Rivelazione Acustica di Particelle

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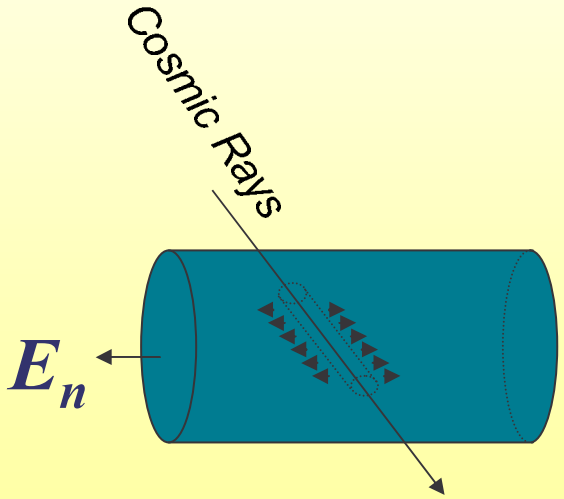
Carlo Ligi

Scientific Motivations

The NAUTILUS Gravitational Wave Antenna has recently recorded signals due to the passage of cosmic rays.
Large signals at higher rate than expected has been observed in the superconductive state of the antenna.

Thermo-acoustic model



CR crossing the antenna loss energy

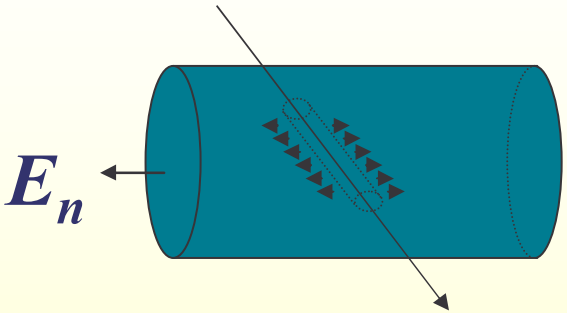
→ *warming up of the material*

→ *local thermal expansion*

→ *mechanical vibrations*

Scientific Motivations

Thermo-acoustic model



The energy deposited by a particle is converted in a local increase of temperature

$$\delta T = \delta E / \rho C_V V$$
$$\delta P = \gamma \delta E / V$$

$\gamma \equiv \beta V / \chi_T C_V$ *is the* ***Grüneisen parameter***

$$E_n \propto \gamma^2 \, (dE/dx)^2 \, F_n^2$$

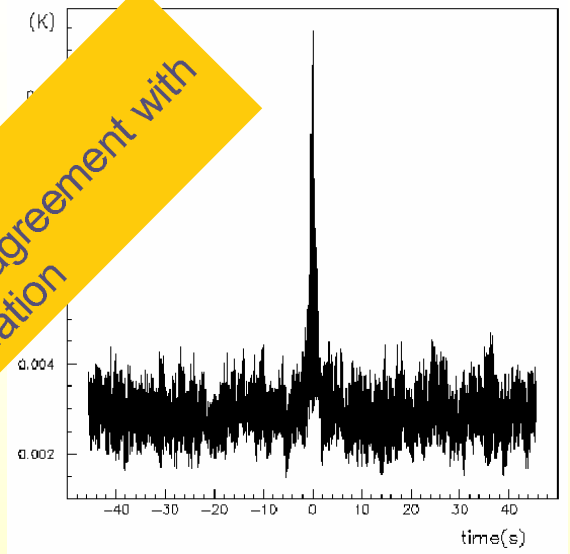
thermal and mechanical — *energy loss* — *Geometric factor*

The Thermo-acoustic Model predicts very small signal for present resonant gravitational wave detector sensitivity.
It has been proven effective at room temperature by previous experiments (Rev. Sci. Instrum. **71** (2000) 1345-1354 and previous papers)

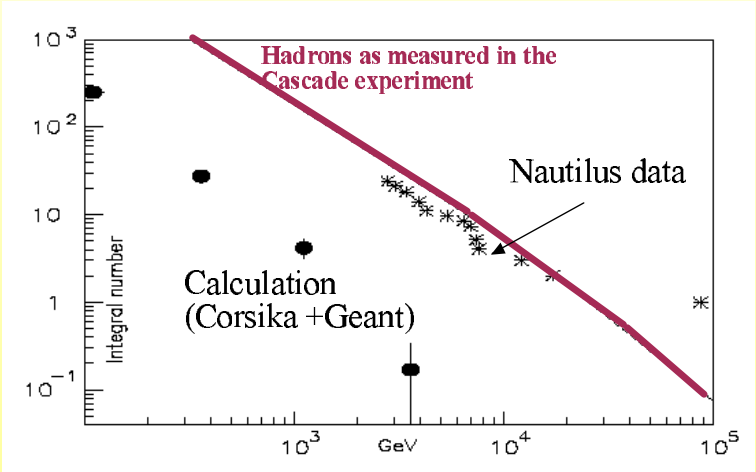
NAUTILUS Results

1999 first measurement of cosmic rays signature in the NAUTILUS antenna
Phys. Rev. Lett. **84** (2000) 14

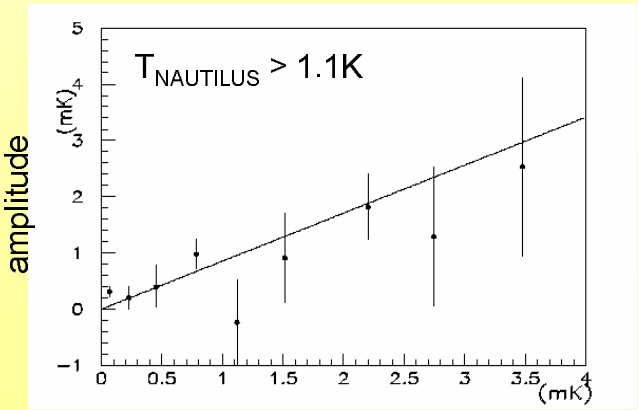
20 σ signal
Fully in agreement with calculation



2000 anomalous signal detected
Phys. Lett. **B499** (2001) 16



2001 dependence from NAUTILUS thermodynamic temperature
Phys. Lett. **B540** (2002) 179



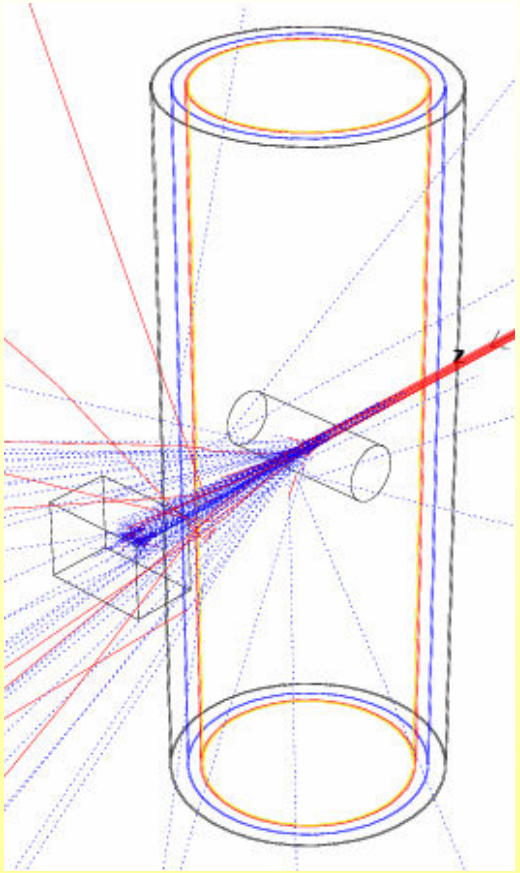
T.A.M. expected signal Induced by measured shower

(End of 2001) RAP Proposal LNF-01-027(IR)

In order to understand:

$$E_n \propto \gamma^2 \, (dE/dx)^2 \, F_n^2$$

- *enhancement of* γ *Grüneisen factor in super-conducting state*
- *enhancement of energy conversion* ***(dE/dx)*** *in super-conducting state*
- *exotic component of cosmic rays in* ***(dE/dx)*** *(nuclearites, monopoles)*



GEANT simulation

Grüneisen Parameter

$$\gamma \equiv \beta V / \chi_T C_V$$

Mechanical and thermal properties of the detector are contained in the Grüneisen parameter, commonly assumed almost constant with the temperature.
The extrapolated value at zero Kelvin from measurements done down to 4 K, gives: $\gamma = 1.6$

β *cannot be directly measured at temperatures below* T_C. *Recent evaluation based on critical magnetic field* $H_c(P,T)$ *measurements and specific heat gives a different value of the Grüneisen parameter in the super-conducting state. In particular at* $T = T_C$:

$$\gamma_s \sim -10$$

DAΦNE Beam Test Facility

e^- / e^+

$n_{average} = 1 - 10^{10}$ *particles*

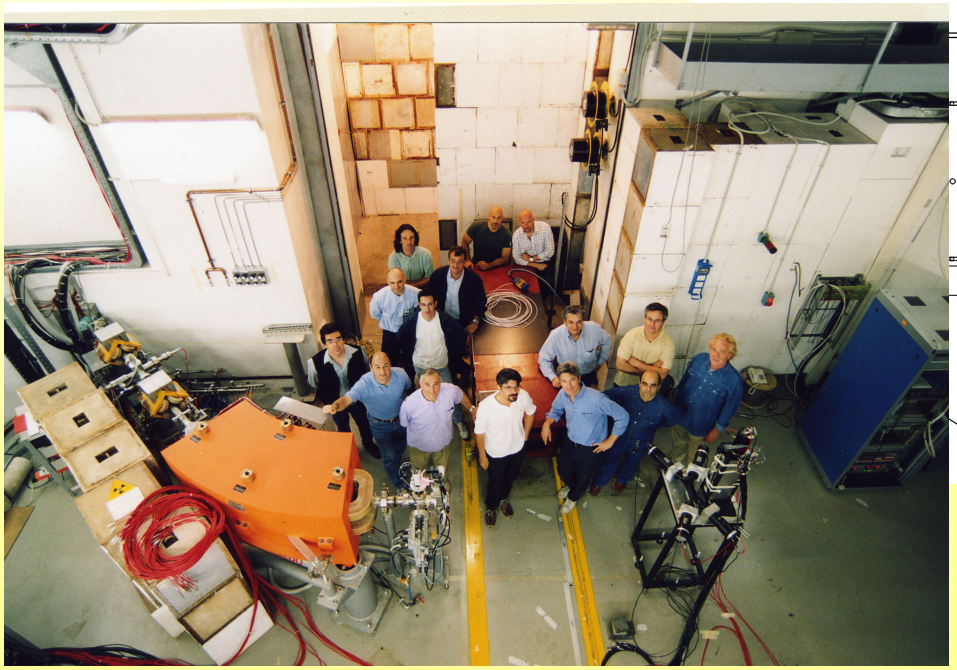
Energy: 20 – 800 MeV

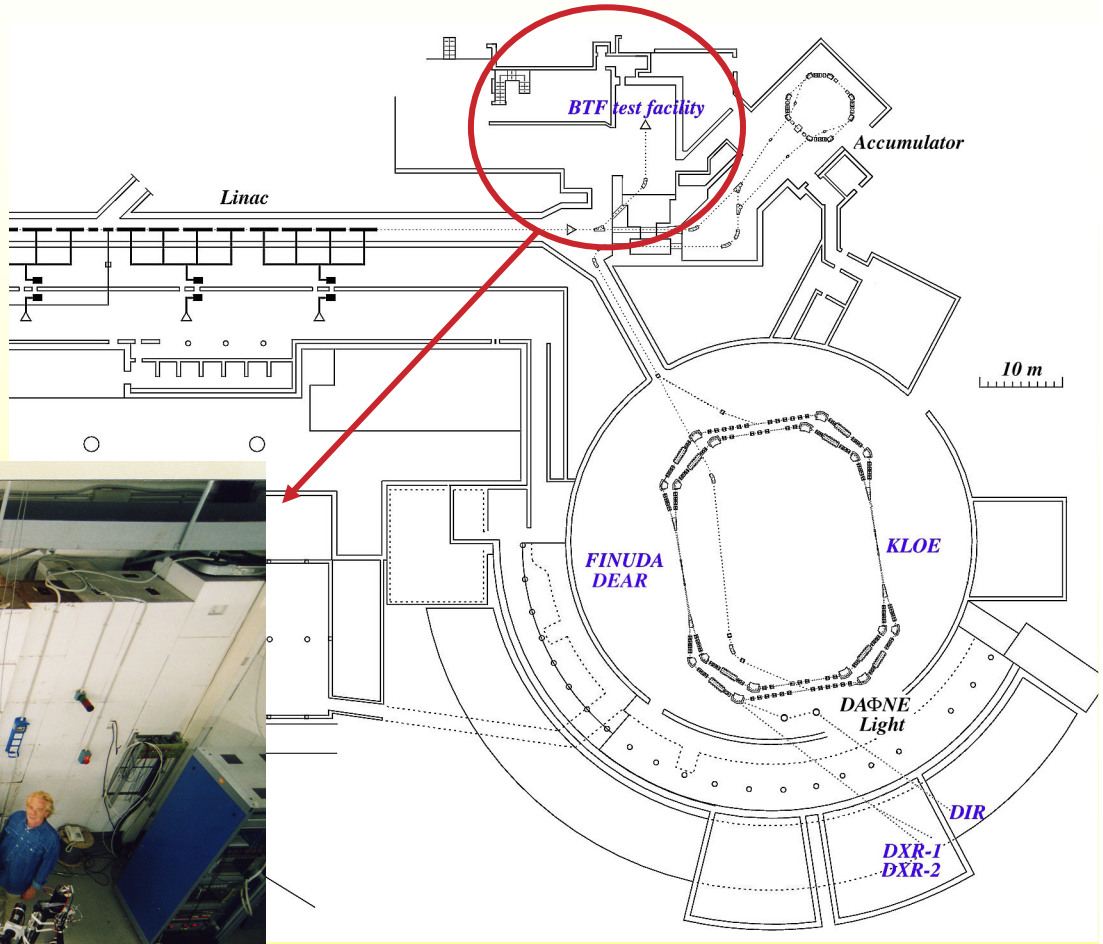
Repetition rate: 50 Hz

Pulse Duration: 1 – 10 ns

1% *energy selection*

100 m^2 *Experimental Hall*

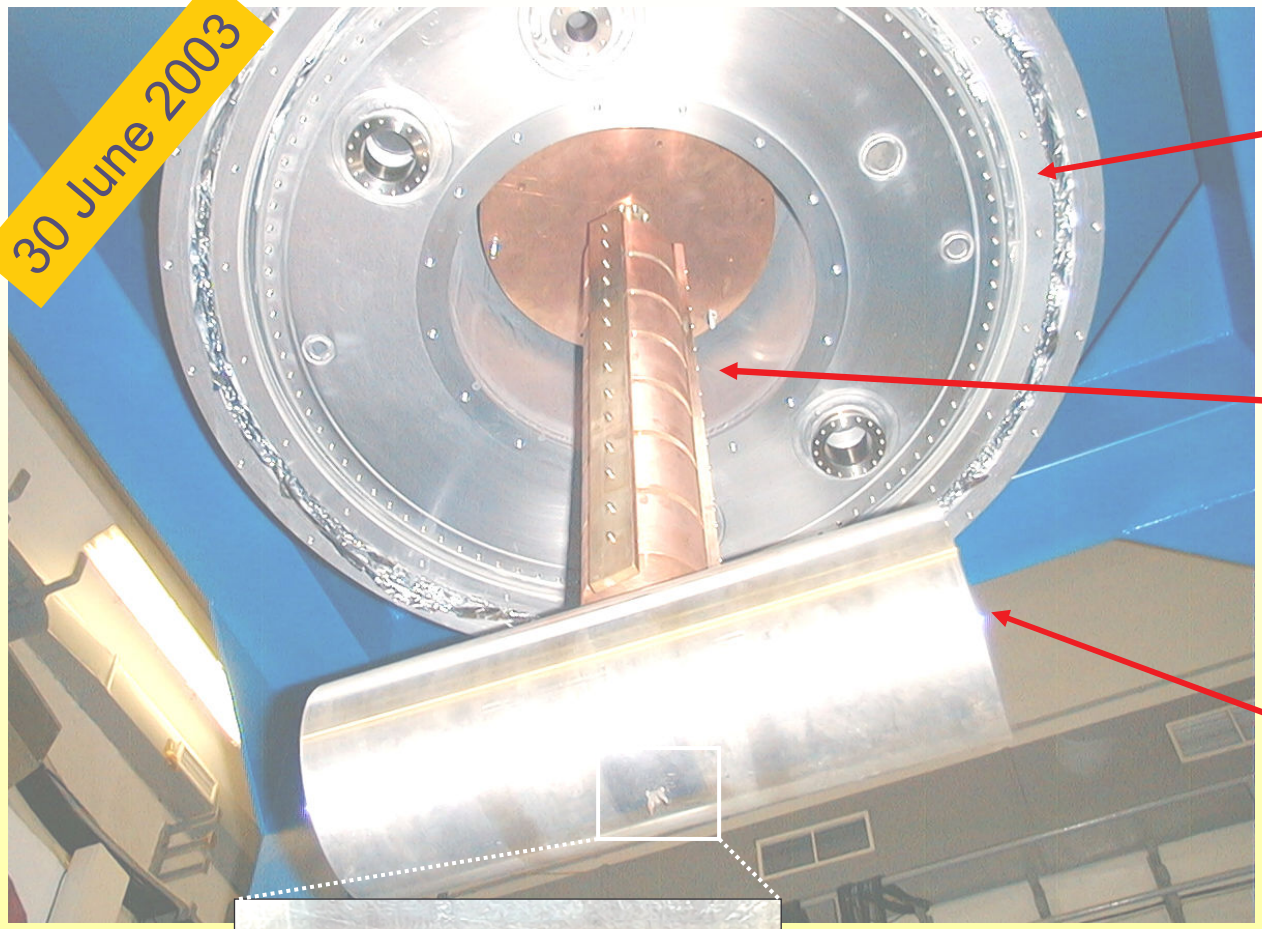




RAP Installation at the BTF

18 June 2003

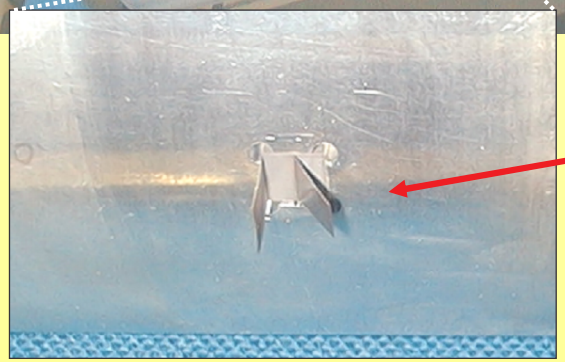
Experimental Setup



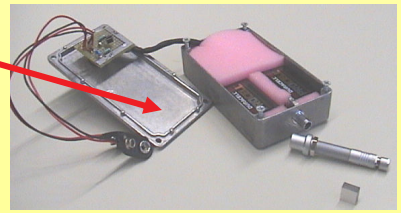
KADEL Liquid Helium
Cryostat + Dilution
Refrigerator
Working Temp: 100 mK

Suspension:
1 OFCH copper tube with
7 OFCH copper masses
Attenuation: -200db @ 5KHz

Antenna: Al 5056 bar
50x18 cm, 35 Kg
Res. Freq: 5096 Hz @ 300 K



Read-out: 2 piezo-electric
ceramics + JFET amplifier
1 nV $Hz^{-1/2}$ @ 5 KHz
bandwidth 25 KHz



Data Acquisition

LN-JFET-AMP
1 nV Hz $^{-1/2}$ @ 5 KHz
bandwidth 25 KHz

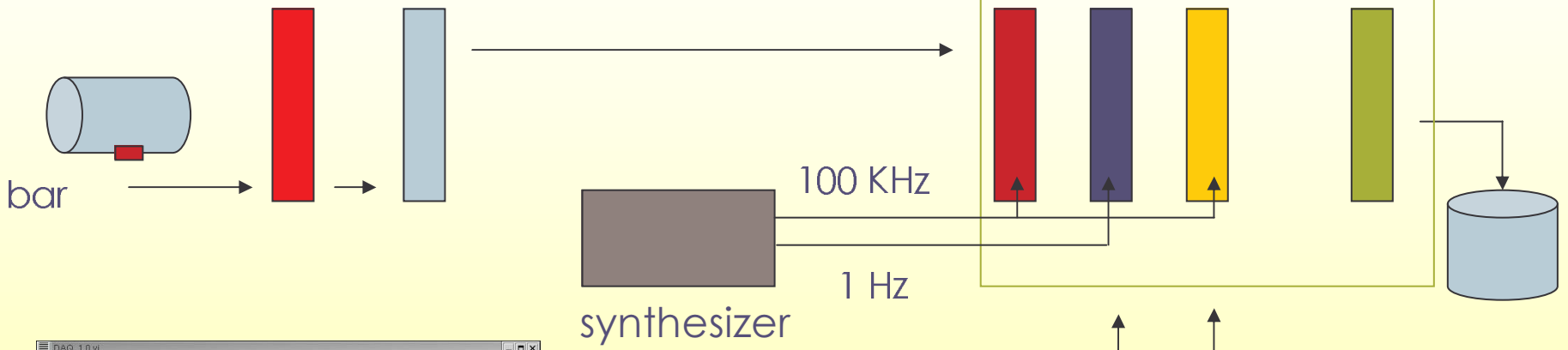
STANFORD
SR560 amplifier
4 nV Hz $^{-1/2}$

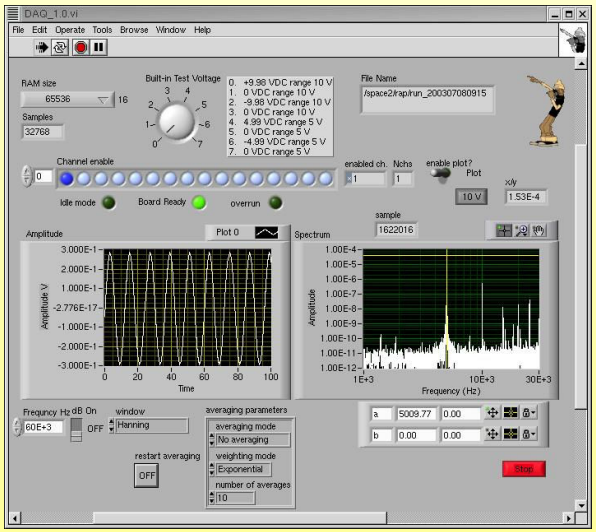
ADC VMIC 3123

ADC INCAA 5758

SCALER

LINUX VME
controller
VMIC 7740



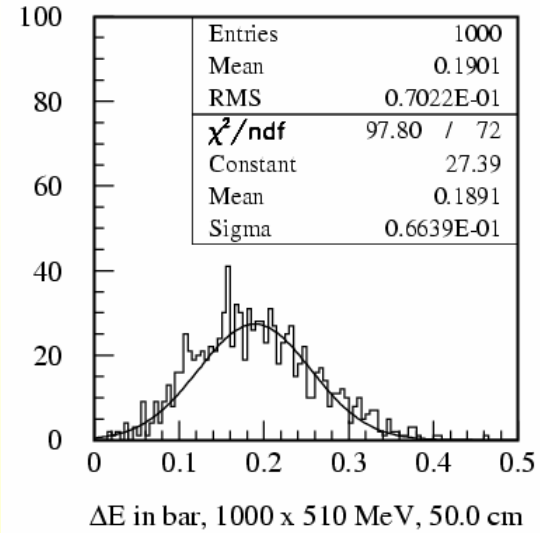


auxiliary channels

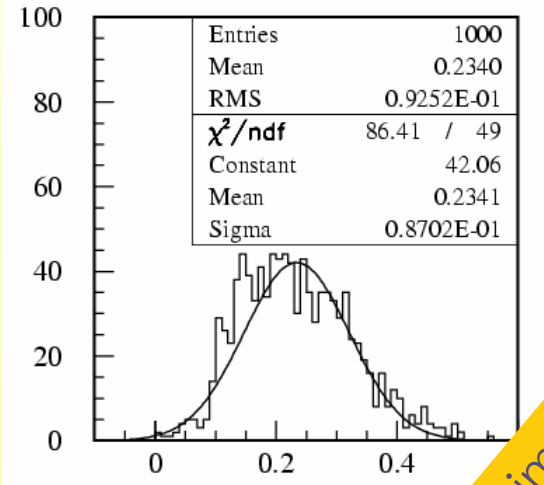
LabView™ run
controller & monitor

beam trigger

Expected Signal



ΔE in bar, 1000 x 510 MeV, 50.0 cm



ΔE in bar, 1000 x 750 MeV, 5

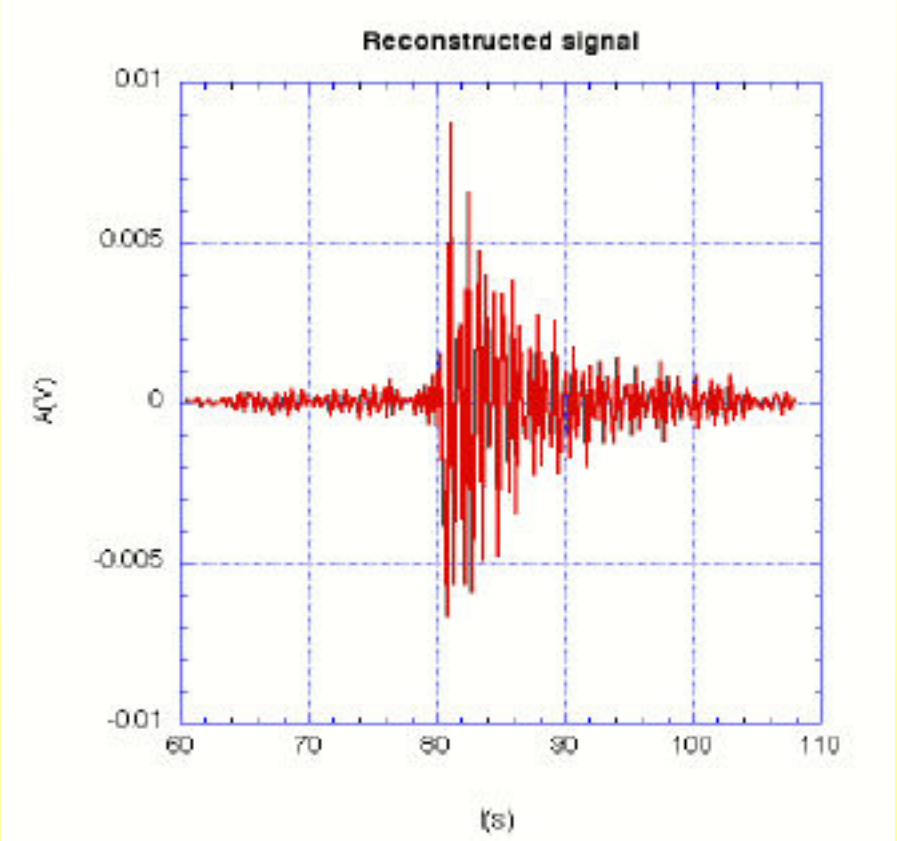
GEANT simulation

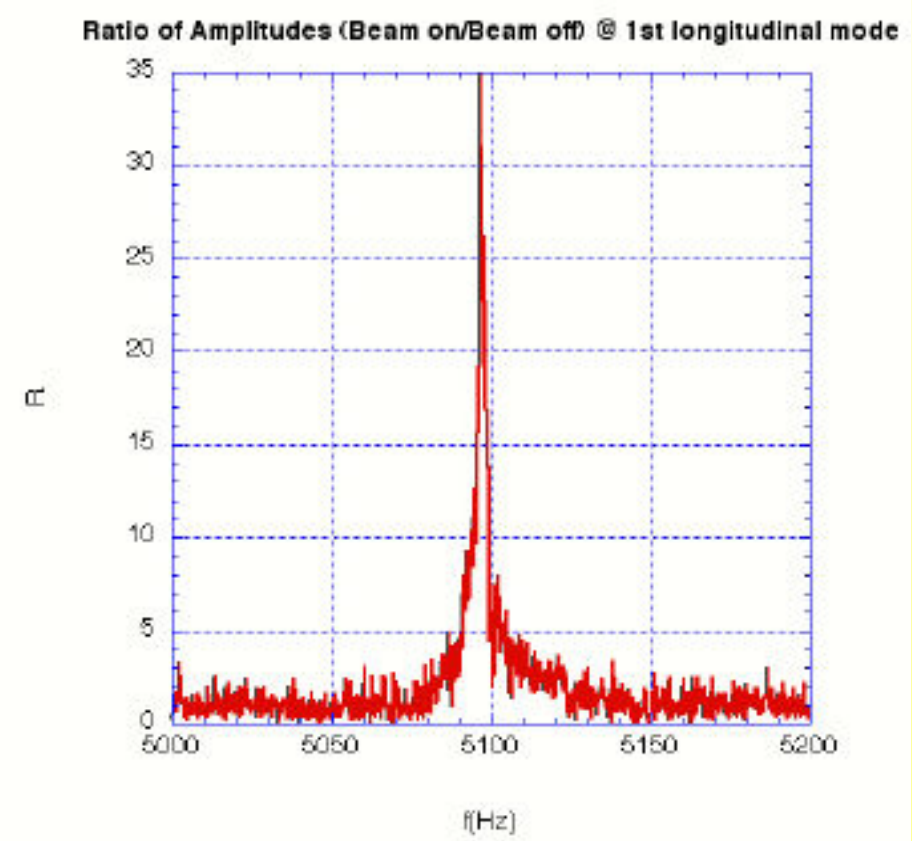
From 300 K to 100 mK

Phase 1: *installation and test of full apparata at room temperature, suspension, electronics, mechanical structure ready, first measurements at room temperature*

DONE !

9.4 10^7 electrons @ 510 MeV
Energy released in the bar = 1.8 10^{-3} J
Expected vibration in the 1L mode = 4.99 10^{-13} m





From 300 K to 100 mK

Phase 2:

- *cryogenic test*
- *low temperature measurement in normal-conducting state (4.2 K)*

(end 2003)

Phase 3:

- *dilution refrigerator installation*
- *measurement in super-conducting state*

(2004)

RAP on the WEB

www.lnf.infn.it/esperimenti/rap/