Rivelazione Acustica Particelle

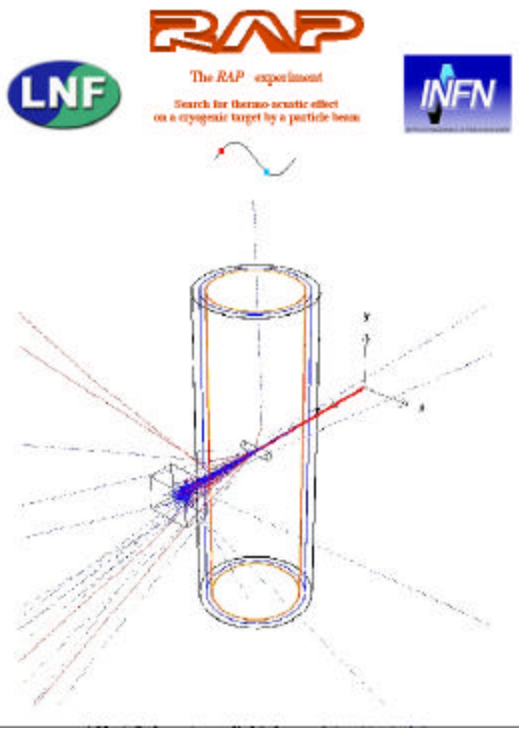
A bassa temperatura e in Superconduttori

Sommario

• Modello termo-acustico ed esperimenti precedenti

• Raggi Cosmici con rilascio di energia anomalo nell'antenna Gravitazionale Nautilus

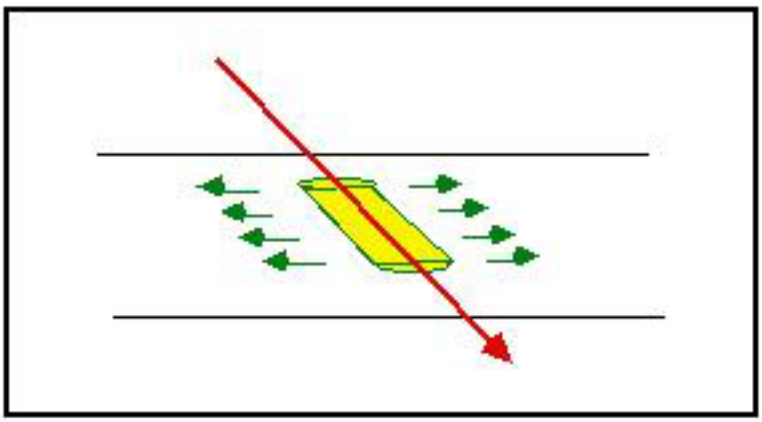
• La proposta al DA? NE Beam Test Facility



Cosmic ray in the bar:

Thermo Acoustical Conversion

under the hypothesis that all the ***deposited energy***, is converted in a ***local*** heating of the medium:



$$\delta T = \frac{\delta E}{\rho C V_0}$$

$$\delta p = \gamma \frac{\delta E}{V_0} \qquad \gamma = \frac{\alpha Y}{\rho C}$$

γ is the Gruneisen "constant"

C is the specific heat

Thermo Acoustical Conversion

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

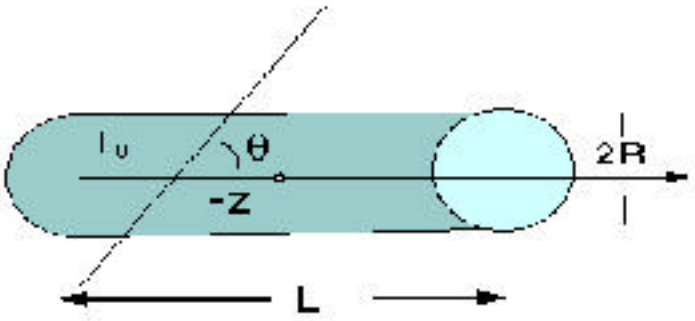
Allega A.M. & Cabibbo N. Lett Nuovo Cim 38 (1983) 263-

A. De Rujula & B. Lautrup, Nucl Phys. B242 (1984) 93-144

G_n form factor

in the case of a cylinder and at the first order in R/L (Barish-Liu Phys Rev Lett 61 1988)

$$T_{eff} = 2.75 * 10^{-9}\left(\frac{dE}{dX}\right)^2\left(\sin\left(\frac{\pi z}{L}\right)\frac{\sin\left(\frac{\pi l_0 \cos\theta}{2L}\right)}{\frac{\pi R\cos\theta}{L}}\right)^2$$



verified without the R/L<<1 condition and for non axial tracks by Babusci, Quintieri, Raffone with analytic and numerical methods (ANSYS)

Cosmic ray in the bar:

Thermo Acoustical Conversion

Pioneer work : Beron Hofstander piezoelectric disk on electron beam (Ph.Rev.Let. 23 184 (1969)

Sulak beam on water; of interest for neutrino astronomy (NIM 161 1979)

The model with the bar has been roughly checked in 3 experiments on a beam

1)Grassi Strini Tagliaferri (J. Appl Phys 51 1980)

2)Jona Oberski et al (Nikehf, Rev Sci Instr 2000)
measured conversion factor 7.4 ±1.4(nm/J)
theoretical 10.0

3)Bressi Carugno Conti Onofrio : no signal

Open question: is the Grunesein "constant" really constant ? (C==>>0) in superconductor Al

Local heating due to the ionization? Transition superconductor Al to normal?

Thermo Acoustical Conversion: The Nikhef experiment

- 0.76 GeV electron beam 0.01 Joules/burst

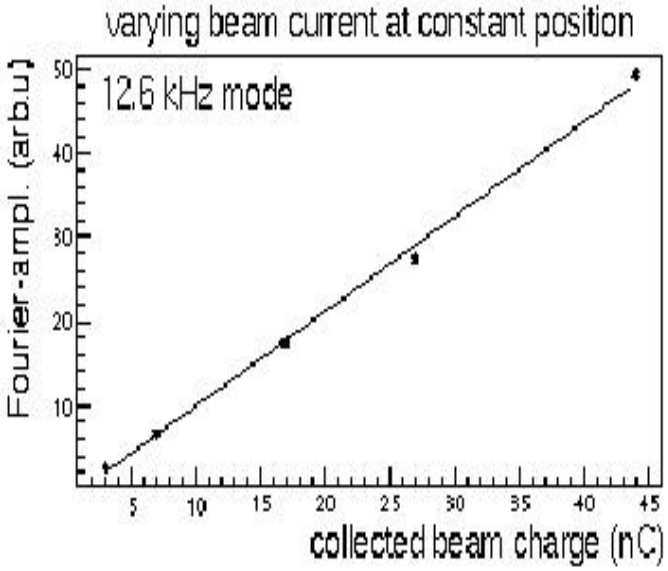


Figure 7: Correlation between the Fourier amplitude of the 12.6 kHz vibrational mode and the beam charge. Data points (*) and straight line fit.

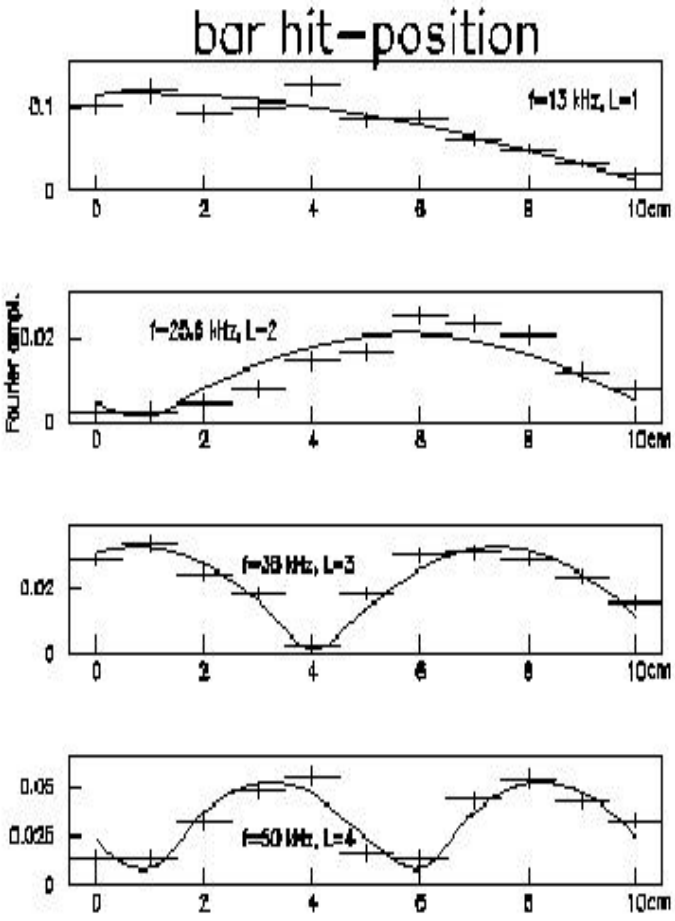
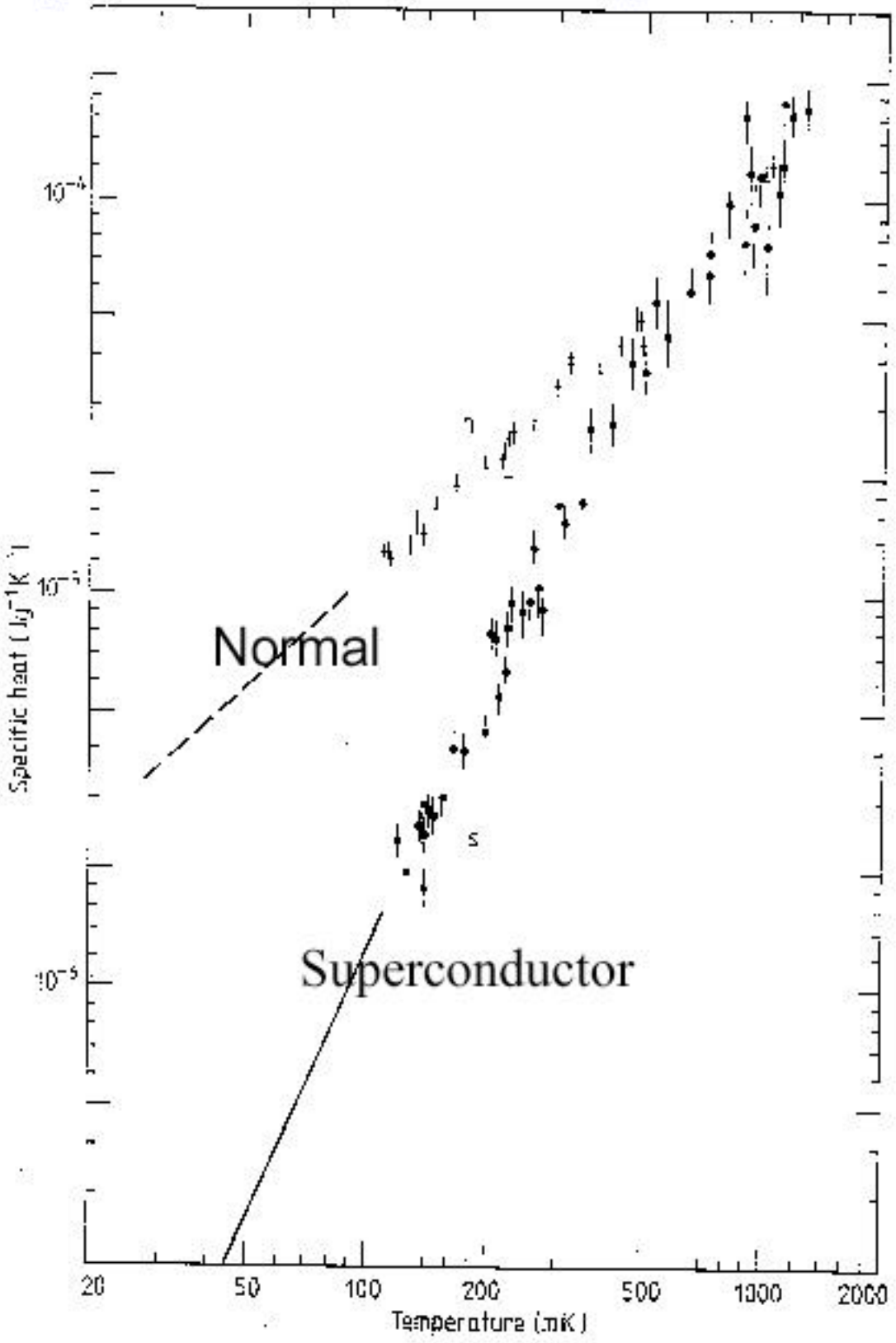


Figure 8: The measured, unnormalised Fourier amplitudes (+) and model calculations (–) as a function of the beam hit position along the cylinder axis for the four lowest longitudinal modes of bar BC.

Specific heat at low temperatures



The passage of a particle **should destroy the Cooper pairs** (0.34 meV binding energy in Al). Transition to normal state.

Evidenze della rottura delle coppie di Cooper a causa di particelle ionizzanti

1) Switching di Granuli di Indio in stato metastabile a temperatura superiore a quella di transizione

(rivelatori studiati per la rivelazione dei neutrini solari)

2) Rivelatori a strip superconduttrici. La rottura delle coppie di Cooper produce una variazione della resistenza locale. Ciò può essere usato per la rivelazione di un segnale elettrico.

Rivelatori studiati a suo tempo per SSC

Nel caso dell'alluminio di Nautilus la rottura delle coppie di Cooper potrebbe eccitare il reticolo (gap dell'ordine di 1 meV) ma a frequenze molto piu' alte di quelle di risonanza (1 KhZ).

Cosmic rays:
rate of events in the bar

- The three components (muons,hadrons,EAS) arrive together. But for purpose of simplicity the three components have been treated separately in the calculation for the effects on a resonant bar antenna.
- The **maximum energy flow** is in the core of the shower, near the direction of the primary.
- the calculations up to now are done for **single components**
- **large uncertainty** for events having many particles (for example multi-hadrons) due to incertitude in the experimental measurements and in the simulations
- Evaluations: **E Amaldi G Pizzella** Nuovo Cimento 9C 1986 ***(analytic)***

  F Ricci NIM A 260 491 (1991) ***(Montecarlo -muons)***

  J. Chiang et al (Stanford group) NIM A 311 (1992) ***(MC muons - single hadrons)***

  E. Coccia et al (Nautilus group) NIM A 355 (1995) ***(MC muons -single hadrons, multi-hadrons, EAS)***

  recently we have done a full calculation using the Corsika Monte-Carlo+Geant (***single hadrons,multi-hadrons)***

Cosmic ray:
rates in the bar (events/day)

E (K)	Muon	EAS	Hadro.	Total
10^{-7}	1540	1890	-	8630
10^{-6}	155	323	-	941
10^{-5}	12.7	50	24.2	87
10^{-4}	1.2	7	3.0	11.2
10^{-3}	0.18	0.8	0.33	1.3
10^{-2}	0.002	0.1	0.05	0.15

With the current antenna performances we expect to have a few “events”/year surviving the analysis cuts

Nautilus the first successful detection of cosmic ray showers with a gravitational bar detector

VOLUME 84, NUMBER 1 PHYSICAL REVIEW LETTERS 3 JANUARY 2000

Cosmic Rays Observed by the Resonant Gravitational Wave Detector NAUTILUS

P. Astone,[1] M. Bassan,[2] P. Bonifazi,[3] P. Carelli,[4] E. Coccia,[2] V. Fafone,[6] S. D'Antonio,[6] S. Frasca,[5] A. Marini,[6] E. Mauceli,[6] G. Mazzitelli,[6] Y. Minenkov,[2] I. Modena,[2] G. Modestino,[6,*] A. Moleti,[2] G. V. Pallottino,[5] M. A. Papa,[6] G. Pizzella,[7] F. Ronga,[6] R. Terenzi,[3] M. Visco,[3] and L. Votano[6]

[1]*Istituto Nazionale di Fisica Nucleare INFN, Rome, Italy*
[2]*University of Rome "Tor Vergata" and INFN, Rome, Italy*
[3]*IFSI-CNR and INFN, Rome, Italy*
[4]*University of L'Aquila and INFN, Rome, Italy*
[5]*University of Rome "La Sapienza" and INFN, Rome, Italy*
[6]*Istituto Nazionale di Fisica Nucleare INFN, Frascati, Italy*
[7]*University of Rome "Tor Vergata" and INFN, Frascati, Italy*

(Received 12 May 1999)

The passage of cosmic rays has been observed to excite mechanical vibrations in the resonant gravitational wave detector NAUTILUS operating at temperature of 100 mK. A very significant correlation (more than 10 standard deviations) is found.

PACS numbers: 04.80.Nn, 95.55.Ym

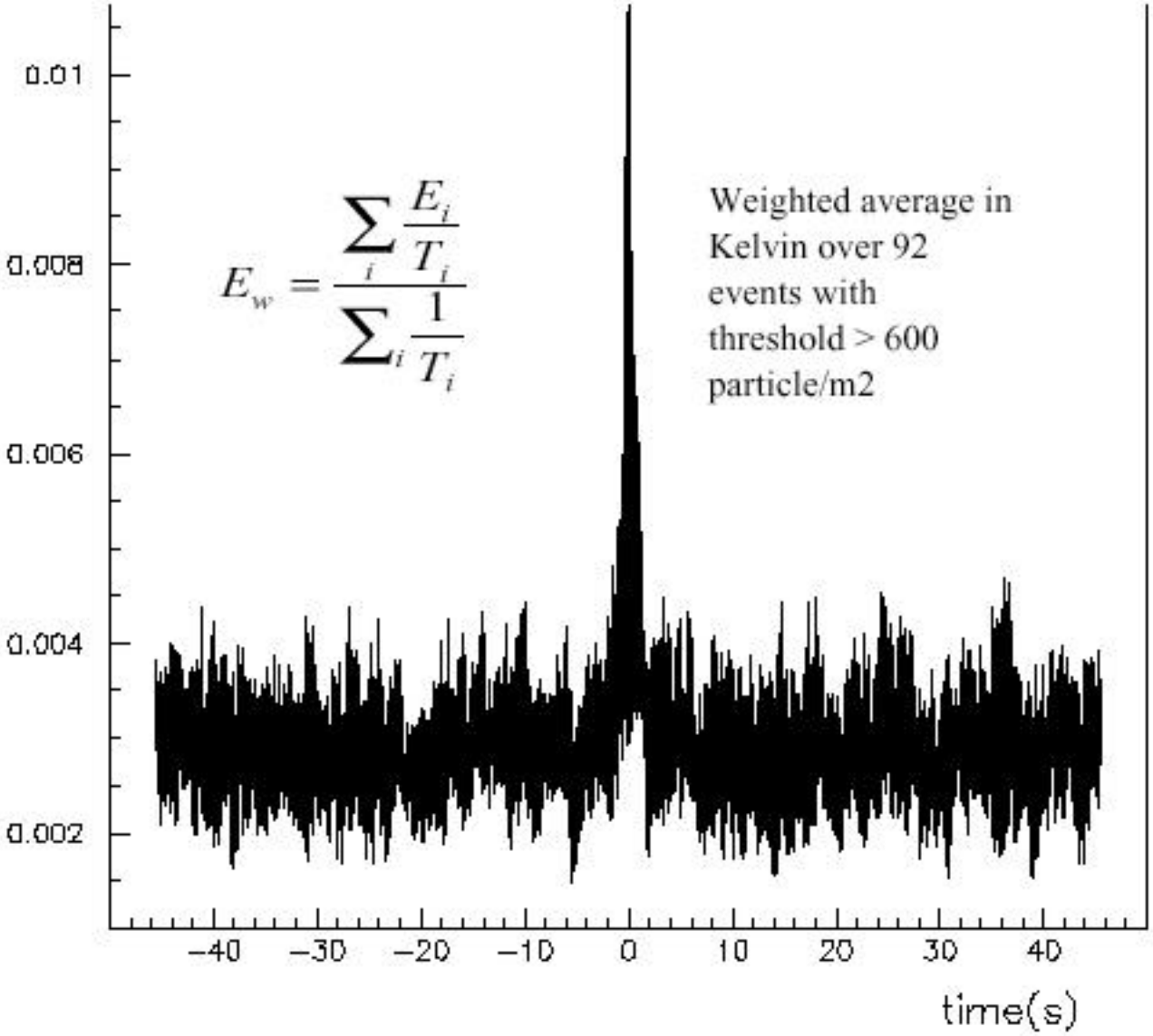
Detection of the "normal" (a few mKelvin) events

~ 80% of the events

Zero-Threshold Search for low amplitude signals:

- Selection of high multiplicity events>600 part/m^2
- Average of all the signals respect to the cosmic arrival time (we use the output of the fast matched filter with 0 threshold, 220 samples/sec)
- It is possible to shows that this method has better sensitivity than the "event" method for the expected "small" signals.
- **cuts was decided before data analysis**

Zero-Threshold Search Results



T_i is the noise temperature around the cosmic ray events. **Cut T_i < 5 mK==>> 47.7 days**

Similar results with the other filters :ZOP-Wiener, but less sensitivity

Then : the detection of several unexpected very large amplitude events

ELSEVIER

1 February 2001

PHYSICS LETTERS B

Physics Letters B 499 (2001) 16–22

www.elsevier.nl/locate/npe

Energetic cosmic rays observed by the resonant gravitational wave detector NAUTILUS

P. Astone [a], M. Bassan [b], P. Bonifazi [c], P. Carelli [d], E. Coccia [b], S. D'Antonio [c], V. Fafone [f], G. Federici [a], A. Marini [f], G. Mazzitelli [f], Y. Minenkov [b], I. Modena [b], G. Modestino [f], A. Moleti [b], G.V. Pallottino [e], V. Pampaloni [f], G. Pizzella [g,*], L. Quintieri [f], F. Ronga [f], R. Terenzi [c], M. Visco [c], L. Votano [c]

The largest : 58 Kelvin ~ 80 TeV

Correlation with the particle density (1998 data)

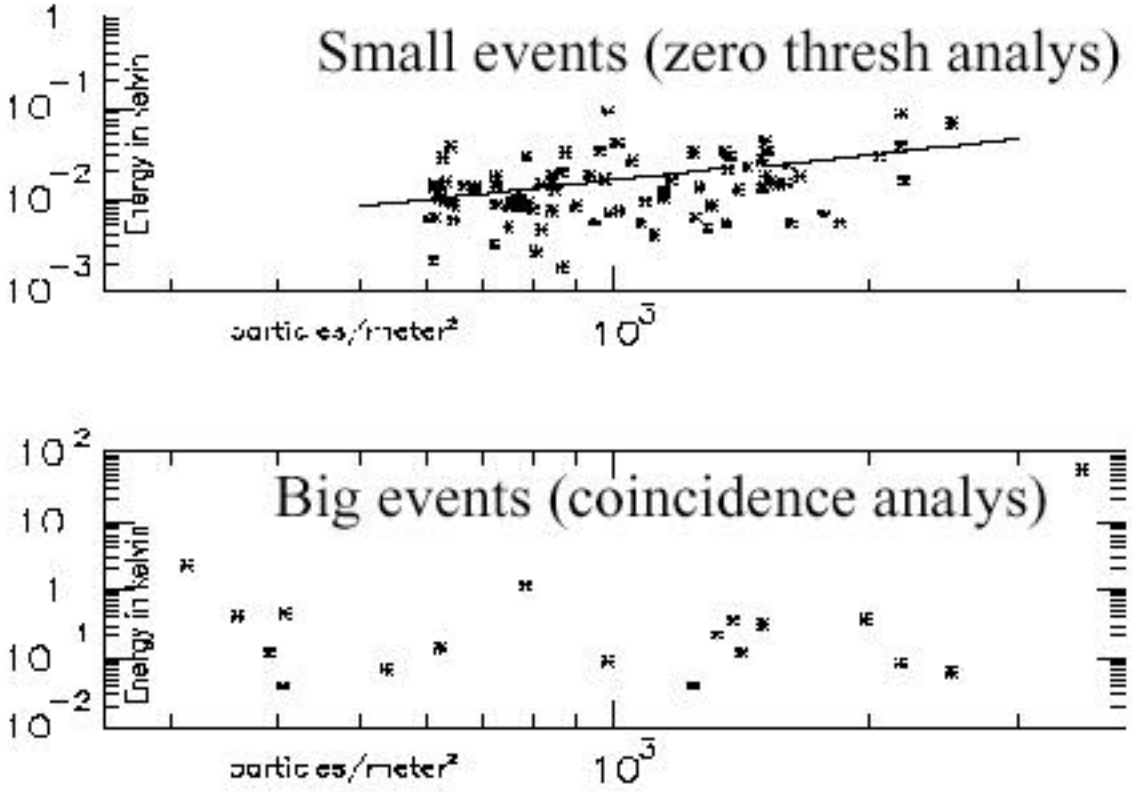


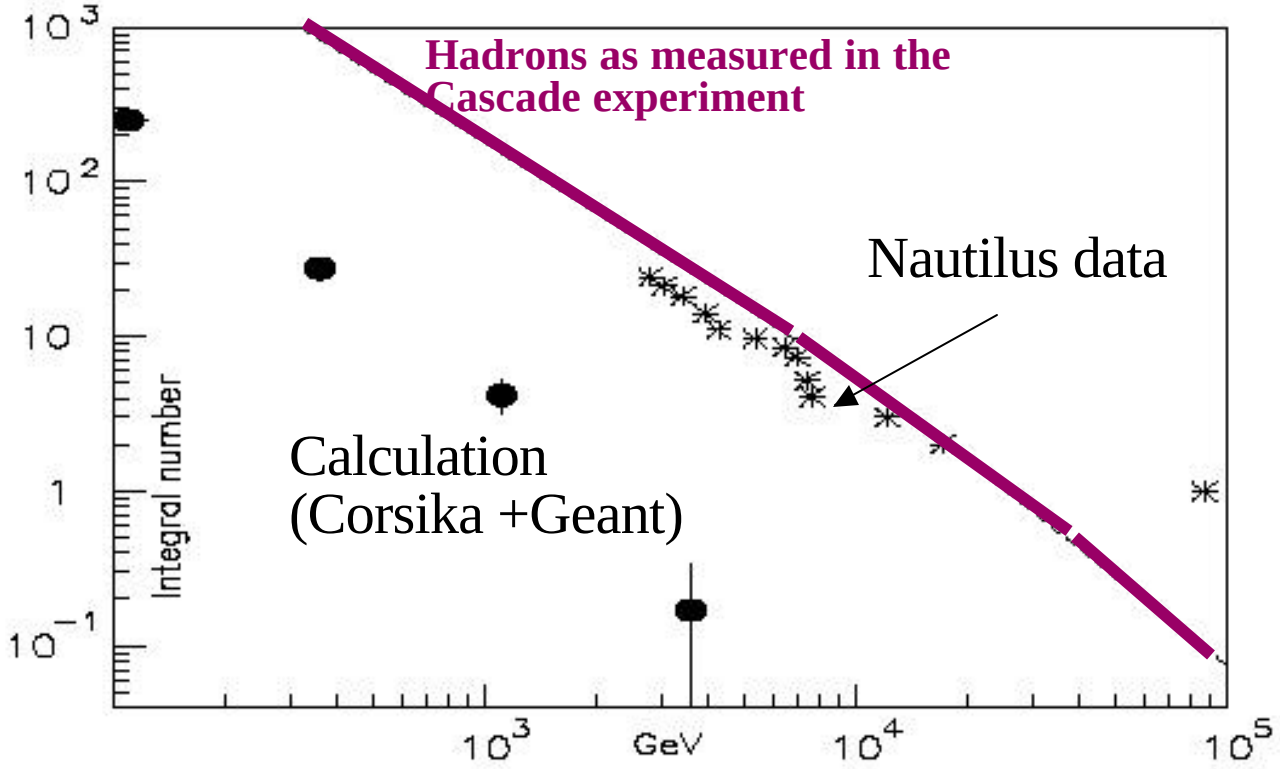
Fig. 3: Correlation between the NAUTILUS signals and the e.r. particle density. The upper graph shows the correlation of the NAUTILUS energy at zero delay (respect to the e.r. events) versus the corresponding e.r. lower particle density, for the 92 data points considered in the previous analysis. The correlation coefficient is 0.30, with a probability to be accidental of less than 1%. If we eliminate the three largest data points with energy greater than 100 nK, which belong also to the family of events of Table 1, the correlation coefficient increases to 0.42 with 89 data points, with a probability smaller than 10^{-4} for the correlation to be accidental. Instead the lower plot shows no correlation between the energy of the NAUTILUS coincident events analysed in this paper and the corresponding e.r. particle density.

For big events no correlation with the particle density (excluding the Big One)

E.A.S. showers and thermo-acustical model unable to explain data

Hadrons in the core of EAS?

Integral Distribution as function of energy calculated with the themo-acustical model



Our calculation is in agreement with the direct measurement (Cascade experiment) taking into account the small energy containment in the antenna (a few percent at the energy of interest)

Event Rate 2 order of magnitude higher than expected or…

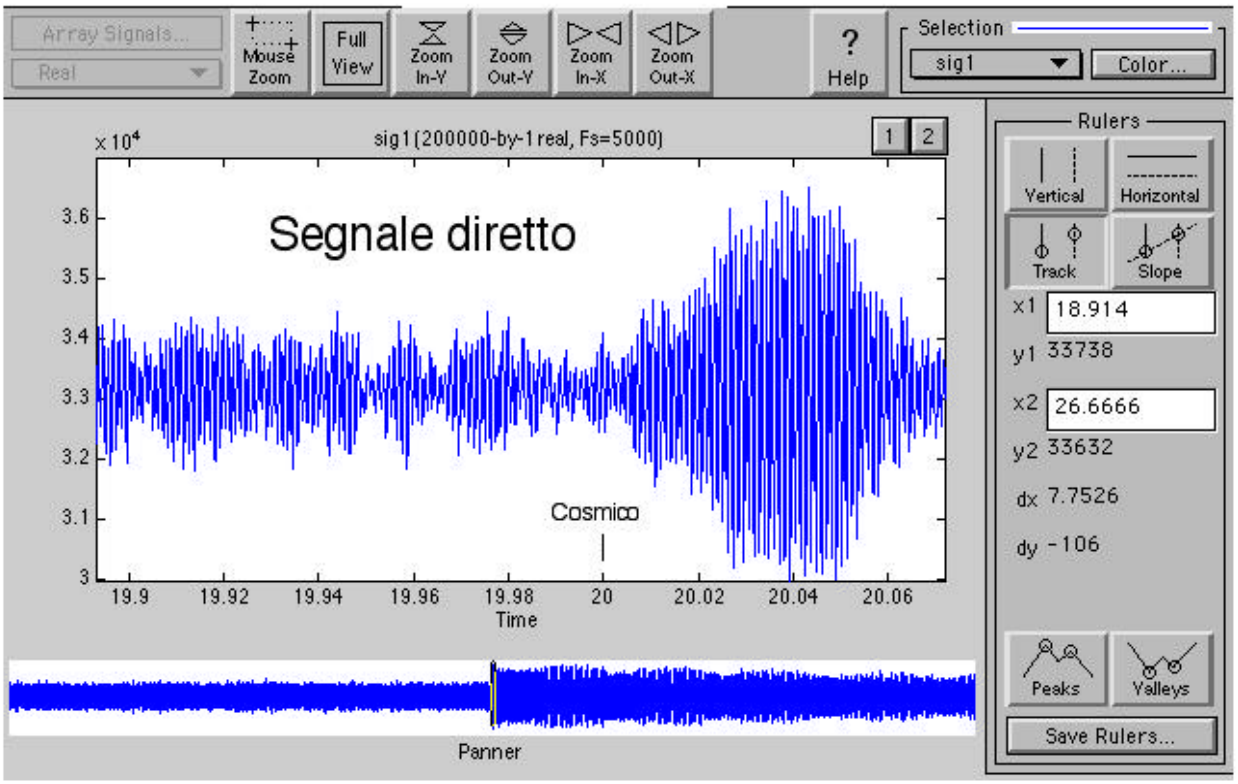
Energy 2 order of magnitude higher than the one computed with the thermo-acustical model

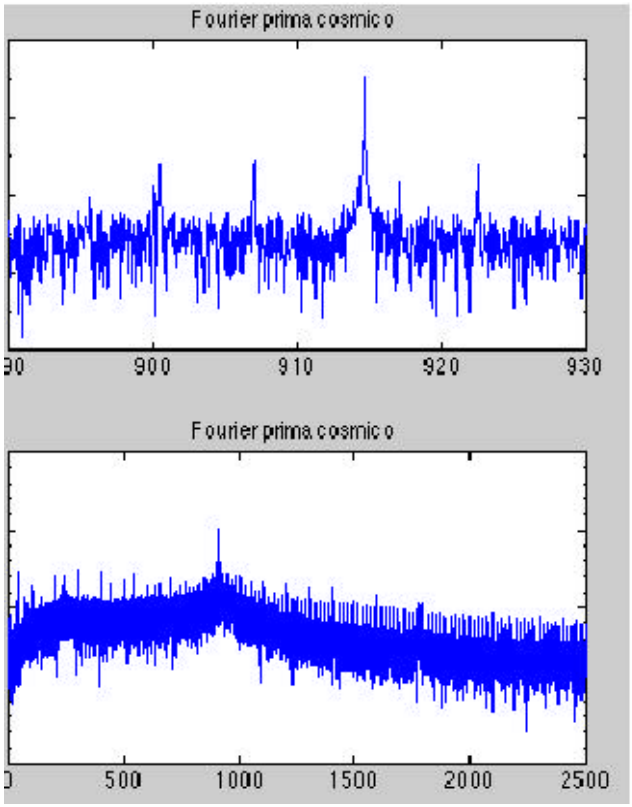
Hadrons + thermo-acustical model unable to explain the data

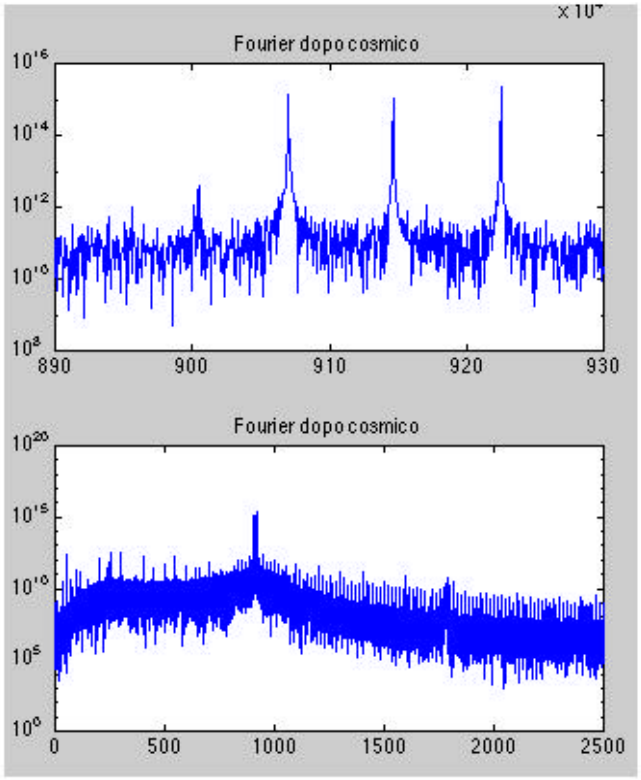
A Big Event (9 Kelvin)

The time is in agreement with the expectations

Evento 4298 60222 Giugno 2000







Possibilities to explain data

1) Something wrong in the calculations, but we are confident no mistake at a level of 2 order of magnitude

2) Something strange in the cosmic rays at the energy of interest (energies in the region of the knee of the cosmic ray)

3) Something strange in the Nautilus detector:

a)the cosmic rays could trigger a release of non elastic audiofrequency modes (creep..)

b) effects related to the superconductivity:
the normal assumption is that at the passage of a particle breaks the Cooper electrons and therefore in the thermo-acustical model is assumed normal Alluminium, but there are no experimental data for this model

or

the cosmic rays trigger some sort of metastable state due to the superconductivity (magnetic vortex)

Possibilities to explain data (con't)

c) charge effects if the bar has a residual charge. If $m_{bare\ electron}=0$ divergence (?).

O' Connel Phys Lett A 281 (2001)

Unlikely: Nautilus is grounded !

The 2000-2001 Nautilus data

• Nautilus was a bit more noisy than in 1998 data

After August 2000 run at a temperature T>1.1 Kelvin (Non Superconductor Aluminum)

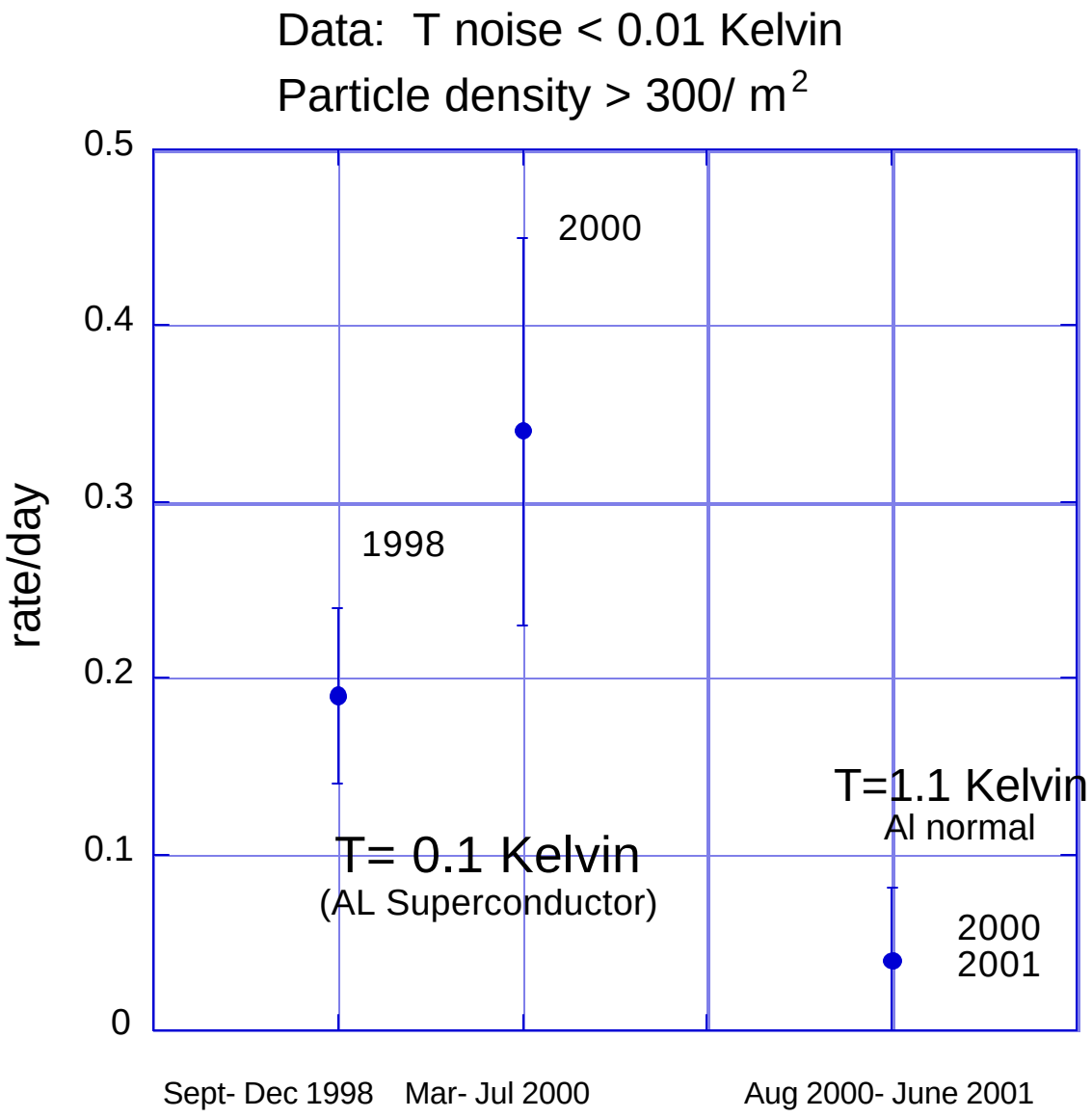
• search for coincidences using criteria similar to the 1998 data (SNR>19.5, Tnoise<10 mKelvin,Particle Density >300/m^2)

	Coincidences	Accidentals	Days
Sep-Dec1998	18	2	83.4
Mar-Jul 2000	13	2.3	31.8
Total Superc Alluminium	31	4.3	115.2
Aug 2000 Aug 2001	6	3.4	65.7
(non Superc Alluminium)			

~ 3 sigma effect

The Superconductivity is now the preferred origin of the anomalous events

•After August 2000 Nautilus is running at 1.1 Kelvin



RAP: Study of this effect in a controlled environment

• of interest to understand the limitations in the sensitivity of the gravitational bar detector (not a problem for the current sensitivity)

• may be useful for the future generations of interferometers

• of general interest to understand the effect of particles on a supercondutor material

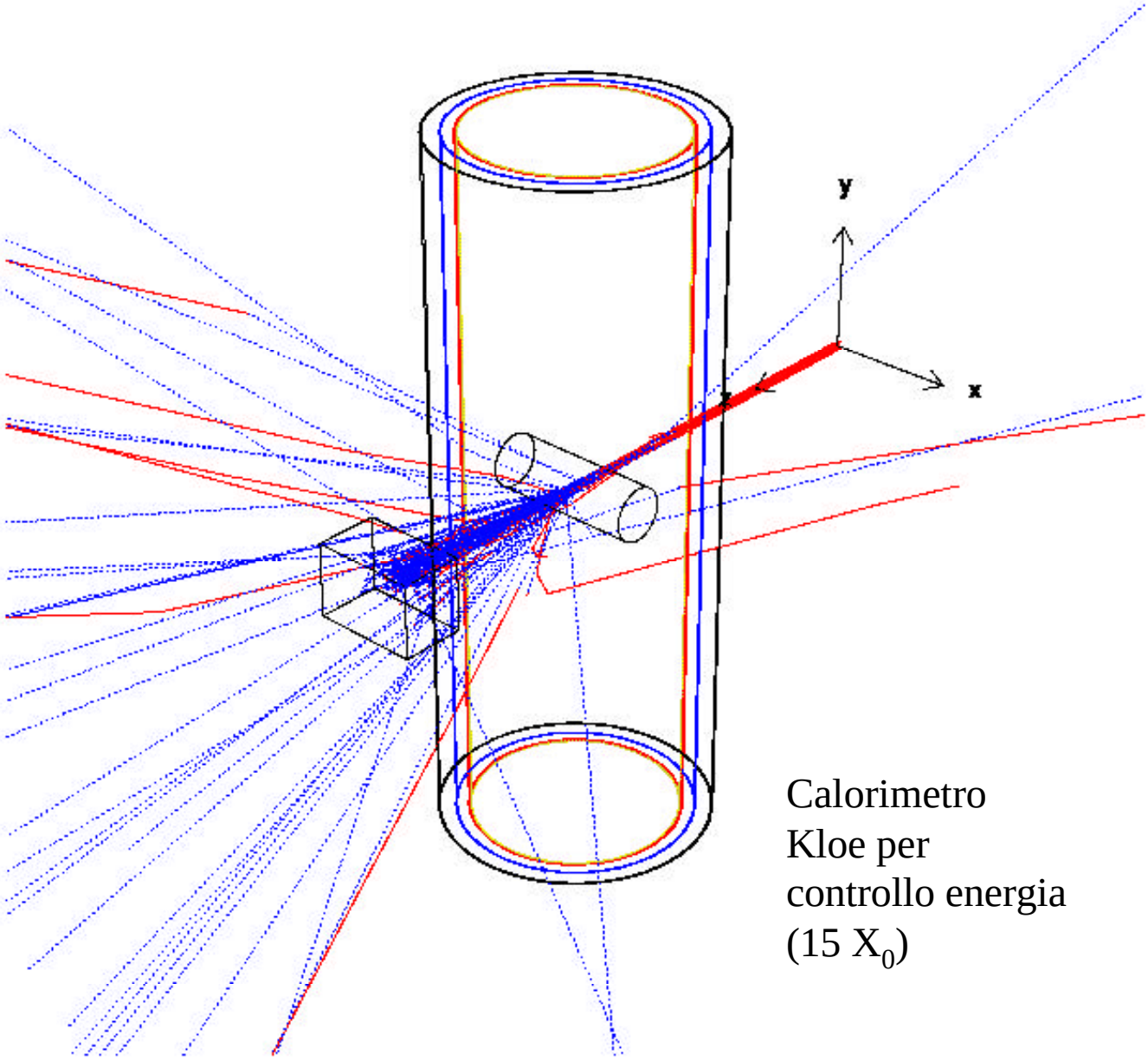
• we plan to repeat the NIKHEF experiment at temperature < 1 Kelvin, using the Dafne Linac (800 MeV electron beam) in Frascati

Device:

• small cylindrical antenna with piezoelectric readout in a cryostat with a dilution refrigerator

sensitivity < 1 Kelvin (˜ TeV in the bar)

Simulazione fascio criostato sbarra



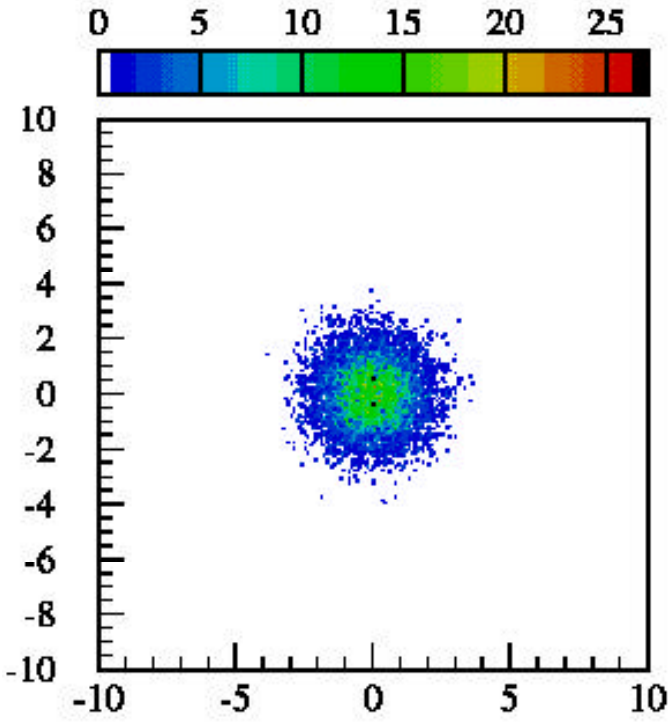
Calorimetro Kloe per controllo energia (15 X_0)

Figure 14: *Example of simulated Monte Carlo events.*

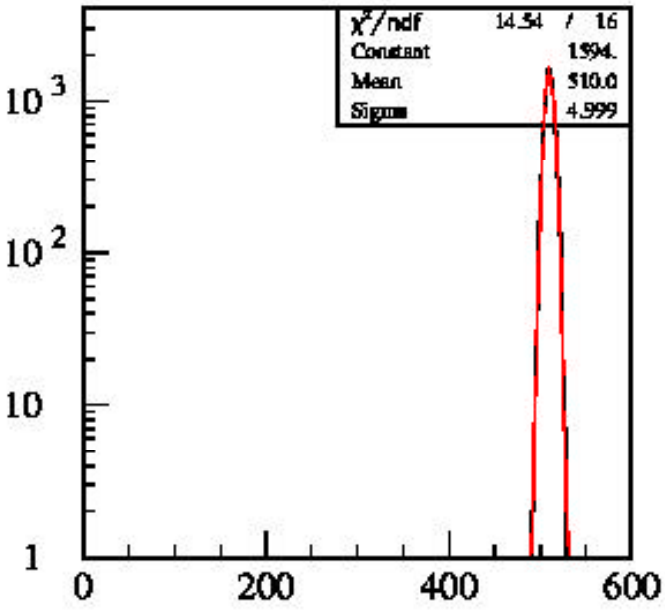
Criostato : 4 schermi di alluminio 1+5+5+6 mm

Sbarra alluminio 10 cm raggio 58 cm lunghezza

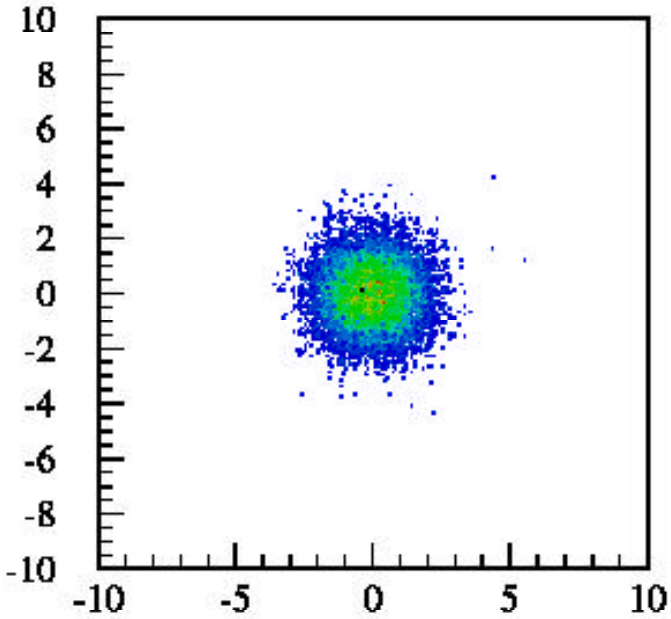
Simulazione effetto del criostato sul fascio



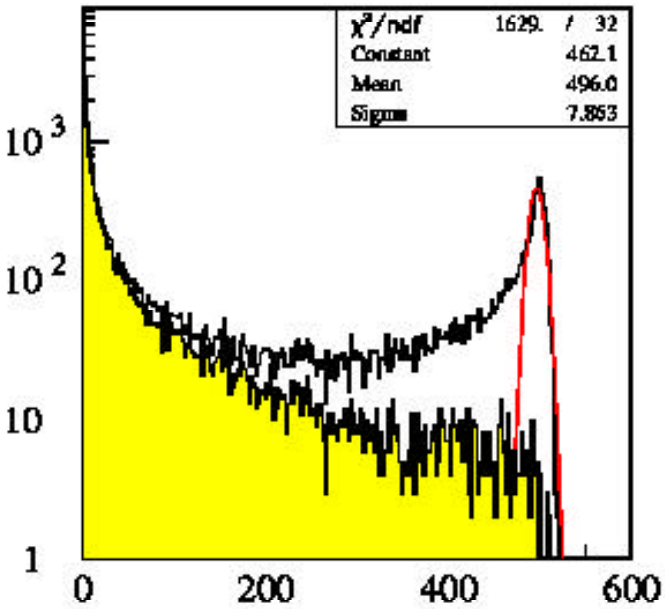
Y vs X at BEAM



E at BEAM (MeV)

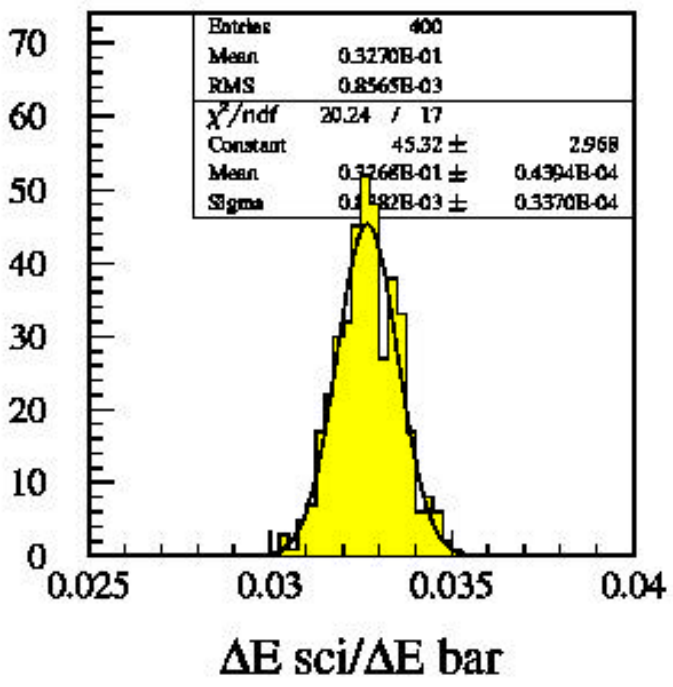


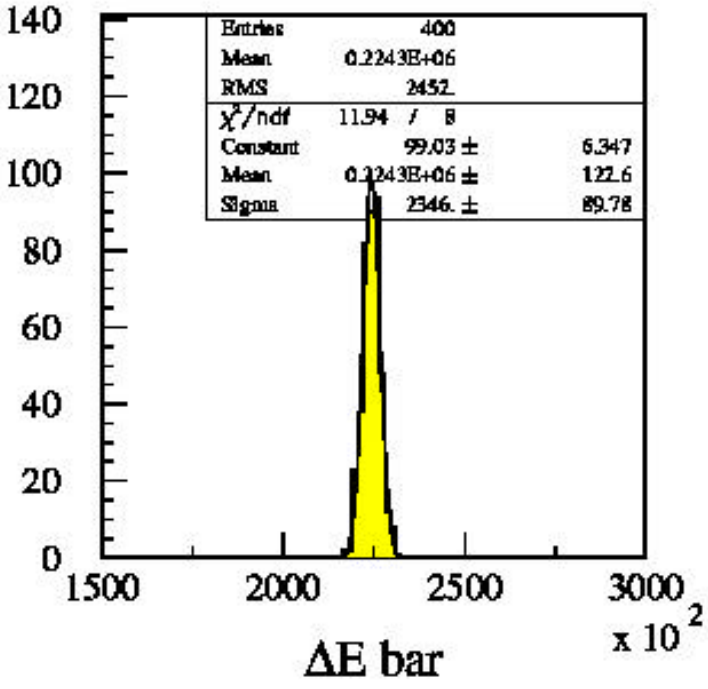
Y vs X before BAR

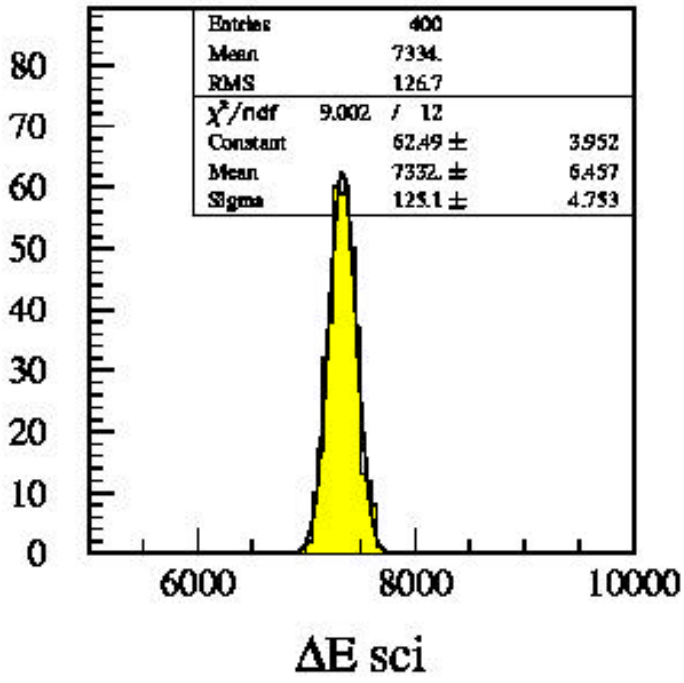


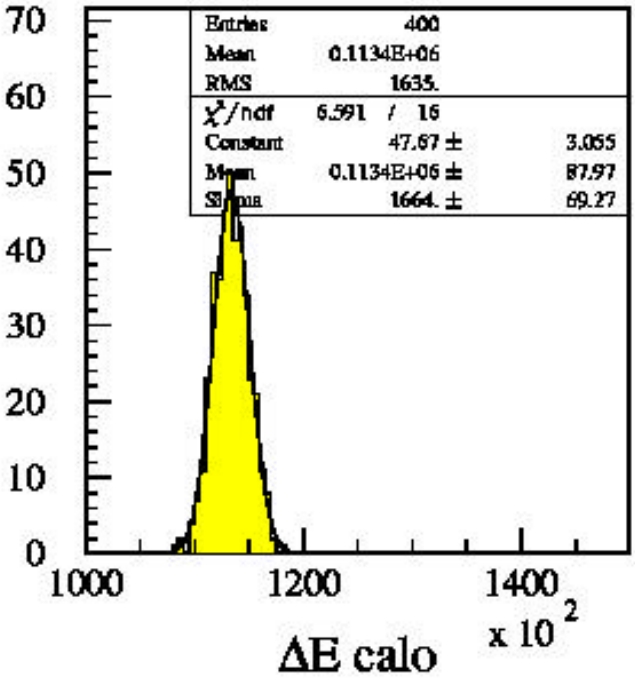
E before BAR (MeV)

Distribuzioni in energia rilasciata (1000 elettroni)

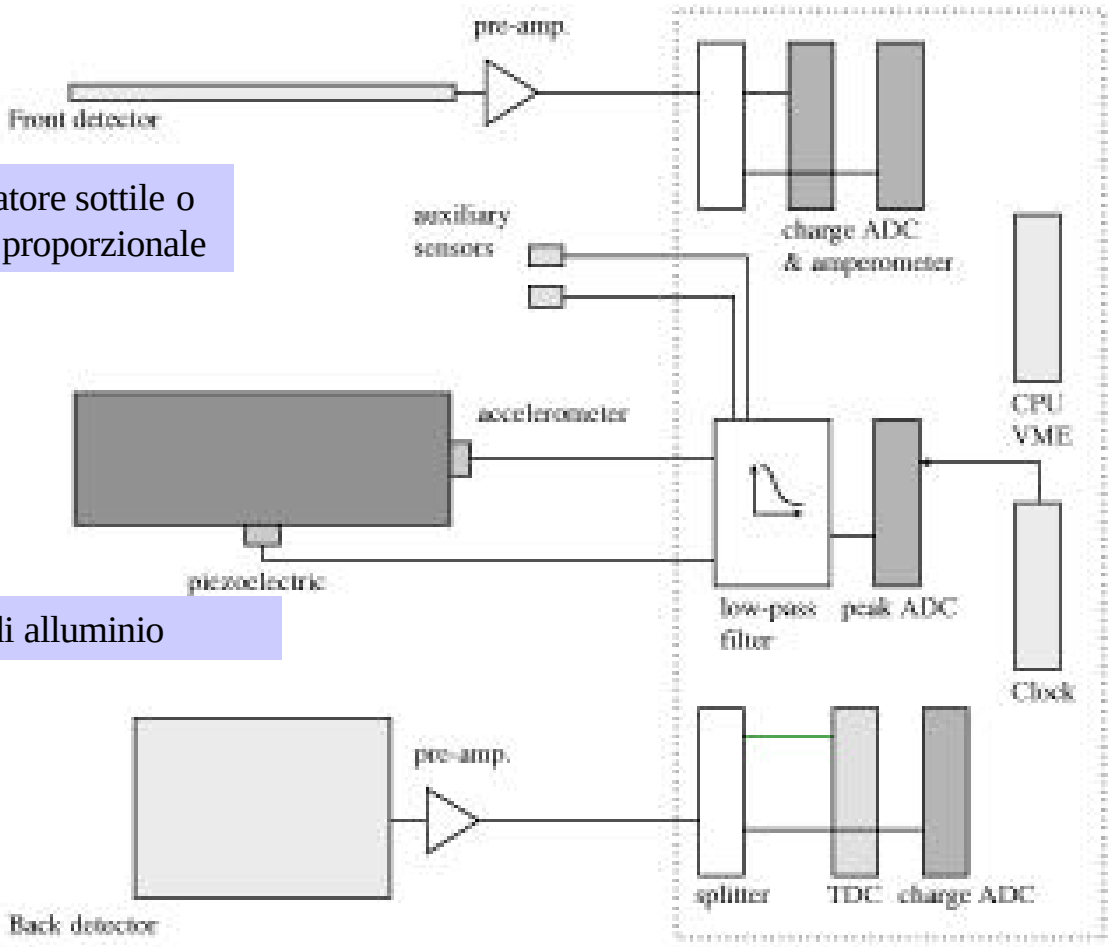








Schema acquisizione

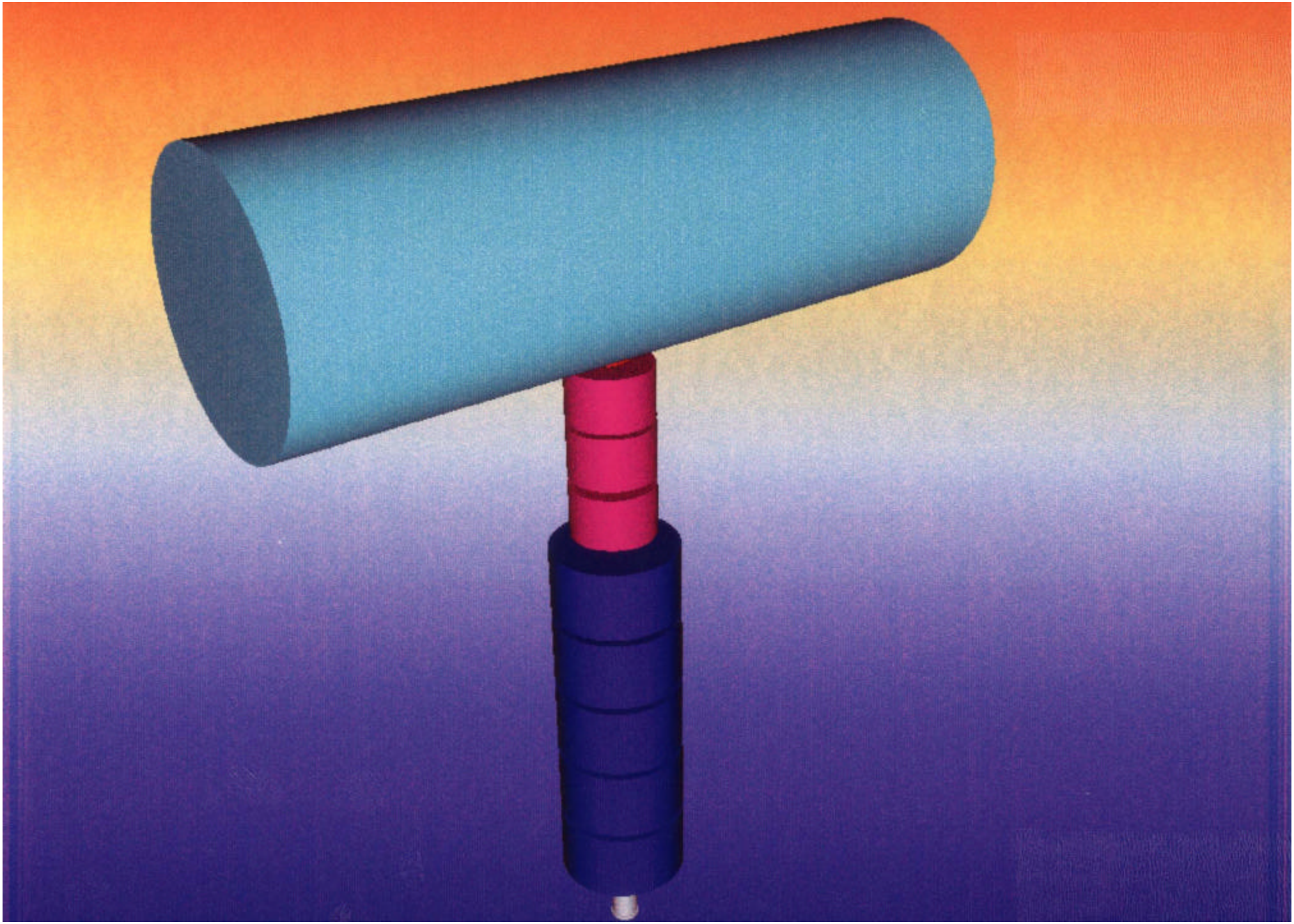


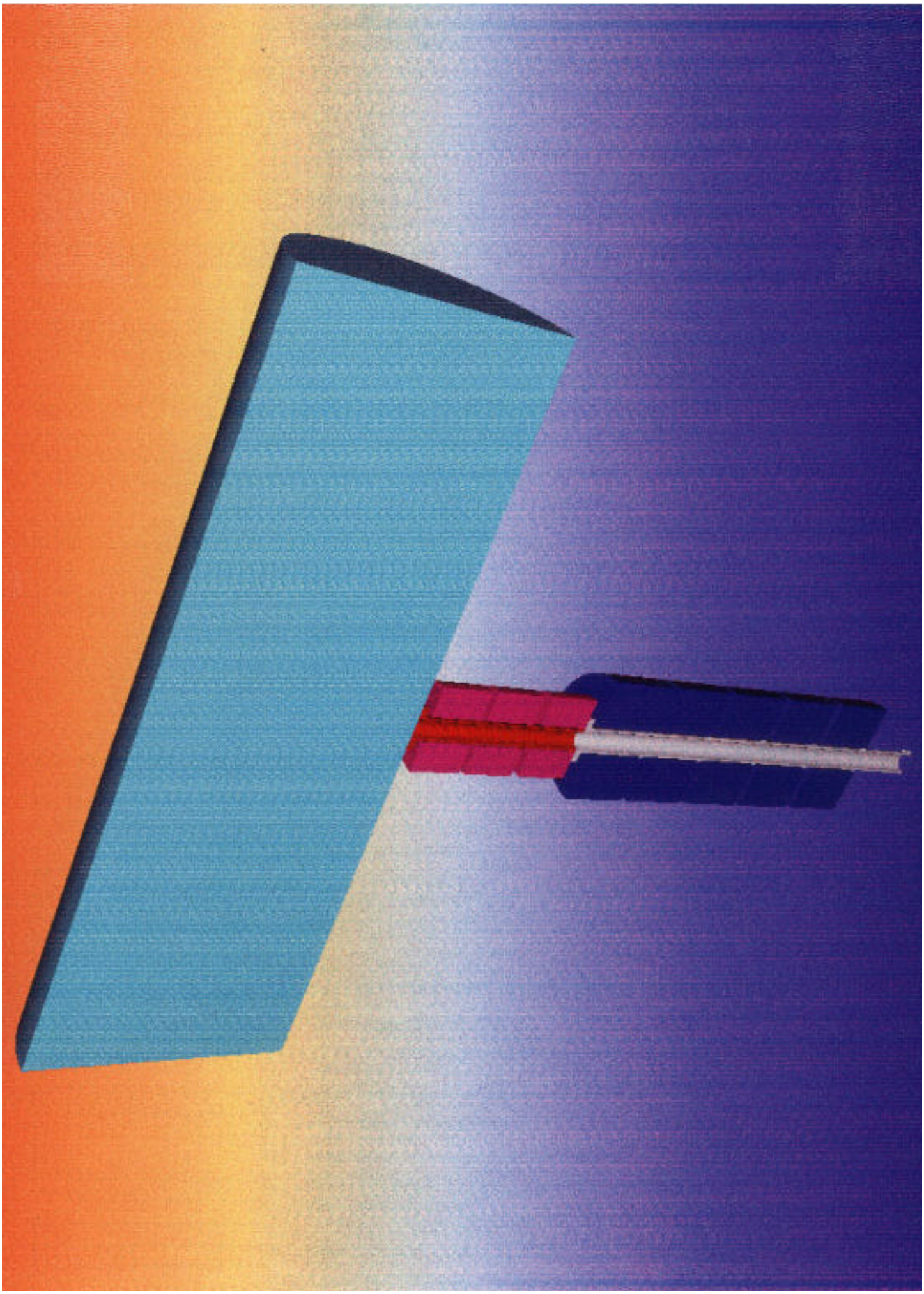
Scintillatore sottile o camera proporzionale

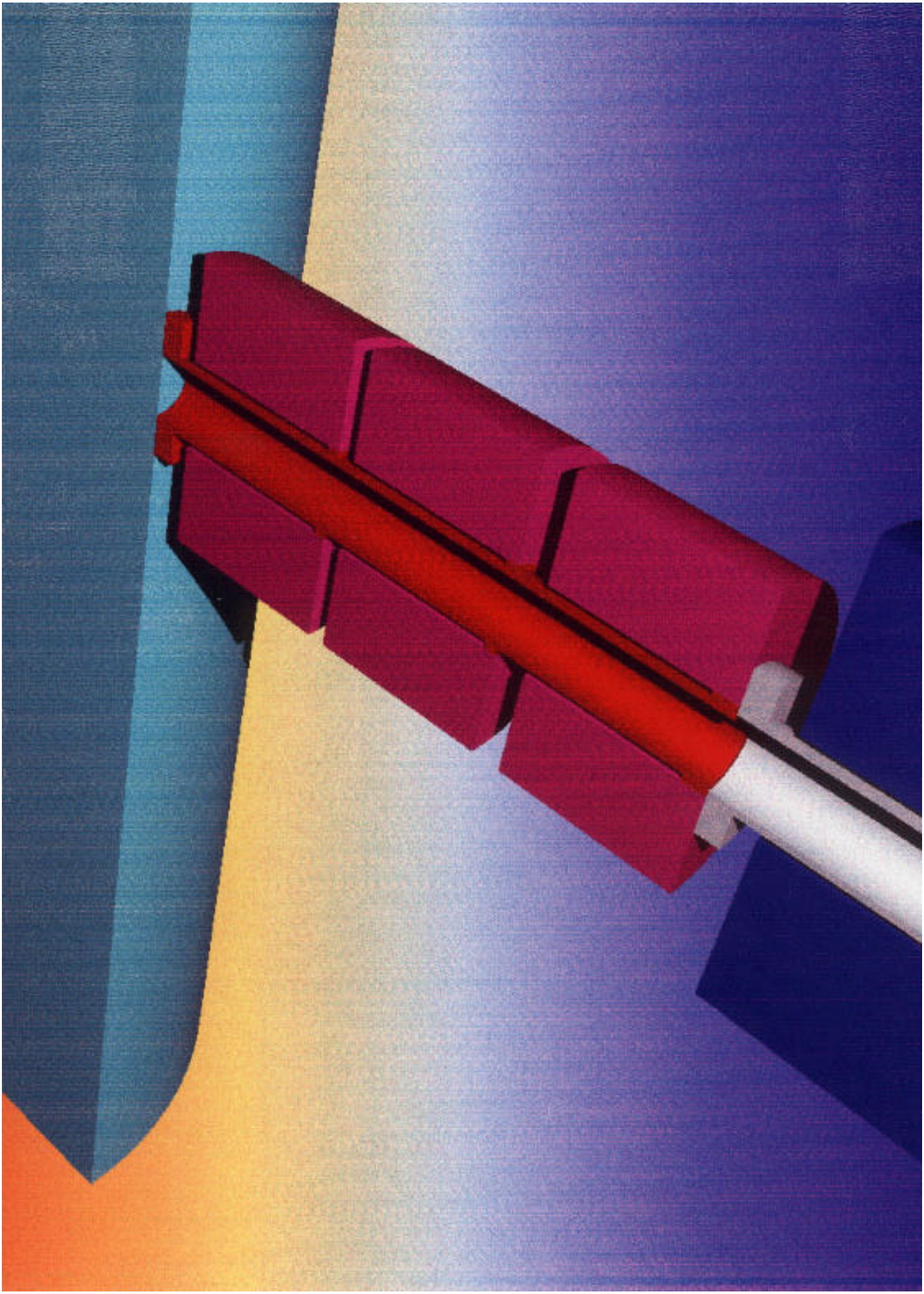
Cilindro di alluminio

Calorimetro a fibre scintillanti (Kloe)

e 18: *Schematic layout of the DAQ chain.*







Preventivo per l'anno **2002**

Struttura
L.N.F.

RAP	

PREVENTIVO LOCALE DI SPESA PER L'ANNO 2002

In l

VOCI DI SPESA		DESCRIZIONE DELLA SPESA	IMPORTI Parziali	IMPORTI Totale Compet.	Acura Comm Scien
Viaggi e Missioni	Int.				
	Est.				
Materiale di Consumo		Magazzino Sospensioni e lavorazioni meccaniche	2 20	22	
Trasp. e facch.					
Spese Calcolo		Consorzio | Ore CPU | Spazio Disco | Cassette | Altro			
Affitti e Manutenz. Apparec-chiature					
Materiale Inventar.		Refrigeratore a diluizione Pompe da vuoto Sistema acquisizione dati	45 40 10	95	
Costruzione Apparati					
		Totale		117	

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno **2002**

Nuovo Esperimento	Gruppo
RAP	2
Resp. loc.:	Matteo Cirillo

Struttura
ROMA II

PREVENTIVO LOCALE DI SPESA PER L'ANNO 2002

In kEuro

VOCI DI SPESA		DESCRIZIONE DELLA SPESA	IMPORTI Parziali	IMPORTI Totale Compet.	A cura della Comm.ne Scientifica Nazionale
Viaggi e missioni	Interno	Collaborazione Laboratori Nazionali di Frascati	3,0	3,0	
	Estero				
Materiale Consumo		Piezoelettrici e componenti elettronici	4,0	4,0	
Trasp.e facch.					
Spese Calcolo		Consorzio / Ore CPU / Spazio Disco / Cassette / Altro			
Affitti e manutenz. apparecchiat.					
Materiale Inventariabile		Amplificatori a basso rumore	5,0	5,0	
Costruzione Apparati					
		Totale		**12,0**	

Note:

Mod. EN. 2

(a cura del responsabile locale)

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Preventivo per l'anno **2002**

Nuovo Esperimento	Gruppo
RAP	2

Struttura
L.N.F.

PREVISIONE DI SPESA

Piano finanziario globale di spesa

In ML

ANNI FINANZIARI	Miss. interno	Miss. estero	Mater. di cons.	Trasp. e Facchin.	Spese Calc.	Aff. e Manut. App.	Mater. Invent.	Costruz. Appar.	TOT. Compet.
2002	5		28				115		**148**
2003	5		25						**30**
2004	3		15						**18**
TOTALI	**13**		**68**				**115**		**196**

Collaborazione

LNF

S. Bertolucci,D. Di Gioacchino V. Fafone G Mazzitelli G. Modestino A. Marini , L. Pellegrino, G Raffone, F. Ronga, P Valente,

3.5 equivalenti

Roma2

M.Cirillo, V. Merlo, I. Modena, R. Russo

1.6 equivalenti

Leida

A. de Ward, G. Frossati, L. Gottardi (criogenia)

Barcellona

J.A.Lobo

+ *ROG*

Schedula

2002 costruzione e prime misure

2003 misure sul fascio

2004 analisi dati e altre misure sul fascio se necessario