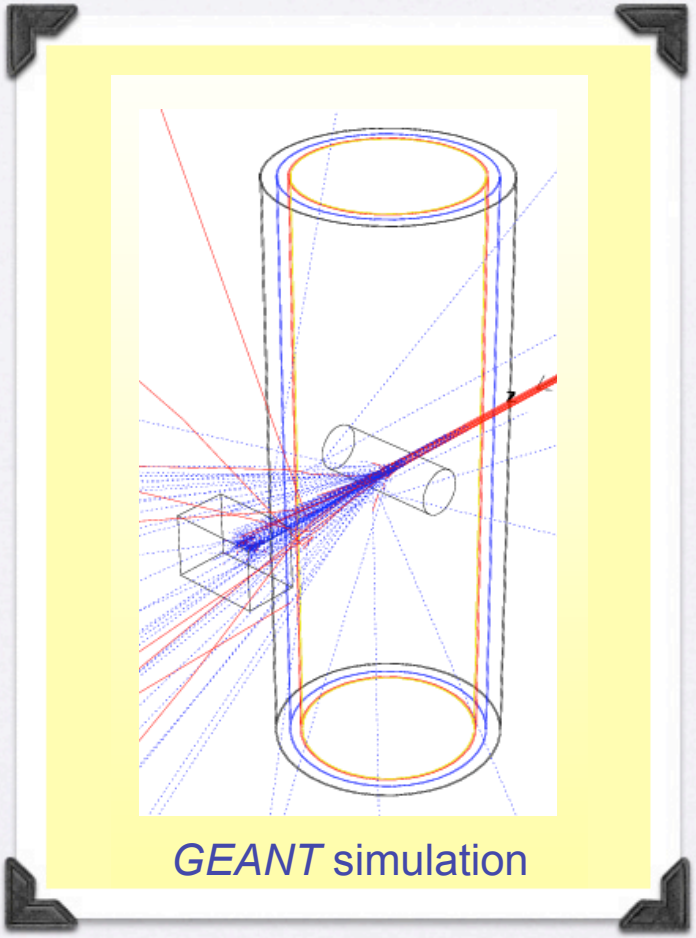
Incoherent hypothesis with Explorer's 2003 data

Feb-Jul 2000 ➪ 308 stretches
Mar-Sep 2001 ➪968 stretches
particle density>300/m^2

RAP PROPOSAL

Possibilities to explain data:

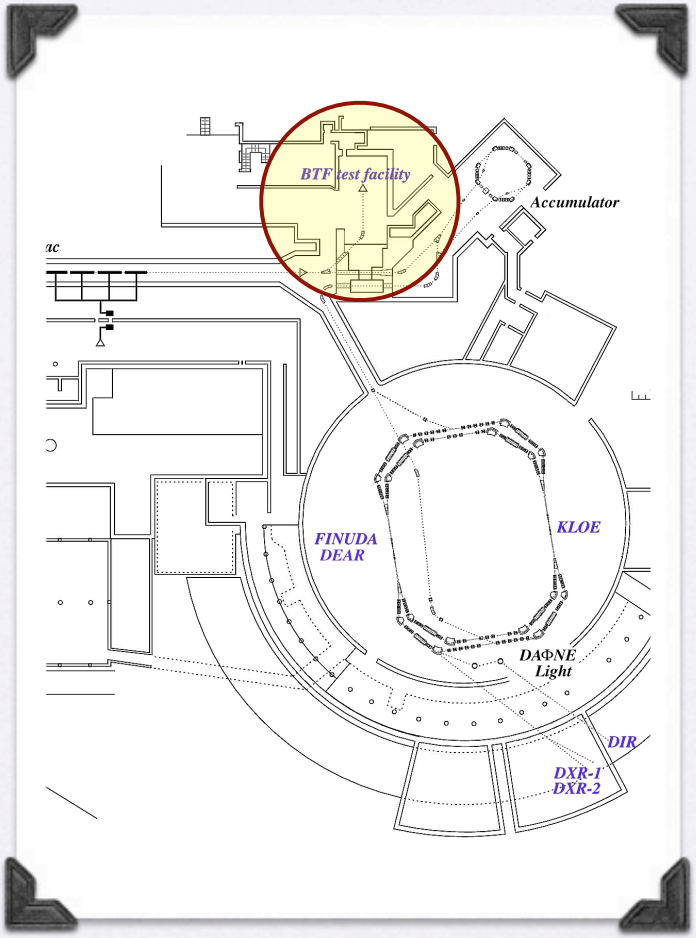
- Unexpected response of a possible metastable state of a massive superconductor to the passage of particles:
  - *Enhancement of* g *Grüneisen factor in super-conducting state*
  - *Enhancement of energy conversion* ***(dE/dx)*** *in super-conducting state*
- Something strange in the cosmic rays composition at the energy of interest (exotic nuclei, monopoles, etc).
- Creep phenomena: impulsive release of accumulate internal tension



DAΦNE Beam Test Facility

e^- | e^+

- n(average)=1-10^{10} particles
- Energy 20-800 MeV
- Repetition rate:50 Hz
- Pulse duration 1-10 ns
- 1% energy selection



BTF experimental hall 100 m^2

Experimental setup

The main component of the detector are:

- Mechanical structure needed to host and suspend the cryostat
- The cryogenic and vacuum system
- The suspension system
- The cylindrical test mass
- The read-out and DAQ

RAP Installation

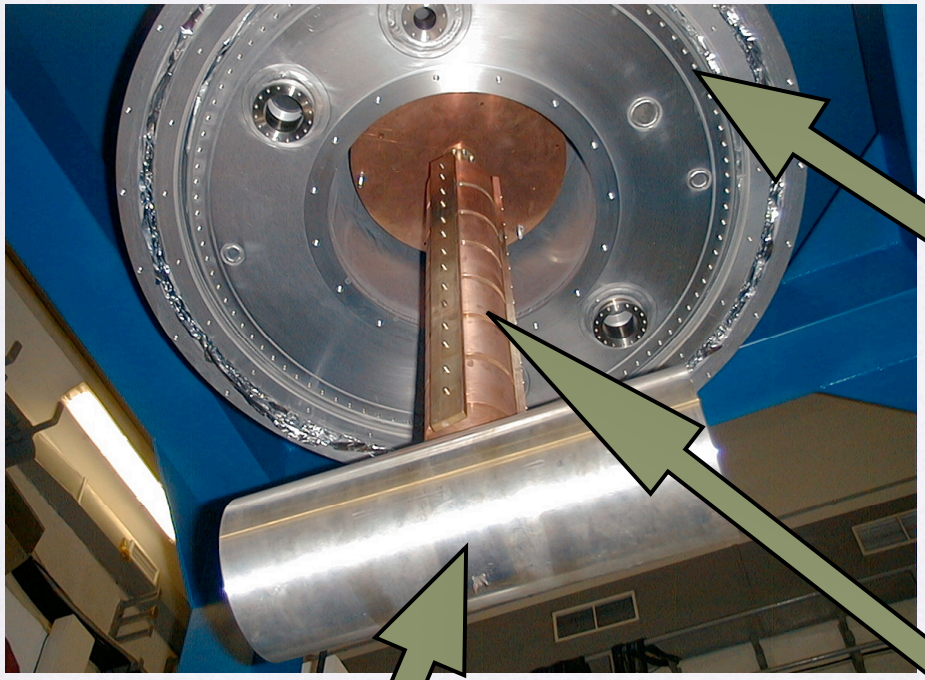
RAP installed @BTF in June 2003

Commercial Cryostat.

H=3.2 m

D=1 m

Suspension System, Test Mass, Cryogenic System



KADEL Liquid Helium Cryostat
+
Dilution Refrigerator
Working Temp: 100 mK

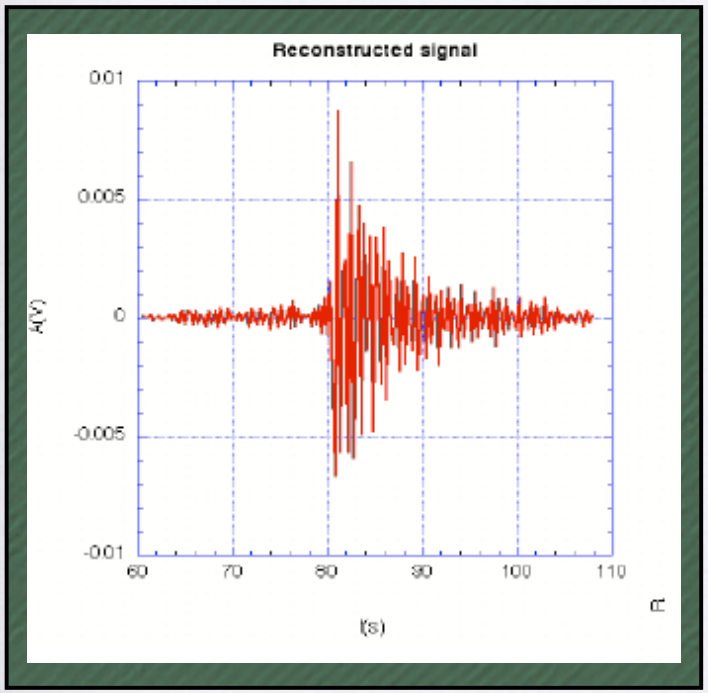
Suspension

7 OFHC copper masses
1 OFHC copper tube
Attenuation: –200db@ 5KHz

Test Mass

Material	Al 5056 bar
L	50 cm
Φ	18 cm
M	35.17 kg
f_{1L}	5096 Hz @ 300 K

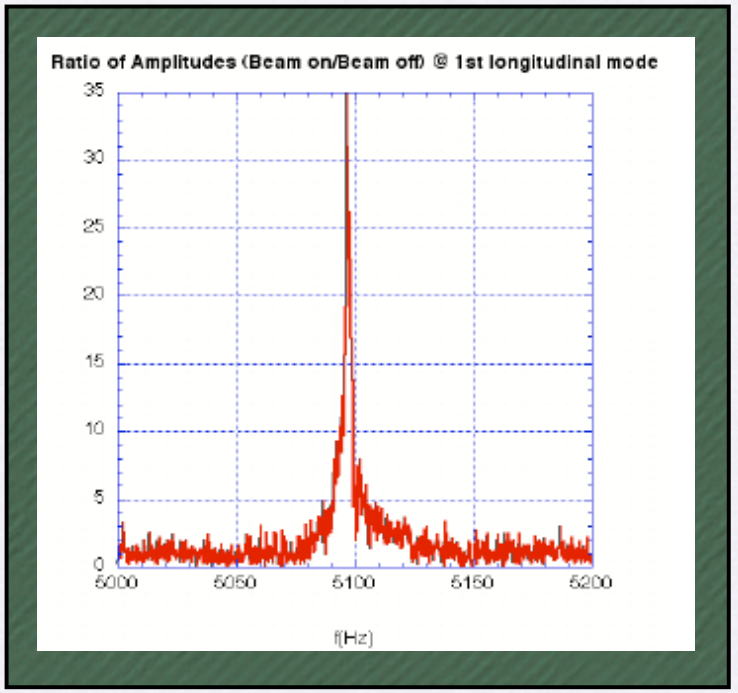
First run @ 300 K



$9.4 \cdot 10^{10}$ electrons @ 500 MeV

Energy released in the bar $1.7 \cdot 10^{-3}$ J

Amplitude of 1L mode $=4.13 \cdot 10^{-13}$ m

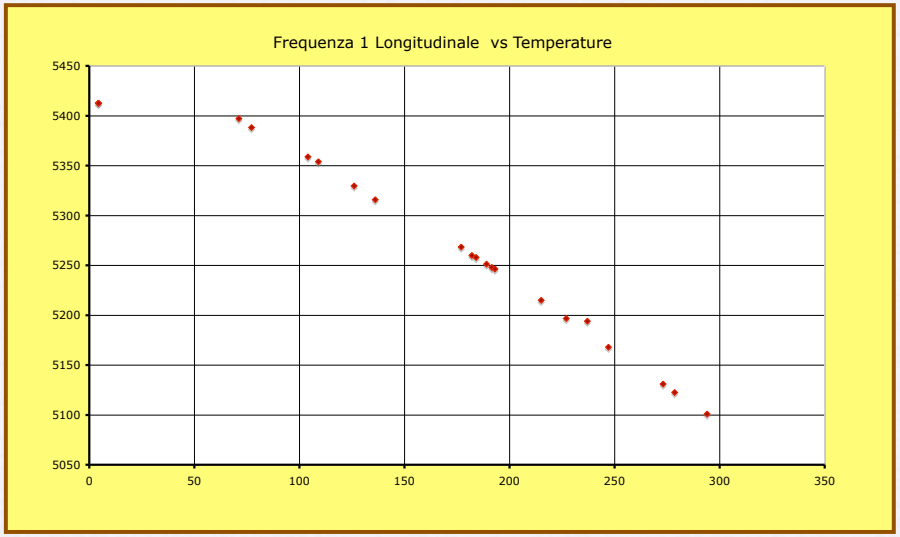


$$\frac{measurement}{theory} = 0.70 \text{ +/- } 0.11$$

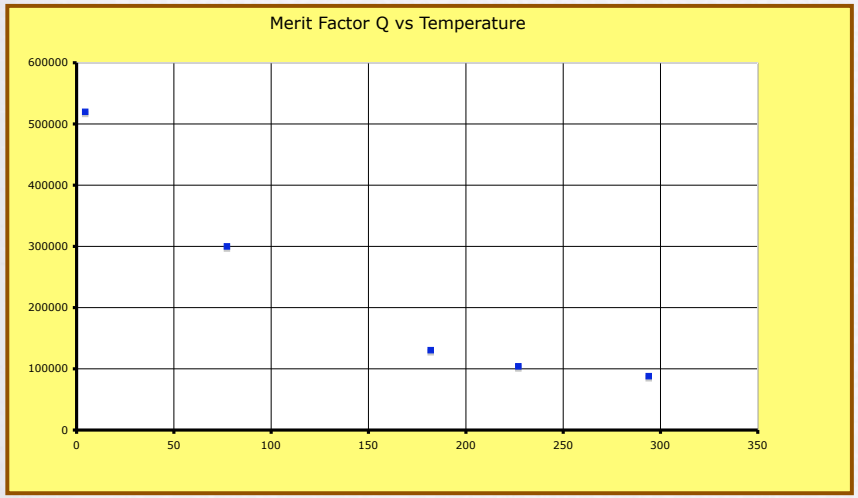
First Rap Cool-down

Date	Temperature
28/05/2004	300 K
5/06/2004	77 K
9/6/2004	8 K
10/6/2004	4.4 K
14/06/2004	77 K
17/06/2004	300 K

Frequency of first longitudinal mode

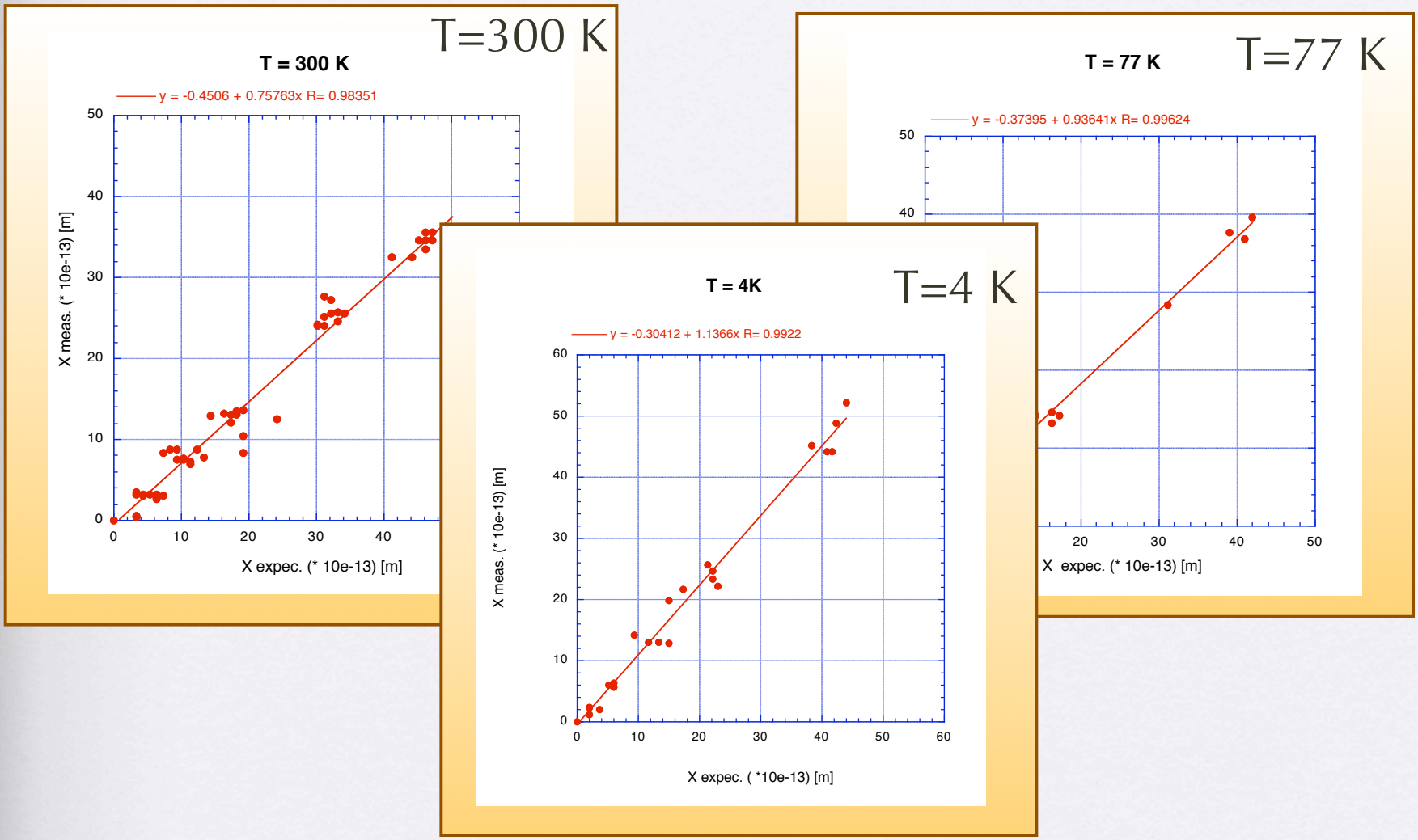


Merit Factor Q vs Temperature

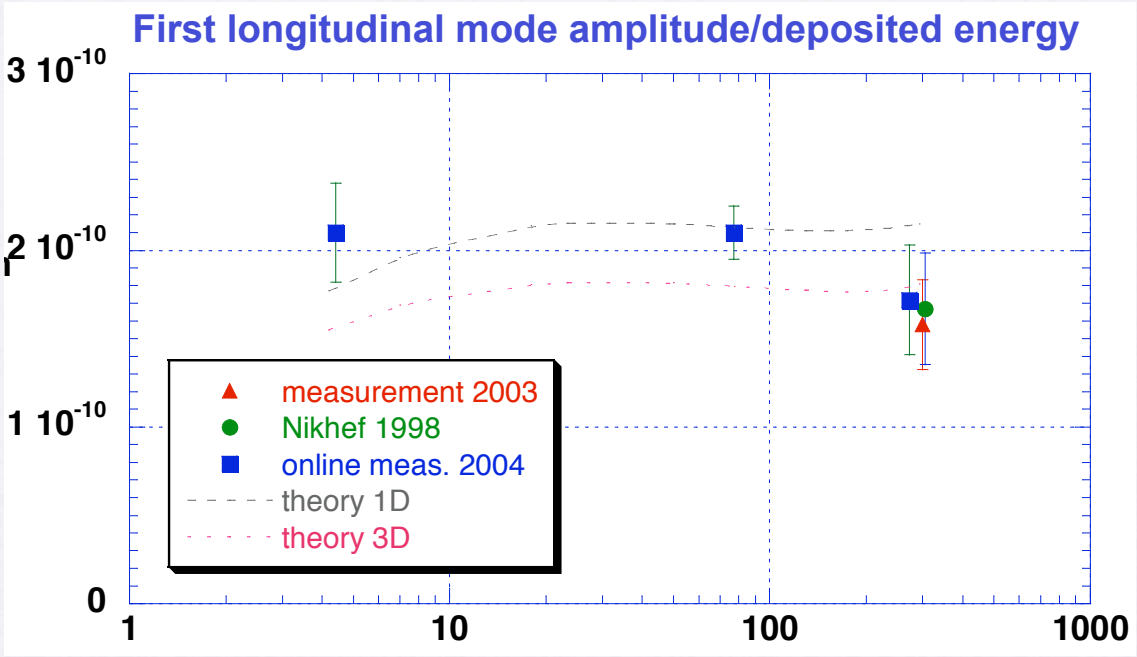


Data Analysis in progress

Correlation between the observed values (on-line S.A.)
and the predicted ones



Preliminary Comparison with other results



Temperature

Good agreement between 1D / 3D calculation results and measured values

Conclusion and future plans

Results:

First Measure @ low Temperature.
Good agreement with previous experiments (room temperature) and theory

Work in Progress:

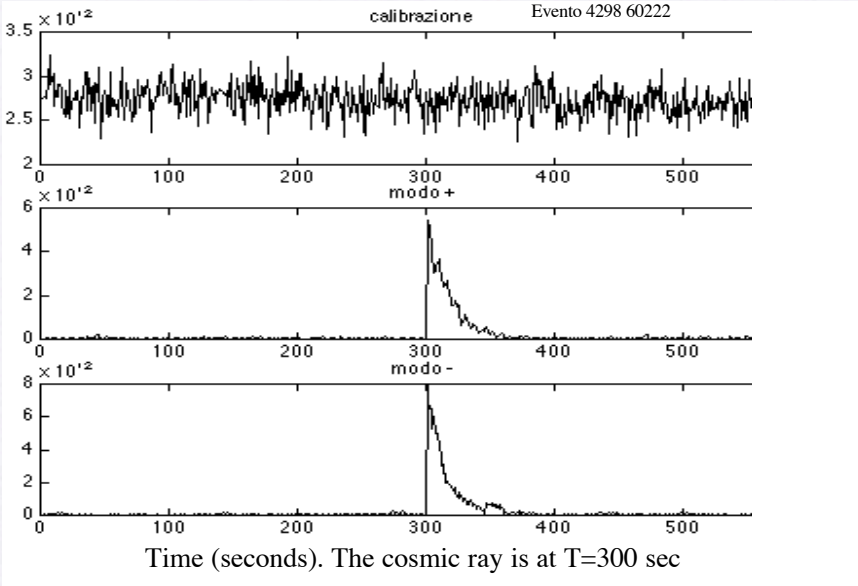
Filtering Optimization + accurate Data Analysis and Errors Evaluation

Future plan:

Installation and Measurement with Dilution Refrigerator in super-conducting state before end of 2005

Raw Data of the largest signal recorded

Mode energy [K]

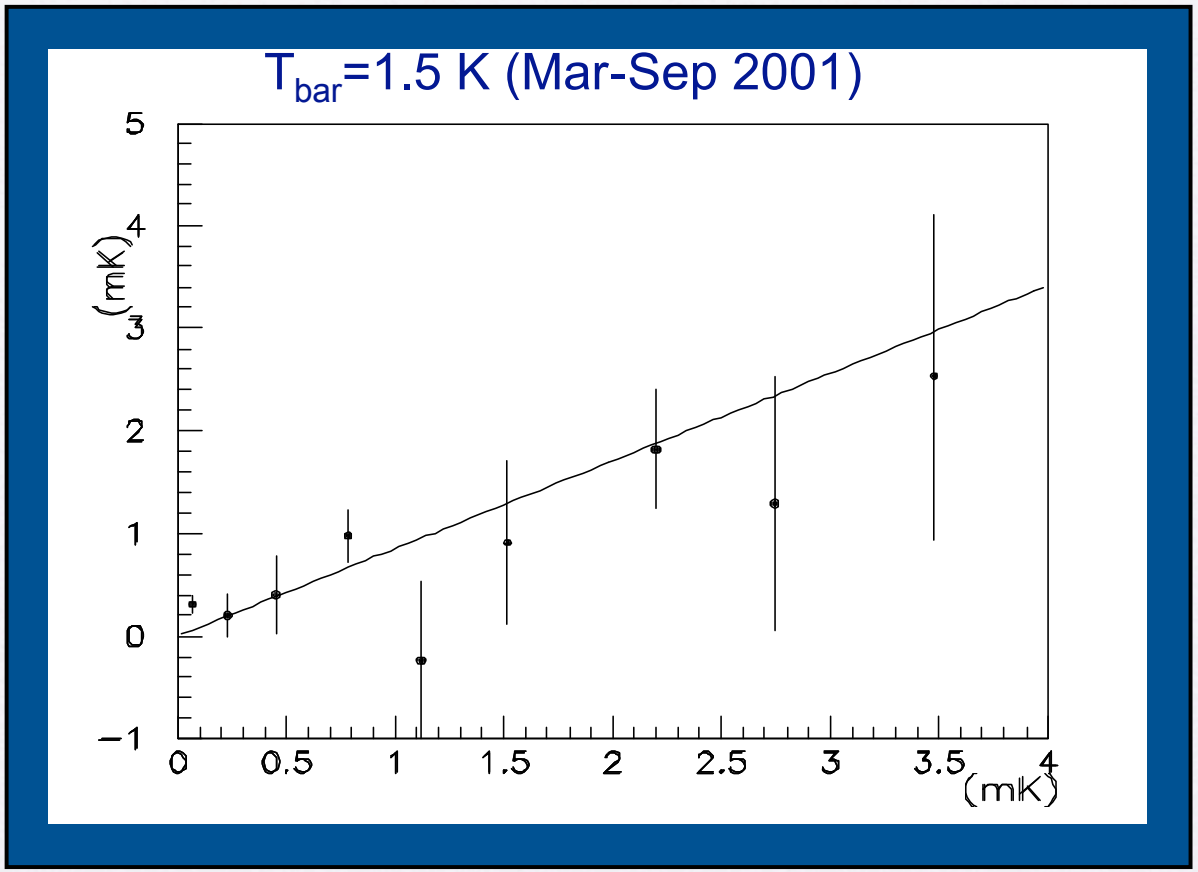


Time [s]

The Thermo-Acoustic model predicts very small signal signal for resonant gravitational wave @ present sensitivity

2001

Dependence on NAUTILUS thermodynamic temperature

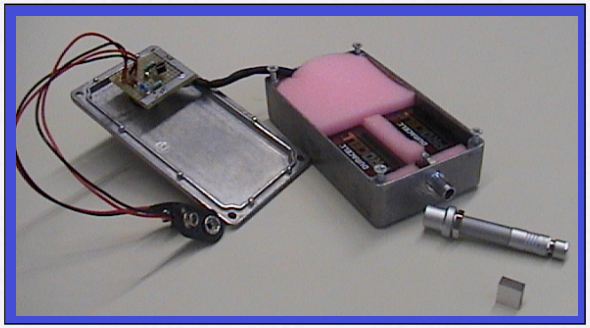


E_{obs}

E_{th}

RAP read-out system

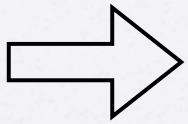
2 piezo-electric ceramics
(PZT24, 1cm^{2}x0.5cm)
embedded in the test mass



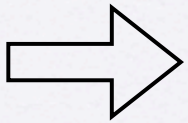
JFET amplifier
1nVHz$^{-1/2}$@ 5KHz
bandwidth 25KHz

Calibrazioni

Obiettivo:
determinare la costante di accoppiamento elettro-meccanio vs Temperatura

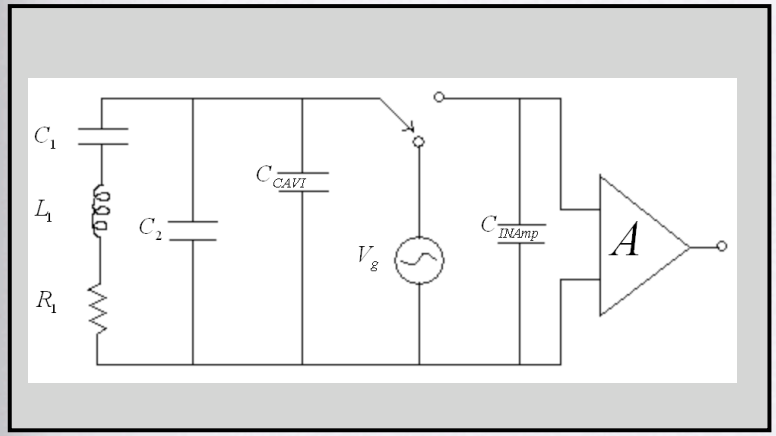


α



$$v(t) = \alpha x(t)$$

Circuito elettrico equivalente



C1= elasticità
L1= massa risonante
R1= dissipazione
C2= capacità del traduttore o piezoelettrico

$$\alpha = \frac{2\pi f_l}{C_2 + C_{cavi}} \cdot \sqrt{\frac{MC_1}{2}}$$

T=300 K	1.35e+10 V/m
T=77 K	1.5e+10 V/m
T=4.4 K	1.33e+10 V/m

Physics News Update
The American Institute of Physics Bulletin of Physics News

Number 465 (Story #3), January 7, 2000 by Phillip F. Schewe and Ben Stein

---

COSMIC RAYS OBSERVED BY GRAVITY-WAVE DETECTOR at the Frascati Laboratory in Italy consists of a 2300-kg aluminum cylinder cooled to a temperature of 0.1 K. The plan is that a passing gravitational wave (broadcast, say, by the collision of two neutron stars) would excite a noticeable vibration in the cylinder. NAUTILUS has not yet recorded any gravitational waves, but scientists have now witnessed the cylinder vibrated by energetic particle showers initiated when cosmic rays strike the atmosphere. The signal generated by the rays is believable because conventional cosmic-ray detectors surrounding the bar also lit up when they were struck by the particles. In effect the detector is able to discern a mechanical vibration as small as 10^{-18} meters, corresponding to an energy deposit as small as 10^{-6} eV. (Astone et al., *Physical Review Letters*, 3 January 2000; Select Article. Contact Giuseppina Modestino, modestino@lnf.infn.it, 011-39-694-032-756.)

One Physics Ellipse, College Park, MD 20740-3843
Email: aipinfo@aip.org Phone: 301-209-3100; Fax: 301-209-0843

Event Rate

~ 2 order of magnitude higher than expected

Energy

~ 2 order of magnitude higher than that one computed with the thermo-acoustic model