First result in low temperature regime of the RAP experiment

(acoustic detection of particles)

Rivelazione Acustica di Particelle

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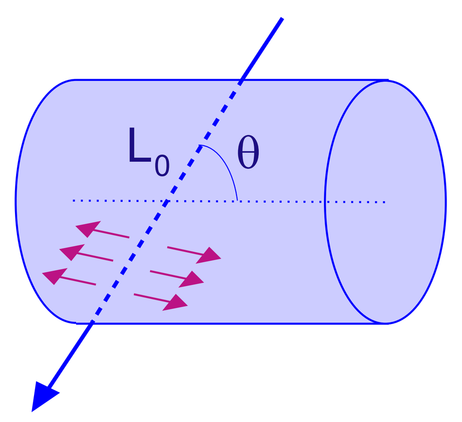
www.lnf.infn.it/esperimenti/rap

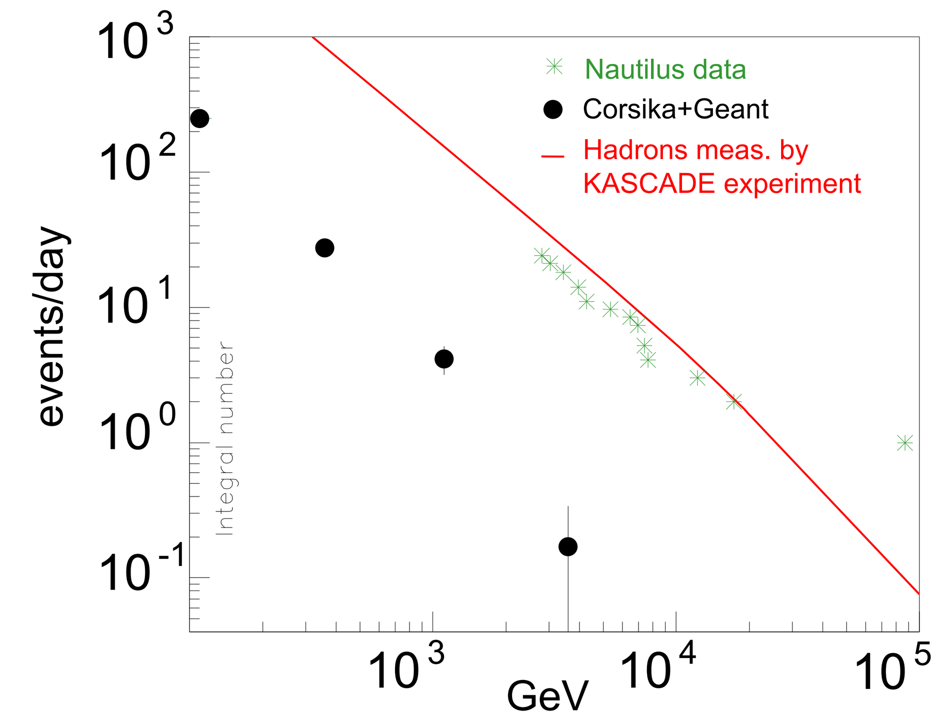
The results on cosmic rays detected by the gravitational antenna NAUTILUS have motivated an experiment (RAP) based on a suspended cylindrical bar, which is made of the same aluminum alloy as NAUTILUS and is exposed to a high energy electron beam. Mechanical vibrations originate from the local thermal expansion caused by warming up due to the energy lost by particles crossing the material. The aim of the experiment is to measure the amplitude of the fundamental longitudinal vibration at different temperatures. We report on the results obtained down to a temperature of about 4 K for an Al 5056 bar, which agree at the level of 10% with the predictions of the model describing the underlying physical process. Very preliminary results for a Niobium bar at temperatures below and above the transition temperature are also reported.



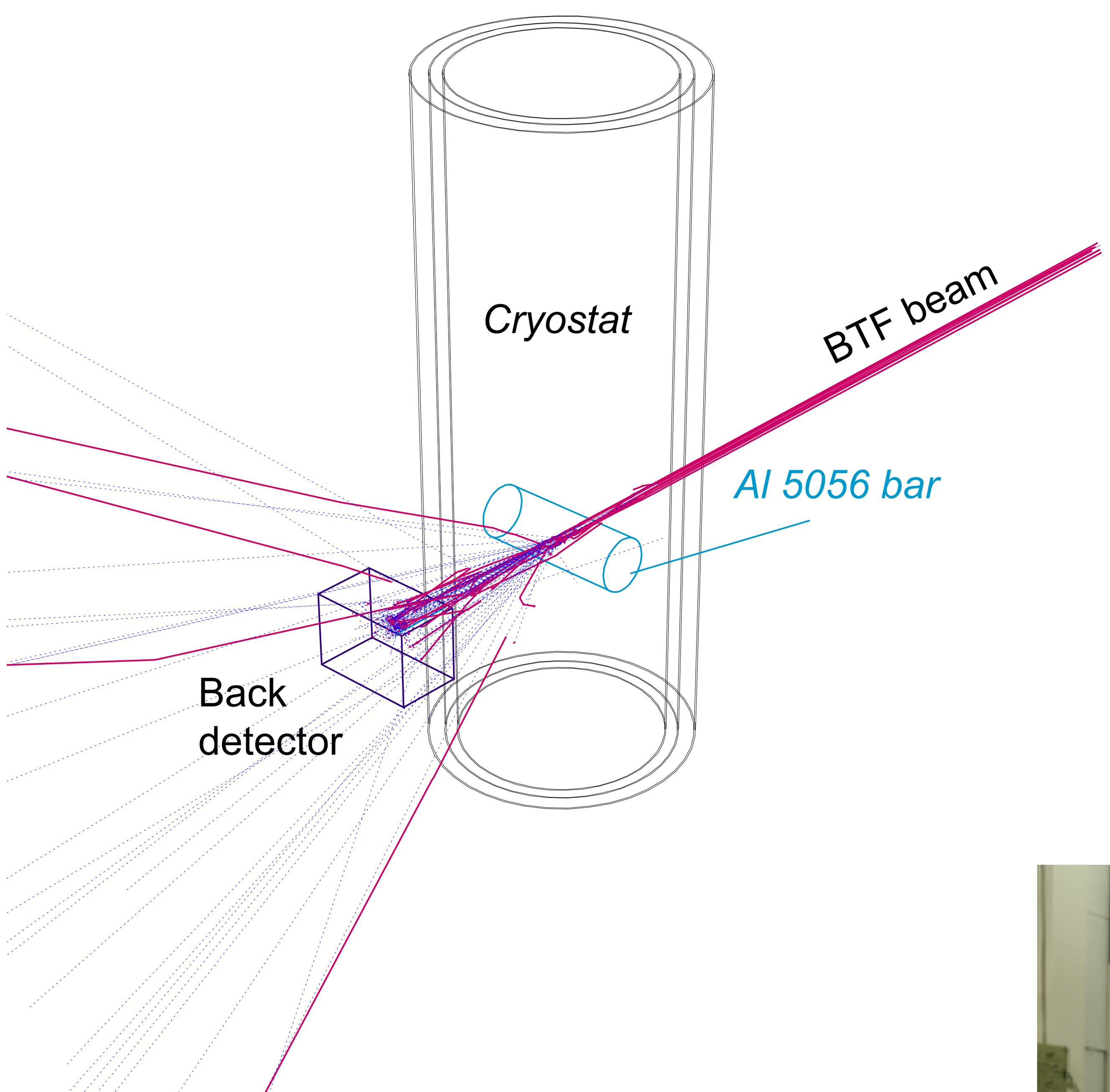
$$E_n = \frac{1}{2}\frac{L_0^2}{V}\frac{G_n}{\rho v^2}\gamma^2\left(\frac{dE}{dX}\right)^2$$

Thermo-acoustic conversion

The energy released by a particle crossing a material gives rise to local heating and thus to a mechanical tension leading to a pressure pulse. The phenomenon is characterized by the mechanical and thermal properties of the material, summarized in the Gruneisen parameter γ, the density ρ, the sound sound velocity v and a geometrical factor Gn.The energy released in the nth eigeinmode is proportional to the square of the energy loss. The Gruneisen parameter is related to the ratio of the thermal expansion coefficient to the specific heat of the material. Thermo acoustic model foresees a local transition of the medium so that normal state thermal expansion coefficient and specific heat should be used in the Gruneisen parameter. Uncertainty in the behavior of the Gruneisen parameter in the superconducting regime or presence in the cosmic ray shower of exotic particles are possible explanations of the anomalous signals obtained by NAUTILUS at ultra-low temperatures



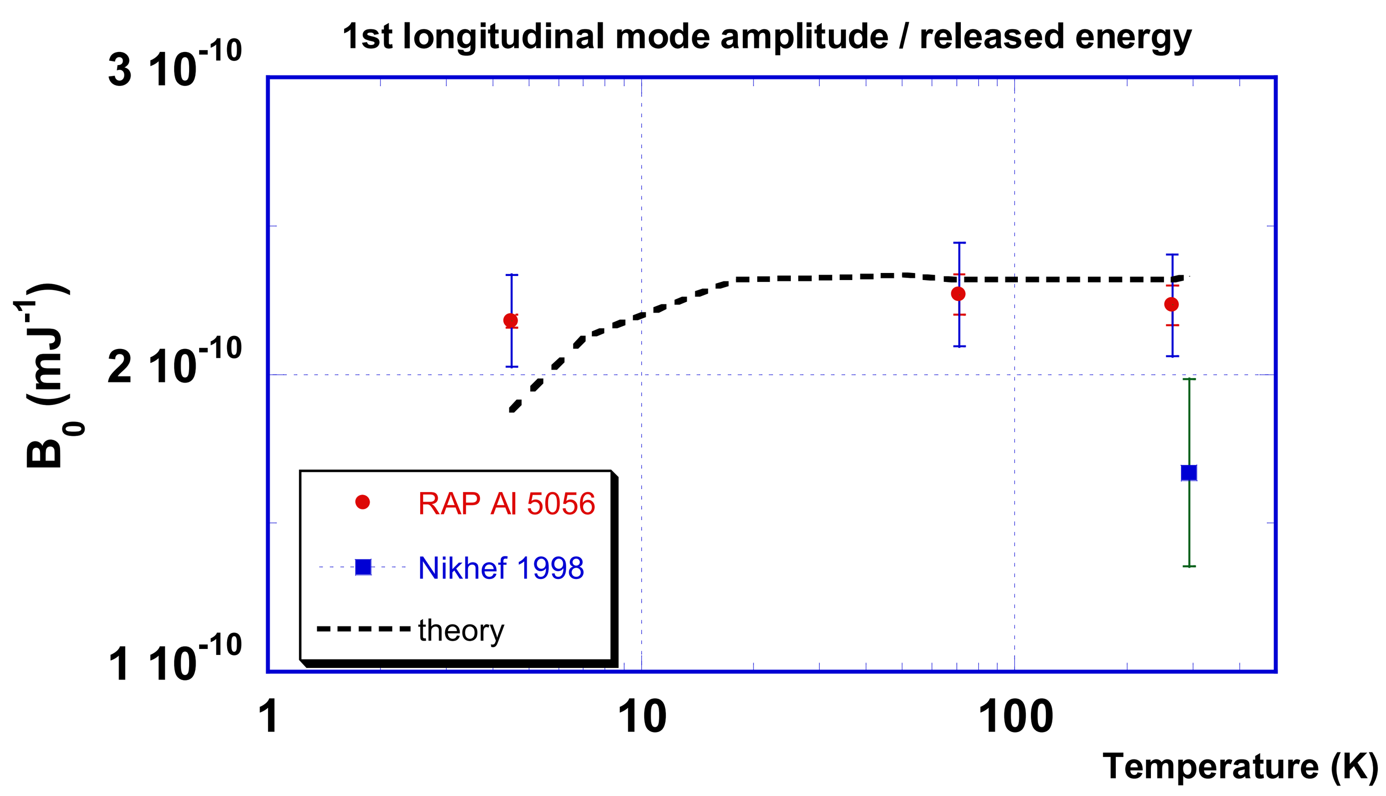
Measured data (green) of the hadronic component of the c.r. showers in the NAUTILUS antenna (superconducting) and expected data (black) from the thermo-acoustic model. Red line is the integral spectrum for the hadronic showers measured by KASCADE



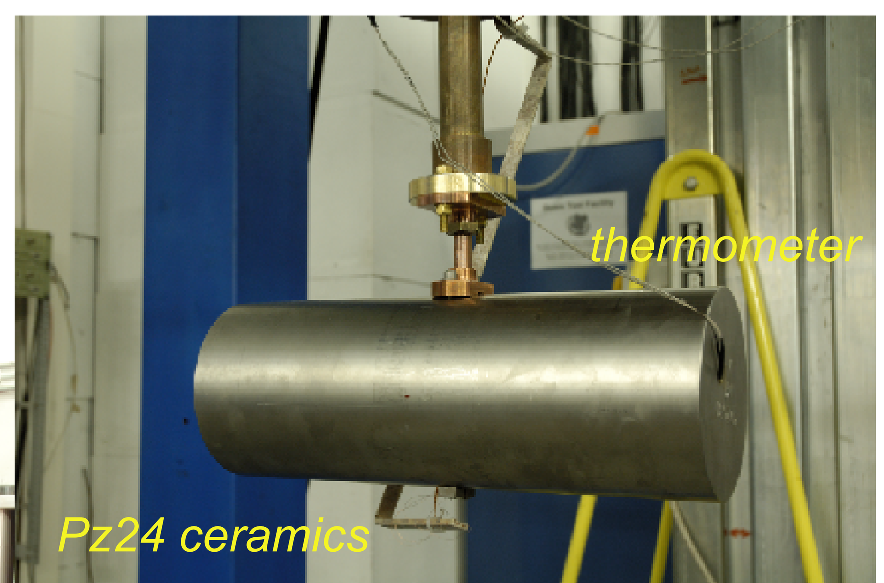
RAP Cryostat & mechanical structure

RAP cryogenic system

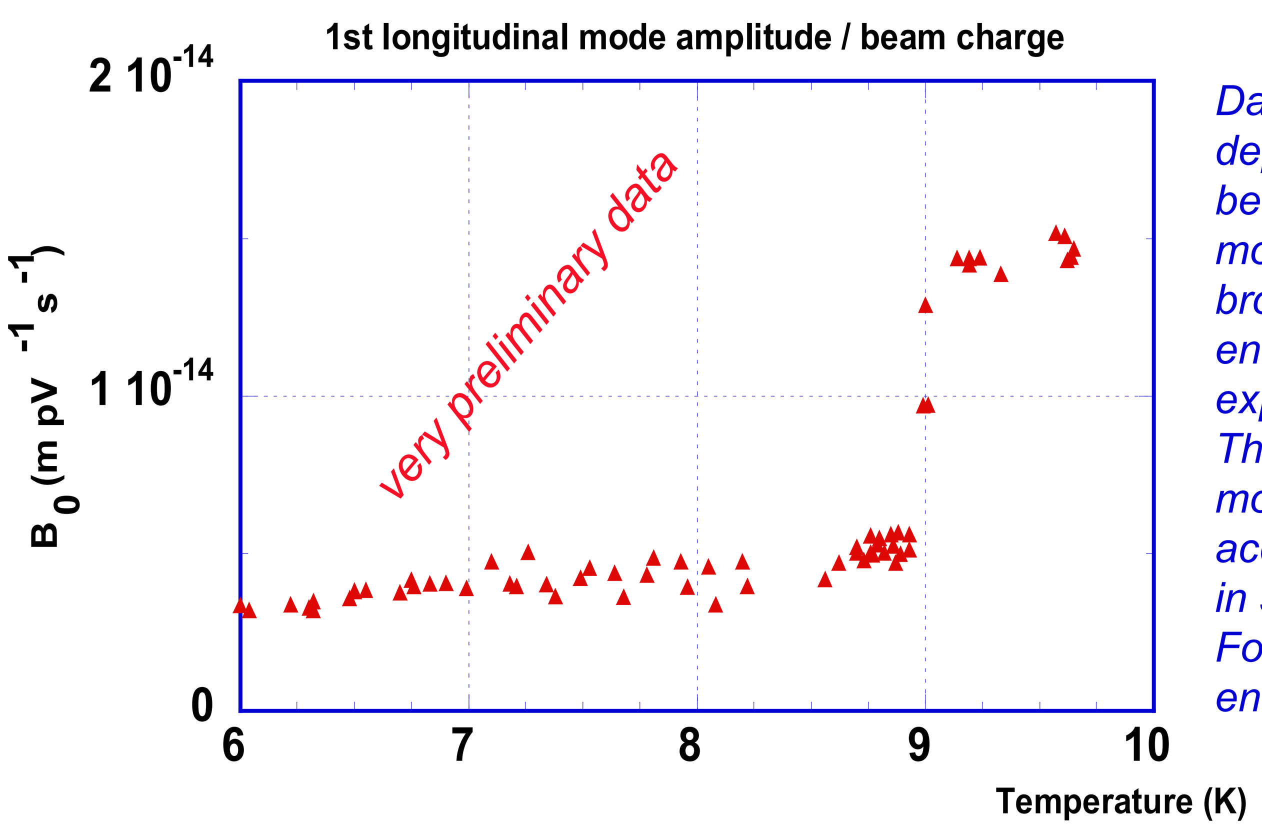
The RAP antenna is inserted in a commercial KADEL cryostat, that precools the experiment down to 4.2 K temperature using liquid helium.
The 100 mK final temperature will be provided by a continuous-flow 3He-4He dilution refrigerator, that at the moment is in construction.
The antenna is mechanically isolated from the cryostat, in order to minimize acoustic interference: detector and suspension are just connected to the top of the cryostat via three stainless steel cables.



Data are related to the 1st longitudinal mode of oscillation of the Al5056 bar. The plot shows that the experimental data are inagreement (within 10%) with the thermo-acoustic model. A systematic error of 7%, obtained from the quadrature of the beam monitor (3%) and calibration (6%) accuracies, affects the measurements.



Installation of Niobium bar at the DAFNE Beam Test Facility, May 2005



Niobium 1st longitudinal mode amplitude around the superconducting transition temperature, where the unexpected behaviour has been observed

Data clearly shows that the amplitude of the signal is depressed well below the transition temperature: this behavior is not foreseen by standard thermo-acoustic model, where is expected that superconductivity is broken by the increase of temperature due to the energy lost by particles and normal state thermal expansion coefficient and specific heat should be used. The depression of the signal is in agreement with a model where the Gruneisen parameters takes into account the thermodynamic properties of Niobium in superconducting state.
For aluminum in superconducting state an enhancement of the amplitude is expected.

The results we obtained for the maximum amplitude of the fundamental mode of longitudinal vibration of the bar are in good agreement with the expectations coming from the thermo-acoustic model describing the particle energy loss conversion into mechanical energy in the temperature range 270-4 K. This is the first time that experimental results on thermo-acoustic energy conversion in Al5056 are obtained below 270 K using our technique.
First measurements in superconducting state have been performed for a Niobium bar, showing that at last parameters for Niobium in superconducting state should be used.
RAP collaboration is ready to perform the last run below 1K with Al5056 bar in order to definitely explain anomalous NAUTILUS signals on cosmic rays.

AMALDI 6, June 20-24,2005 Bankoku Shinryoukan Kise Nago,Okinawa Japan