PaMeLa

a Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics

Bari, Florence, Naples, Roma 2, Trieste, INFN

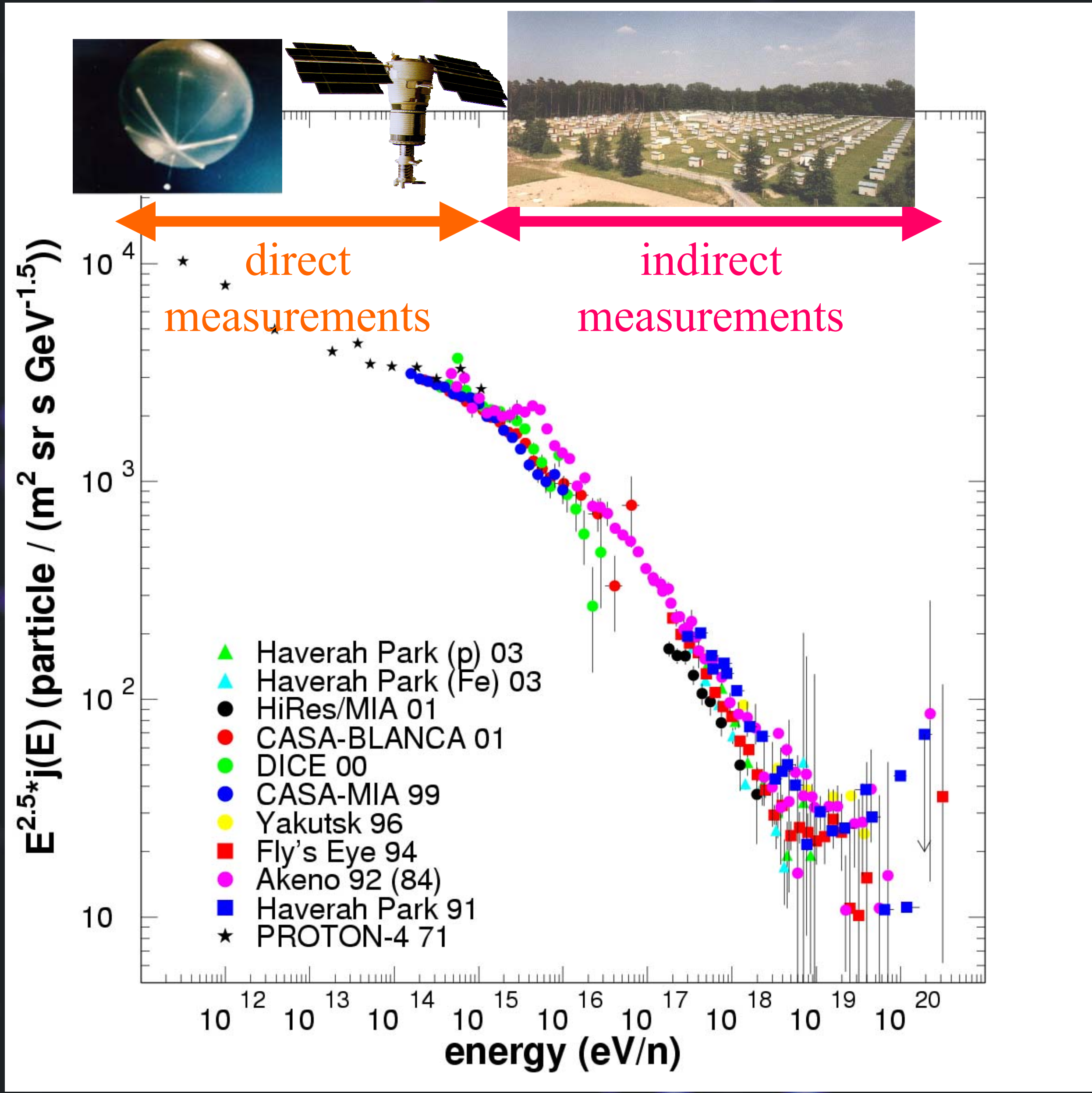
MEPHI, KTH Stockholm, Siegen, NMSU, GSFC, Bombay

Giuseppe Osteria

INFN Napoli

Napoli, 20 Maggio 2004

Cosmic rays


direct
measurements
indirect
measurements
Haverah Park (p) 03
Haverah Park (Fe) 03
HiRes/MIA 01
CASA-BLANCA 01
DICE 00
CASA-MIA 99
Yakutsk 96
Fly's Eye 94
Akeno 92 (84)
Haverah Park 91
PROTON-4 71
$E^{2.5} * j(E)$ (particle / (m^2 sr s $GeV^{-1.5}$))
10^4
10^3
10^2
10
10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17} 10^{18} 10^{19} 10^{20}
energy (eV/n)

Scientific goals

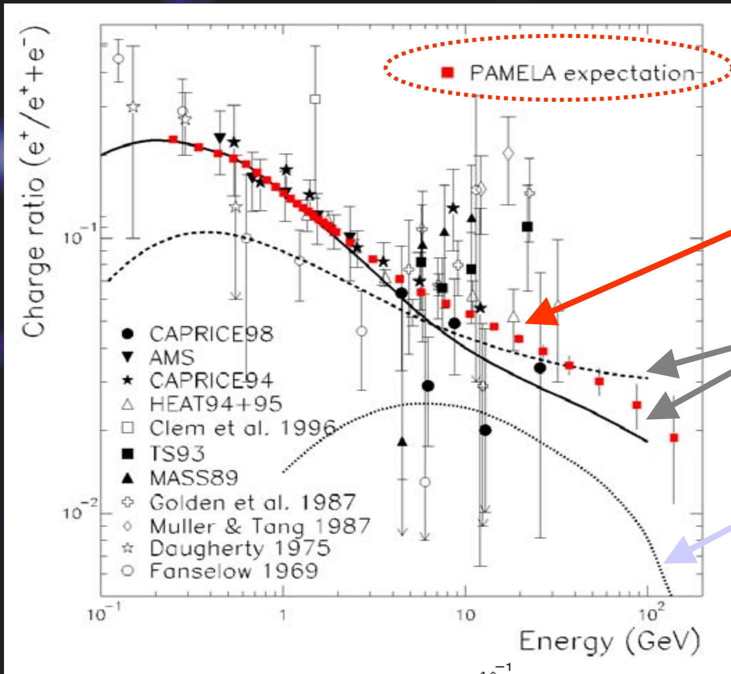
Study of cosmic ray flux with emphasis on the antiparticle component

- antiproton flux 80 MeV – 190 GeV
- positron flux 50 MeV – 270 GeV
- search for antinuclei 10^{-8} antihelium/helium ratio
- proton flux 80 MeV – 700 GeV
- electron flux 50 MeV – 400 GeV
- light nuclei flux (up to C) 100 MeV/n – 200 GeV/n

\+ study of solar cosmic rays, magnetosphere, etc.

- search for possible primary sources (antimatter, dark)
- study propagation mechanism of cosmic rays

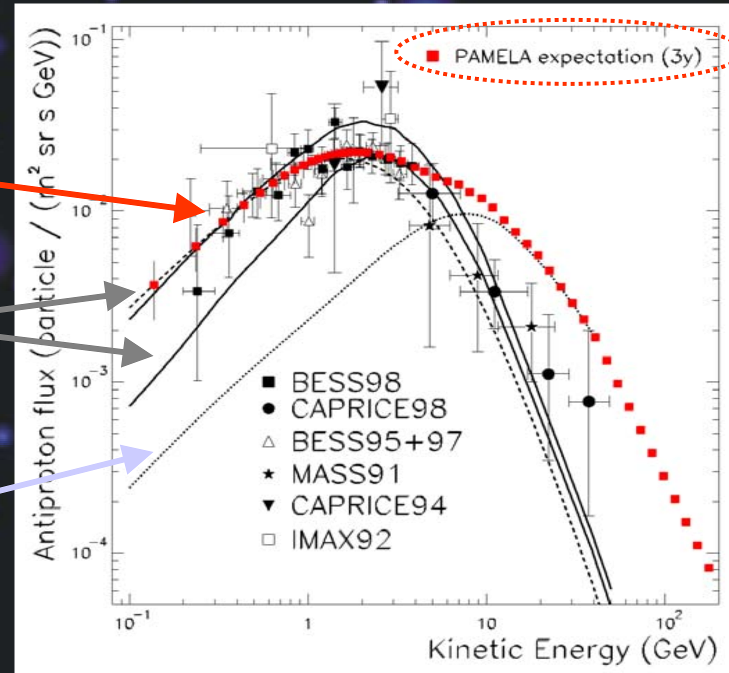
Scientific goals

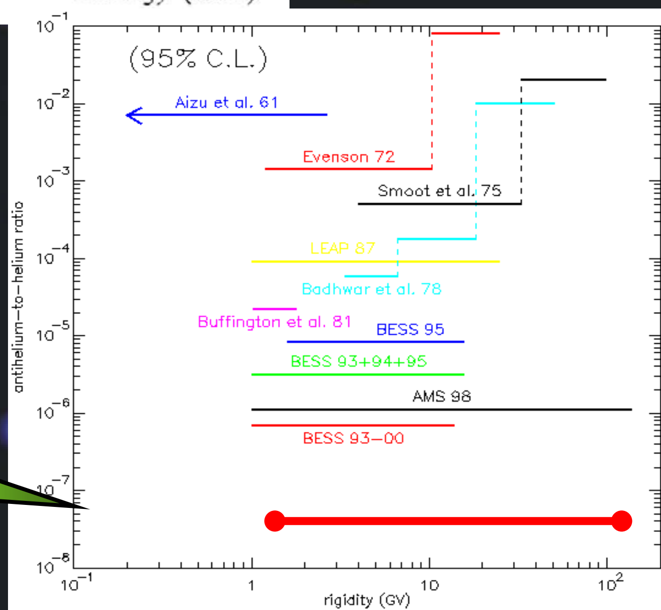


Distorsione da $\chi\chi$

Modelli di produzione secondaria

Flusso primario dovuto all'annichilazione del neutralino $\chi\chi$





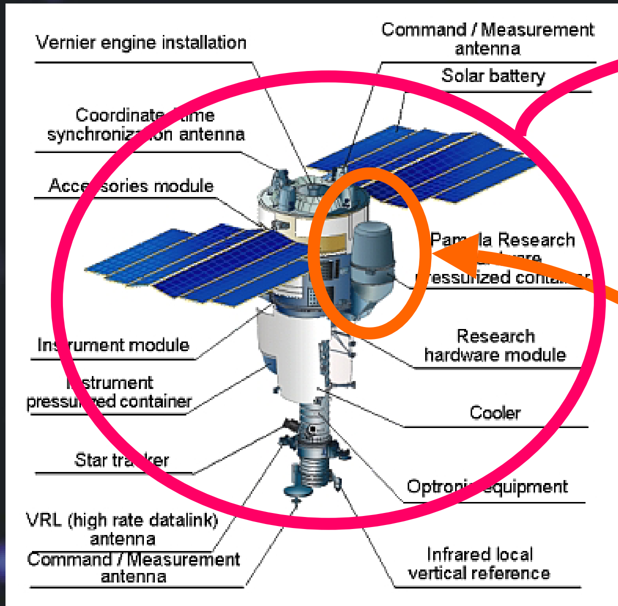
$>10^{-7}$

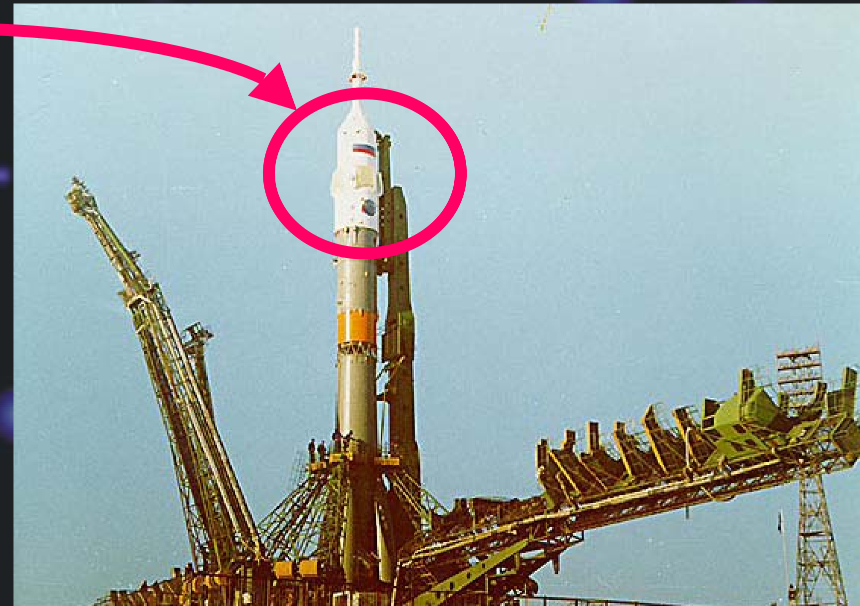
Misure attese da PAMELA

Rapporto antiHe/He

L'eventuale presenza di antiHe è un ottimo indicatore della presenza di Antimateria Primordiale

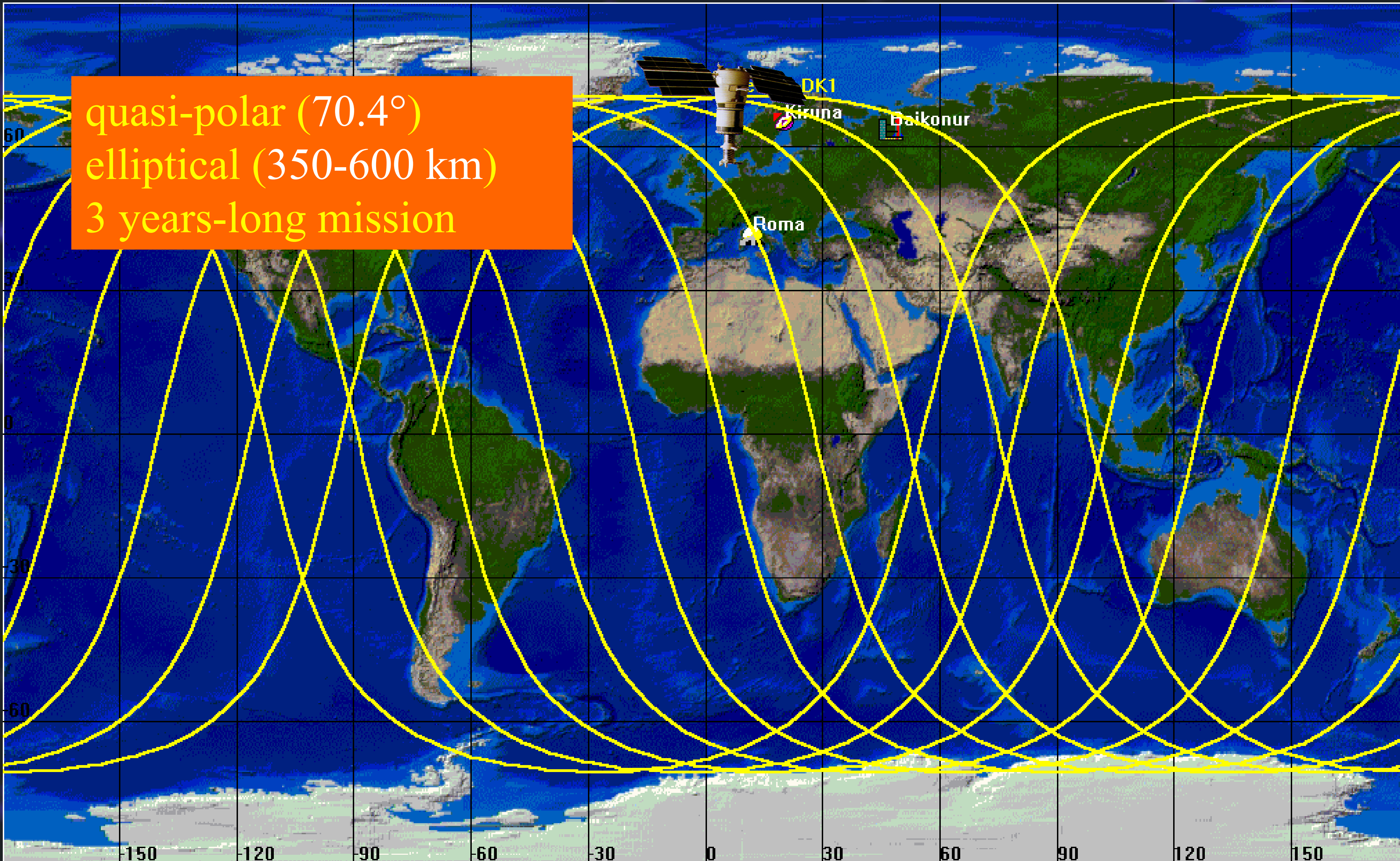
Mission overview





The instrument will fly as "piggy-back" on board of the Russian Resurs-DK1 Satellite for Earth observation, scheduled to be launched in the second half of 2004 from the Baykonur cosmodrome in Kazakhstan by means of a Russian Soyuz rocket

Orbital characteristics



Instrument design

We're looking for rare events (10^{-4}) in the bulk of cosmic rays, over a wide energy interval, and with good statistics

•precise particle identification

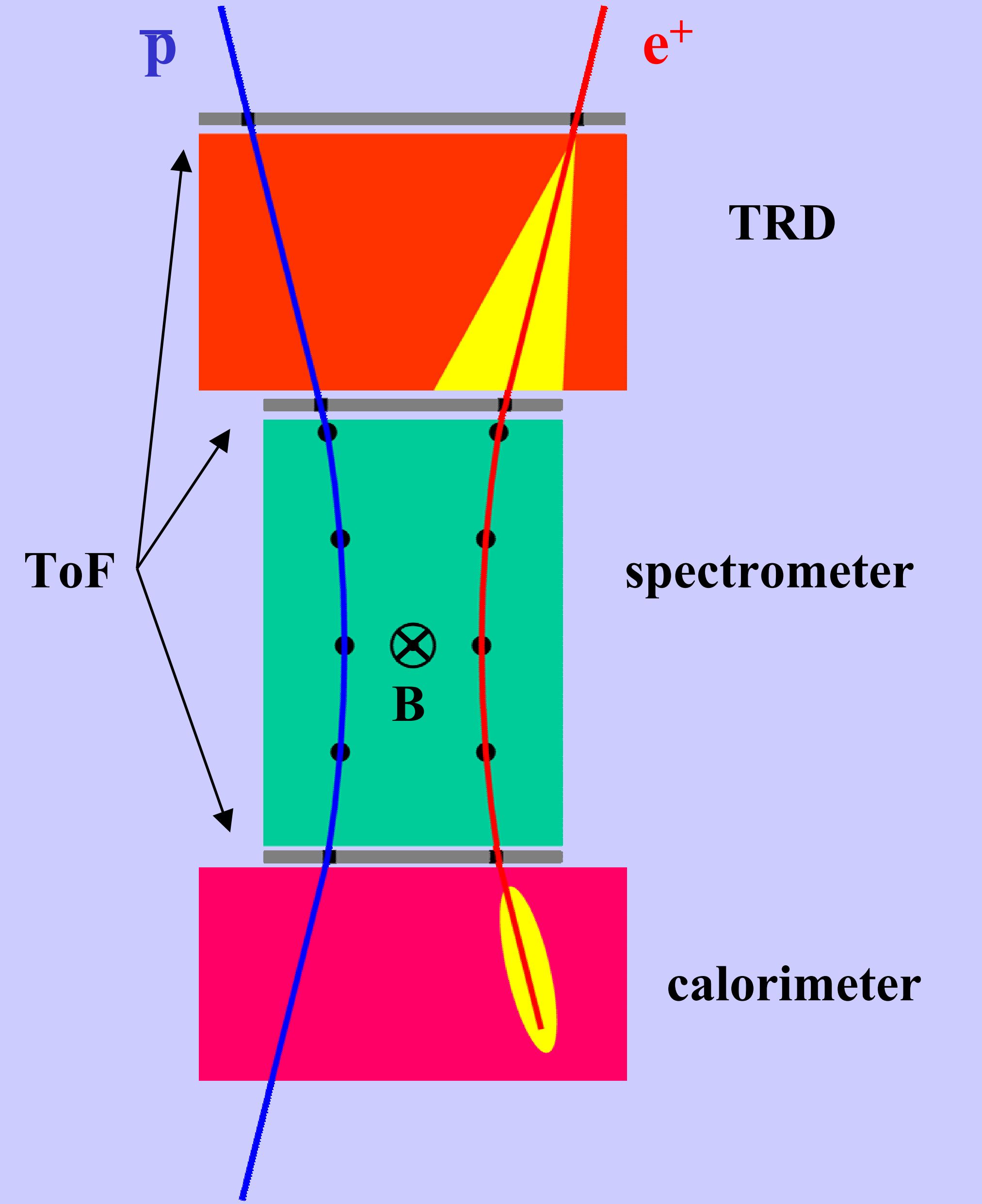
✓mass (momentum and velocity)

✓charge (sign and absolute value)

✓lepton/hadron separation (threshold effect, interaction topology)

•sensitive, redundant detectors (and space qualified, too)

The WiZard concept



magnetic spectrometer

- sign of charge (e^+/e^-, p-bar/p)
- magnetic rigidity ($R = pc/ze$)

ToF

- charge selection ($dE/dx \propto z^2$)
- particle identification (β vs. R)

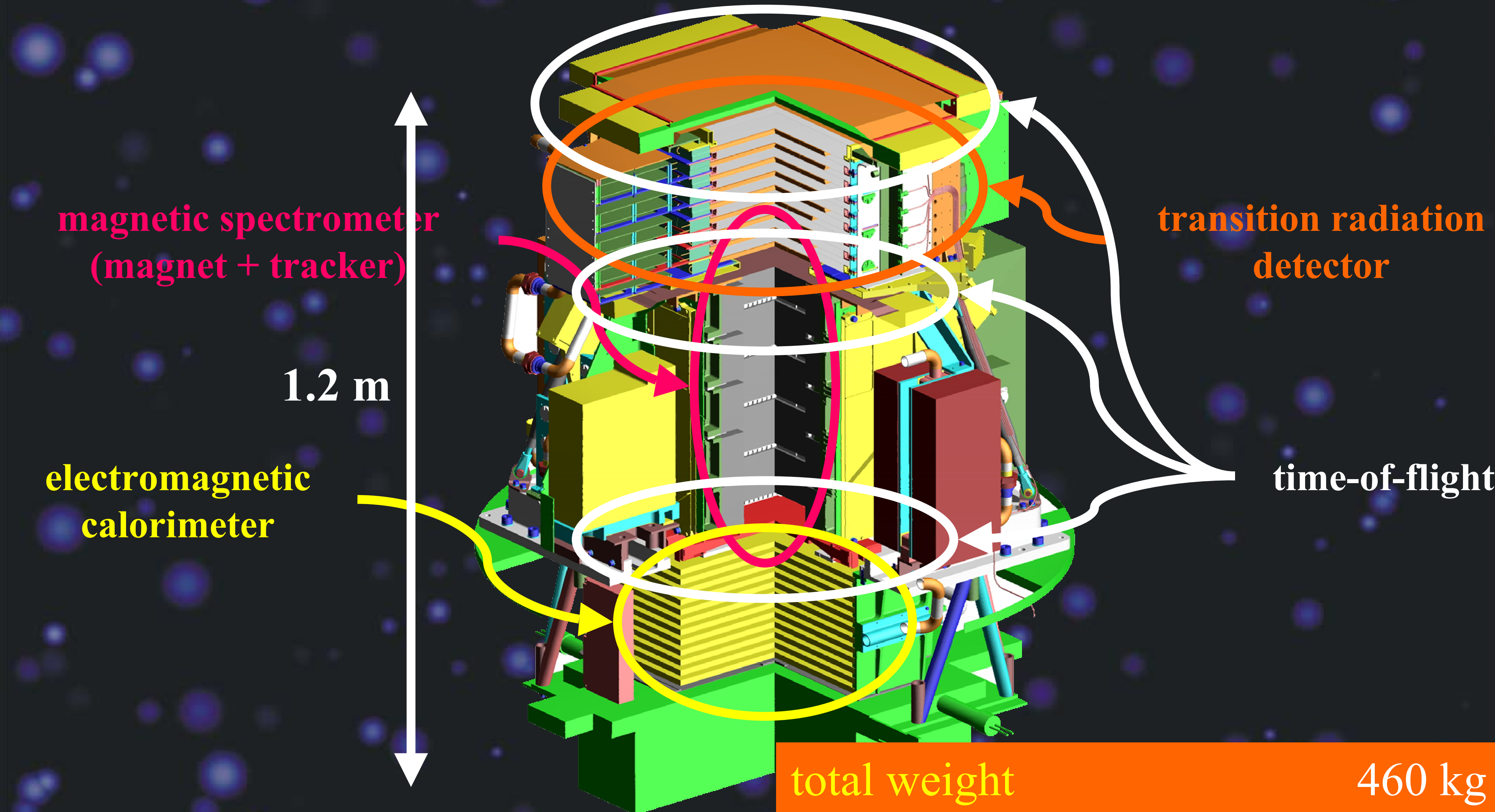
TRD

- particle identification (β vs. R)

imaging calorimeter

- interaction topology

The PAMELA instrument



total weight	460 kg
power consumption	350 W

The PAMELA ToF collaboration

Università "Federico II" and INFN, Napoli

G.C. Barbarino, D. Campana, G. Osteria, G. Rossi, S. Russo

Universität, Siegen

M. Boscherini, W. Menn, M. Simon

NASA Goddard Space Flight Center, Greenbelt (MD)

J.W. Mitchell, R.E. Streitmatter

ToF system requirements

satellite-borne experiment	⇒ low weight, low power consump-tion
space environment	⇒ mechanical endurance, reliable system, redundancy, radiation tolerant
particle identification up to 1 GeV	⇒ time resolution at least 200 ps (flight time $\geq$ 3 ns)

Attività a Napoli

Rivelatore

Progettazione e realizzazione detector

Progettazione e realizzazione meccanica

Test ambientali (vibrazioni e temperatura)

Performance test (PMT’s e scintillatori)

Integrazione sul Modello di volo

Elettronica

Progettazione Front-end (ADC 12 bit TDC 50 ps)

Progettazione interfaccia con DAQ

Progettazione trigger

Test e caratterizzazione elettronica

Integrazione sul Modello di volo

Test Trasferimento dati

Modello termico e di massa

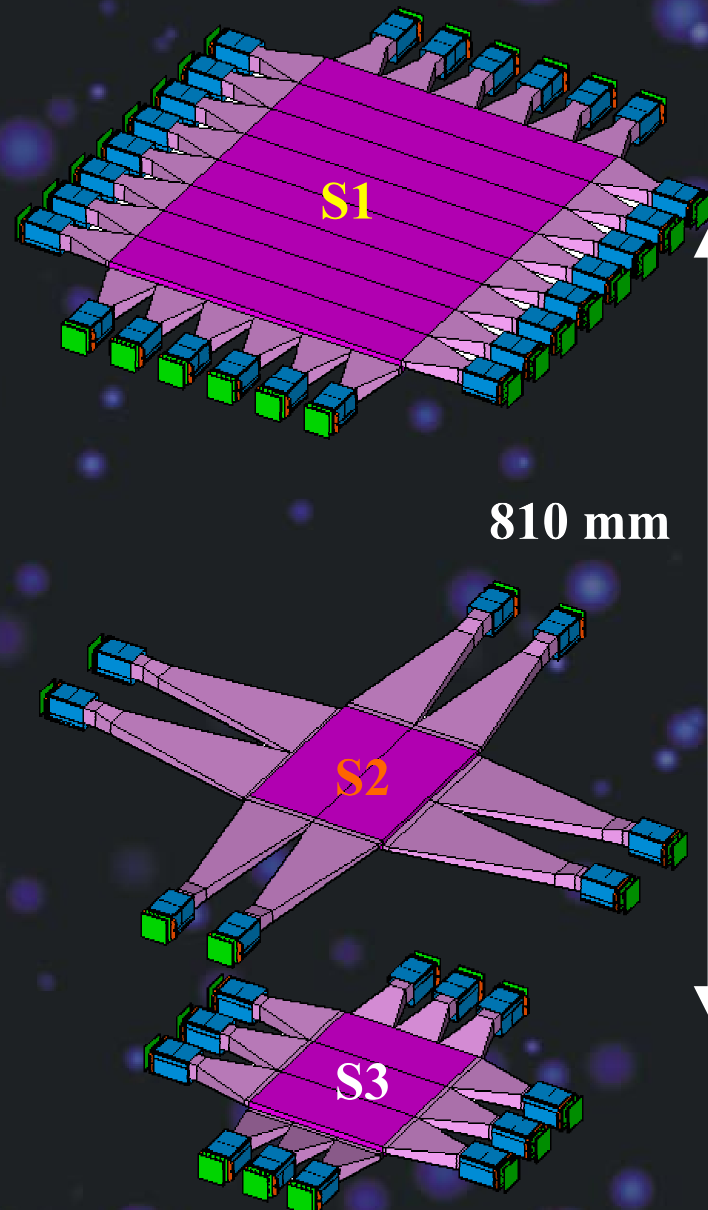
Modello tecnologico

Modello di volo

ToF detector layout

- 6 layers of scintillator strips, arranged on 3 planes
- *x* and *y* orientation of strips
- "good" match between strip section and photocathode area
- 48 channels

S11	8	330 x 51 mm²	7 mm	357 mm²
S12	6	408 x 55 mm²	7 mm	385 mm²
S21	2	180 x 75 mm²	5 mm	375 mm²
S22	2	150 x 90 mm²	5 mm	450 mm²
S31	3	150 x 60 mm²	7 mm	420 mm²
S32	3	180 x 50 mm²	7 mm	350 mm²



ToF materials

scintillator

•Bicron BC-404: organic plastic scintillator (polyvinyltoluene)

•fast (rise time 0.7 ns, decay time 1.8 ns), relatively high light yield (68% of Anthracene)

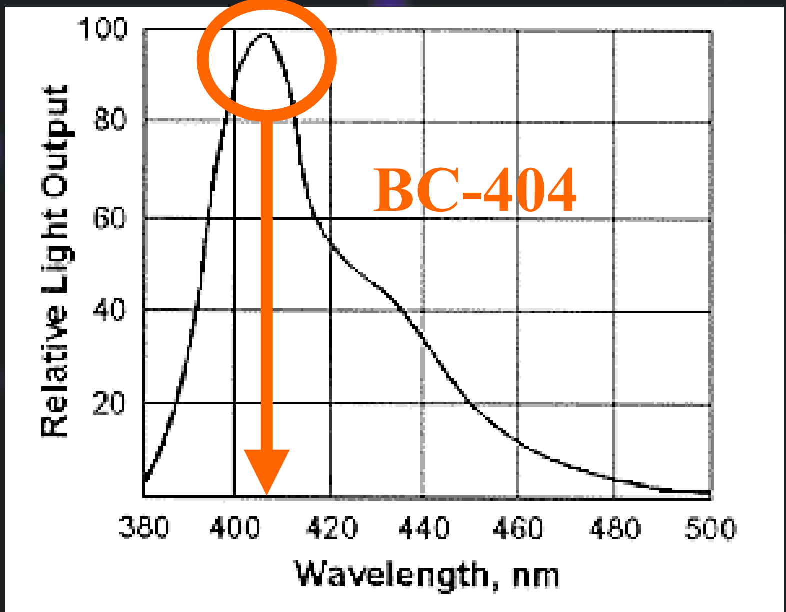
PMT

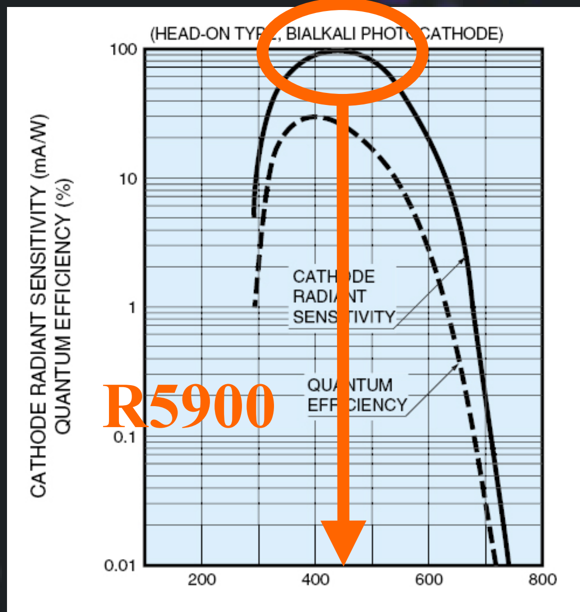
•Hamamatsu R5900: metal package, head-on PMT with section area of 25.7x25.7 mm^2

•metal channel dynode (10 st.), small size, low weight (25.5 g)

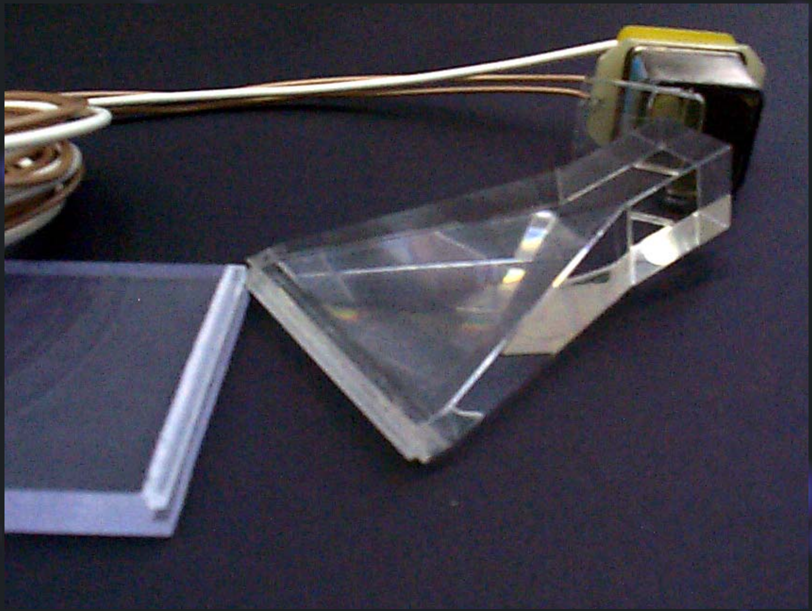
•good gain (10^6), custom power supply (30.6 mW/ch at 900 V)

•maximum of quantum efficiency (20%) at 420 nm, well matching scintillator wavelength of max. emission (408 nm)





ToF assembly (part 1)

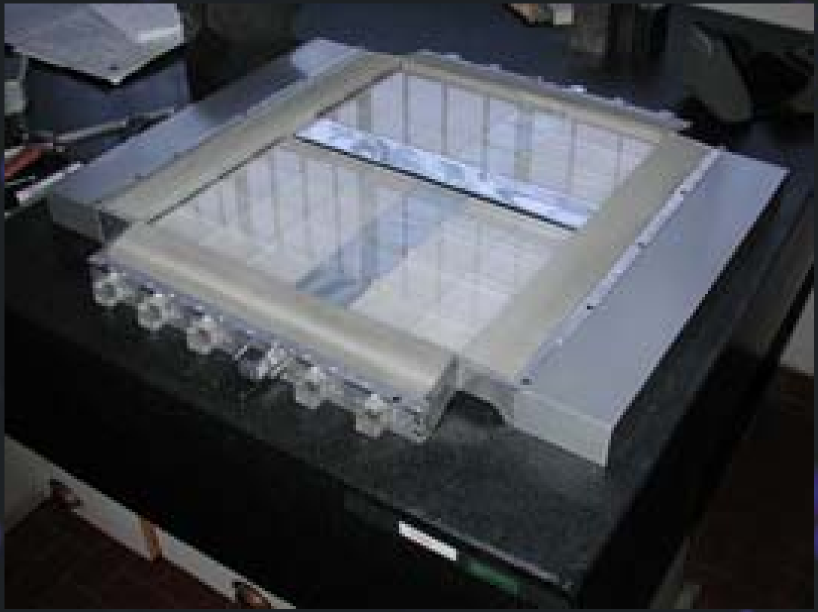


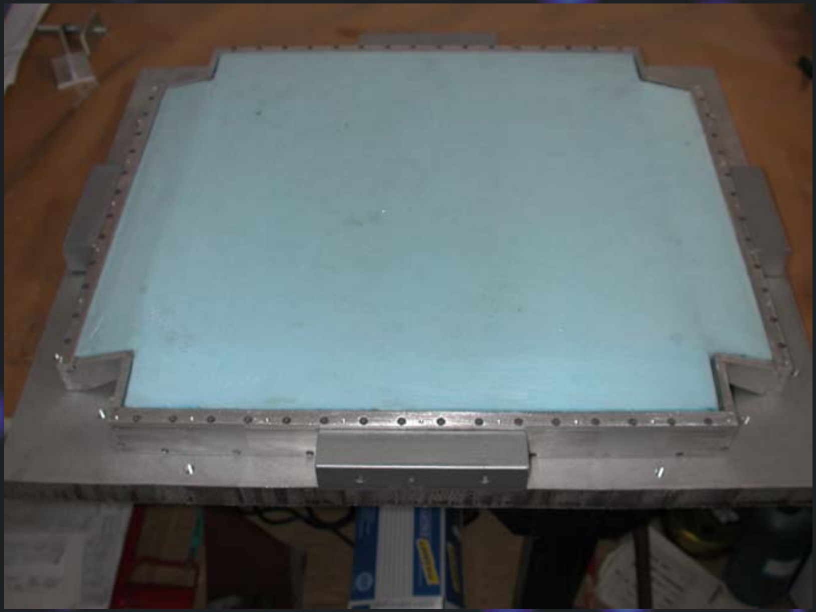
•scintillator paddle glued (BC-600 optical cement) to adiabatic, UV-transparent, plexiglas light guides

•"tooth-shaped" connection surface between scintillator and light guide to ensure greater mechanical endurance

•coupling between light guide and PMT by means of optical pads (BC-634)

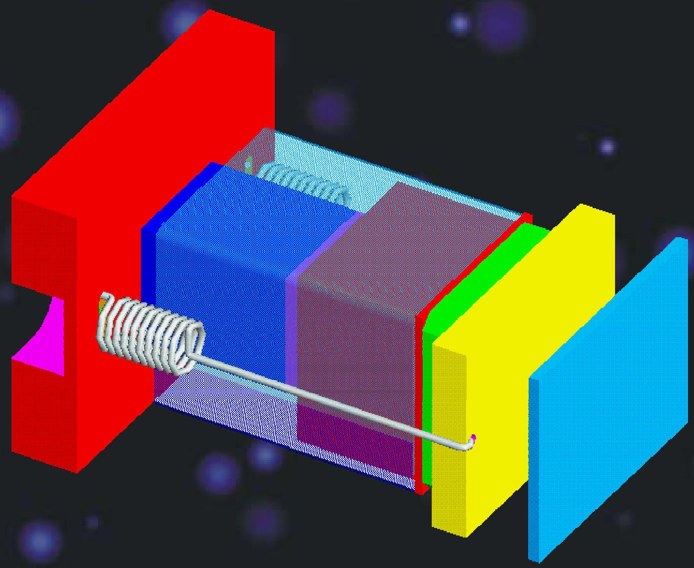
ToF assembly (part 2)





- strip and light guides are enveloped in 25 μm thin mylar foil
- last ToF plane housed directly in PAMELA base plate
- other planes are enclosed in light-proof boxes - external shell 300 μm thick Avional, filling with polyethylene

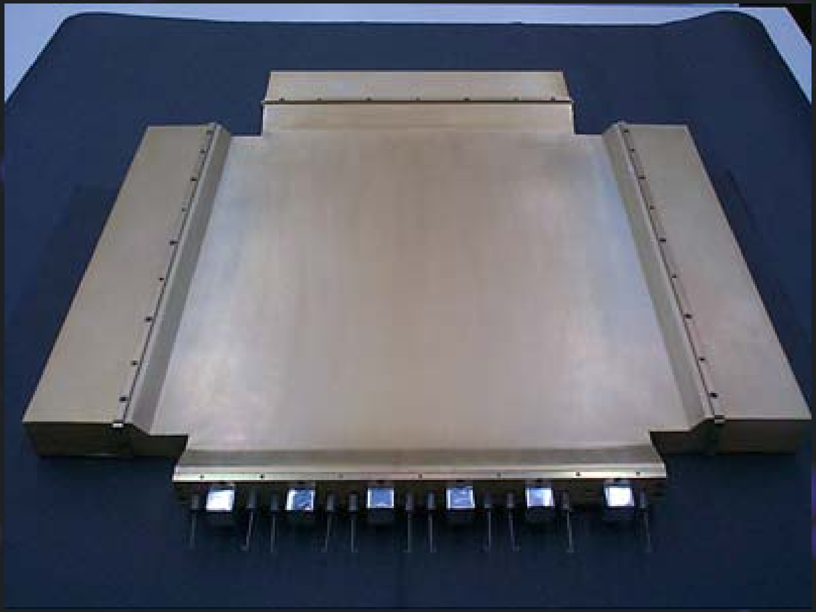
ToF assembly (part 3)

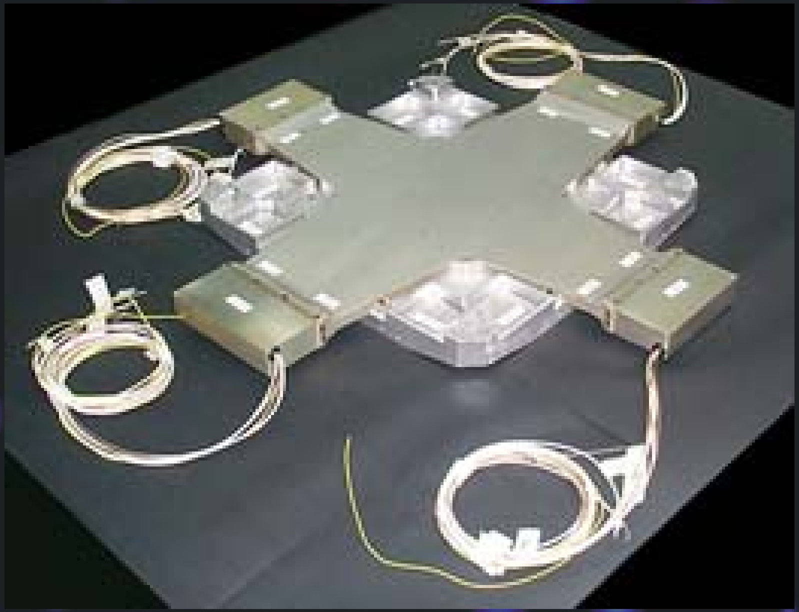


•connection between each PMT and the paddle is not stiff, but is maintained by means of a pair of steel springs, appropriately tensioned.

•vibration tests (see later) have shown that this type of fastening effectively decouples mechanically the tube from the counter, damping the transmitted vibrations

ToF assembly (part 4)





... the final result (total weight 20 kg)!

Environmental tests

Space qualification

- measurement of PMT gain at different temperatures (0-50°C)
- measurement of ground cosmic ray spectra by paddles at different temperatures (0-50°C)
- mechanical tests of single PMTs, paddles and full planes
- radiation hardness tests of electronic components

All these tests have provided satisfactory results!

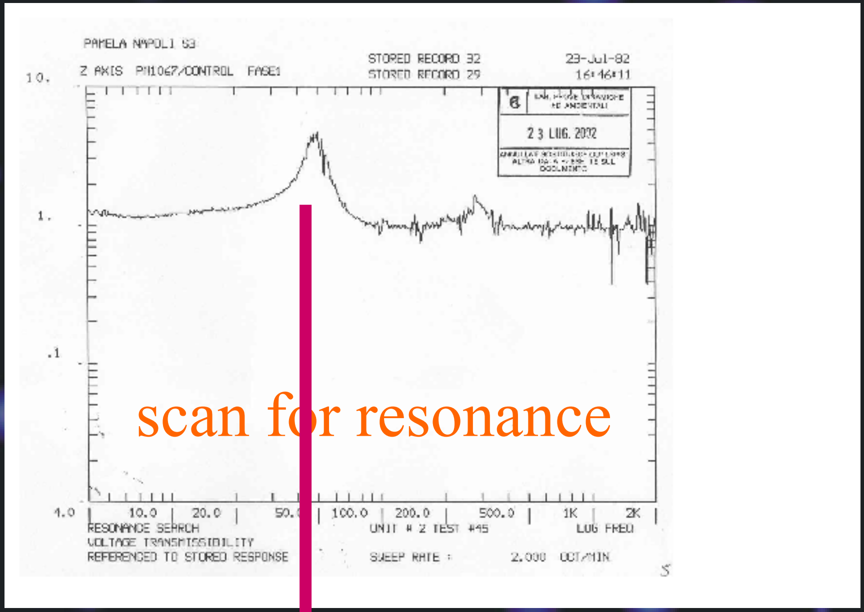
Mechanical tests (part 1)

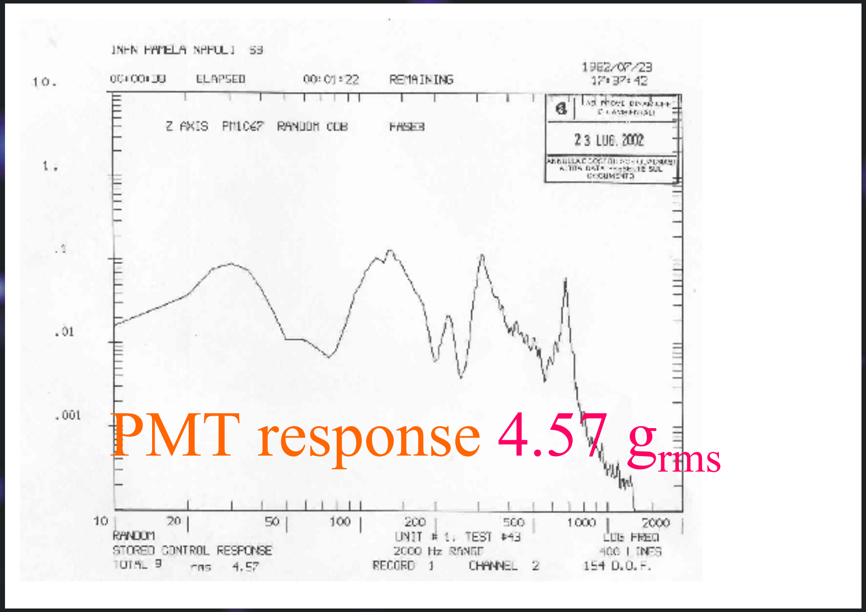
•all components of PAMELA telescope will be subject to vibrations and shocks in the launch phase of the satellite

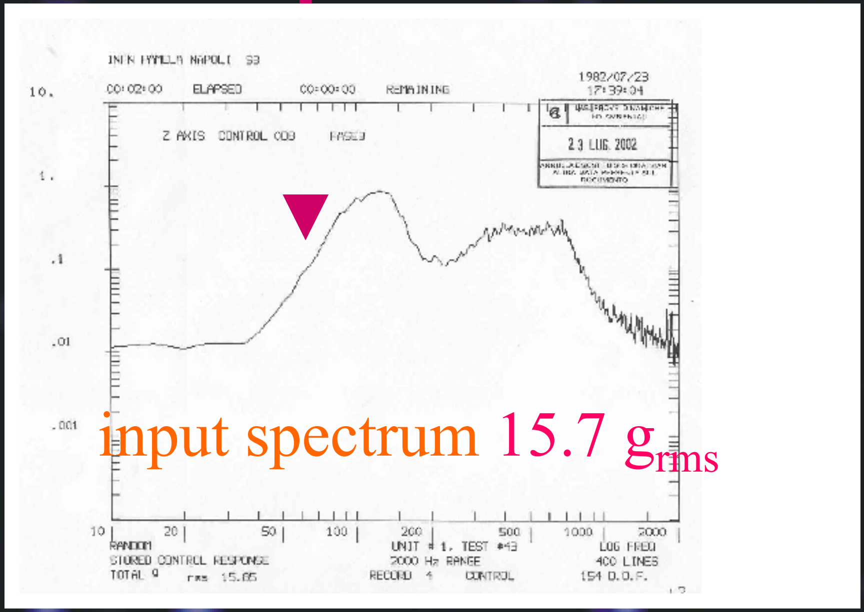
•all components must withstand this mechanical stress, because no replacement is possible

•mechanical tests have been performed on prototypes of single components and full detectors

Mechanical tests (part 2)





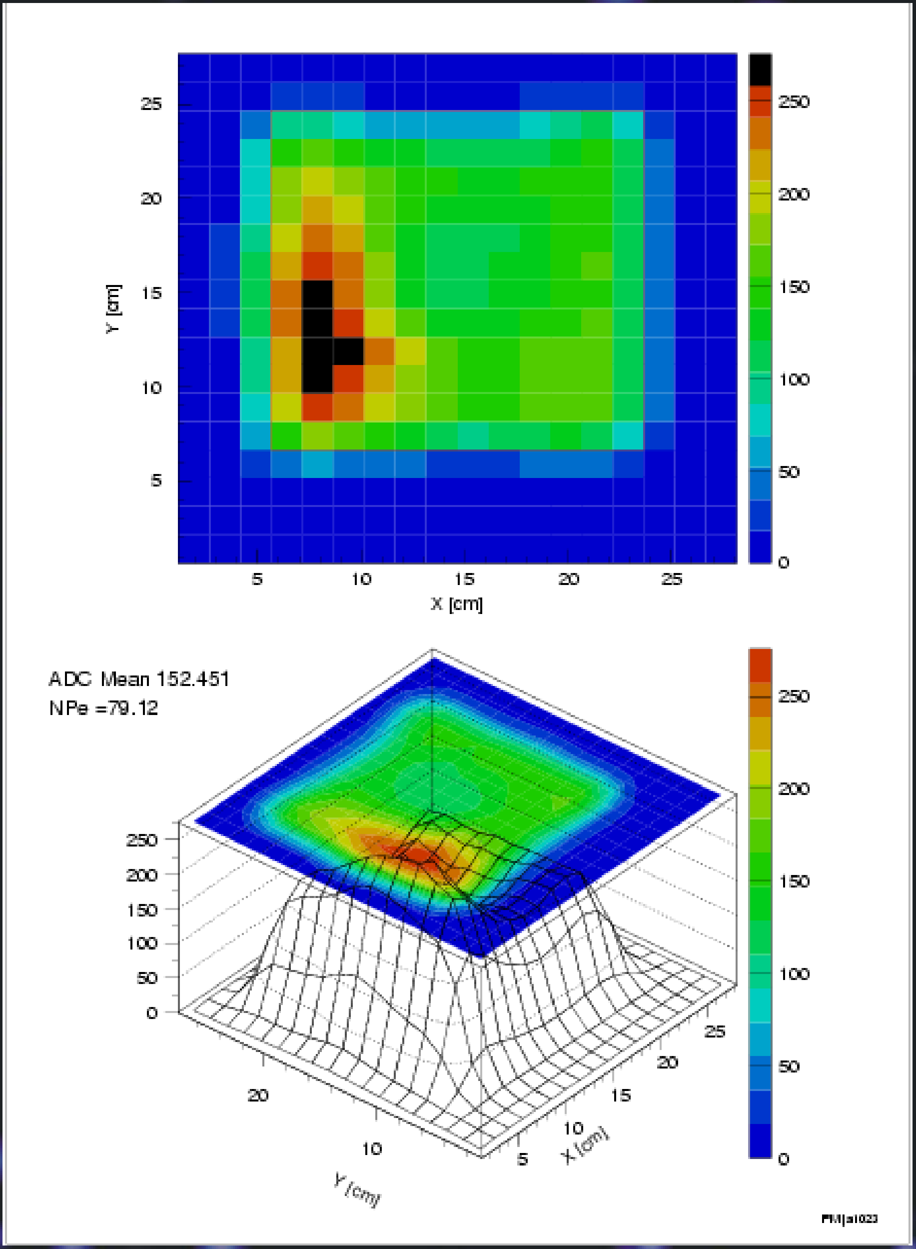


Performance tests – the PMTs

Tests were performed on PMT sample with a custom test station (black box, LED, stepper motor, etc.) to measure:

- PMT gain as a function of HV
- PMT linearity
- photocathode homogeneity

Results were used to choose PMTs for final assembly



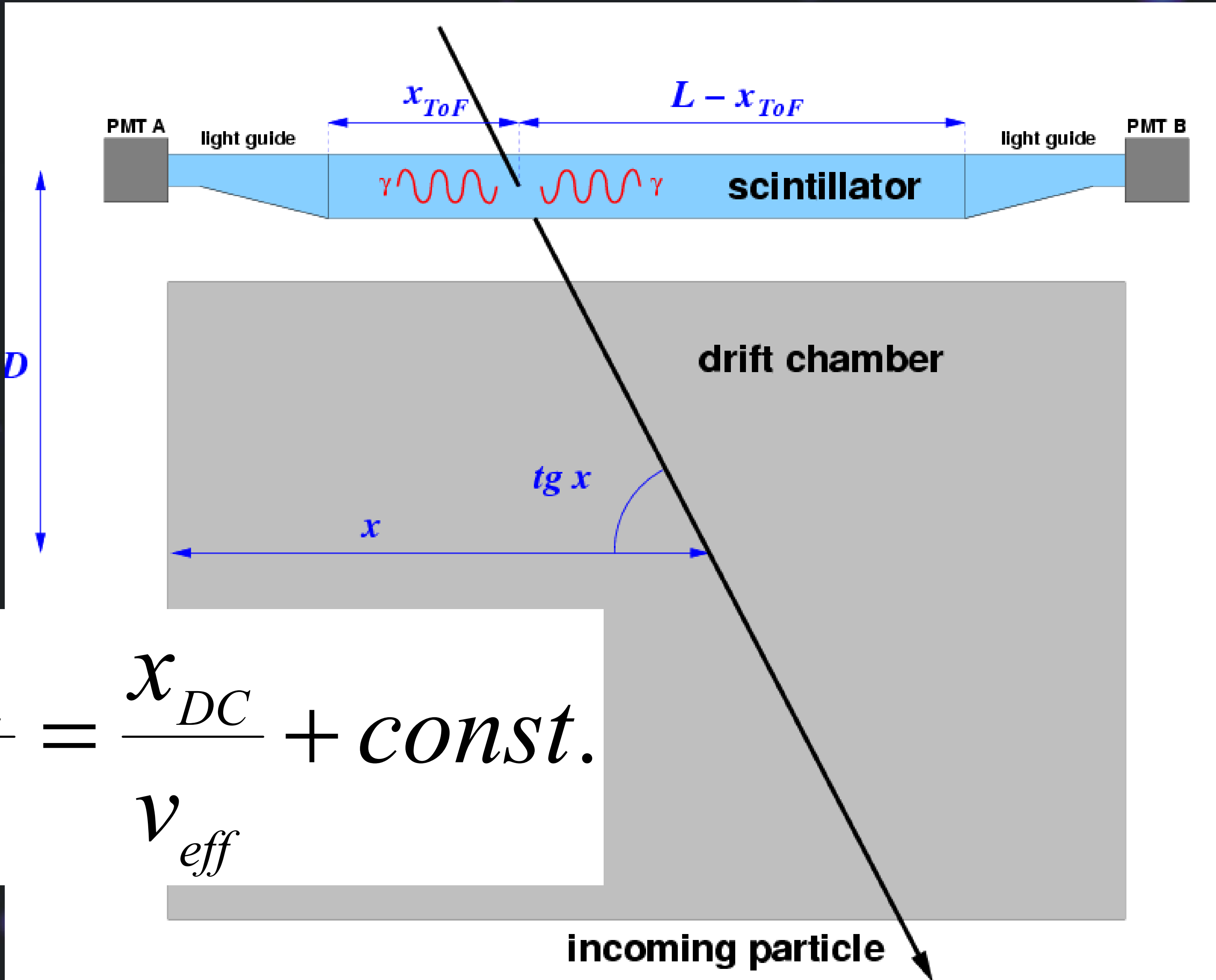
Performance tests - the scintillators

Measurement of ToF counter performance before and after all environmental tests, and before final integration on PAMELA

- measurement of ground level cosmic rays spectra

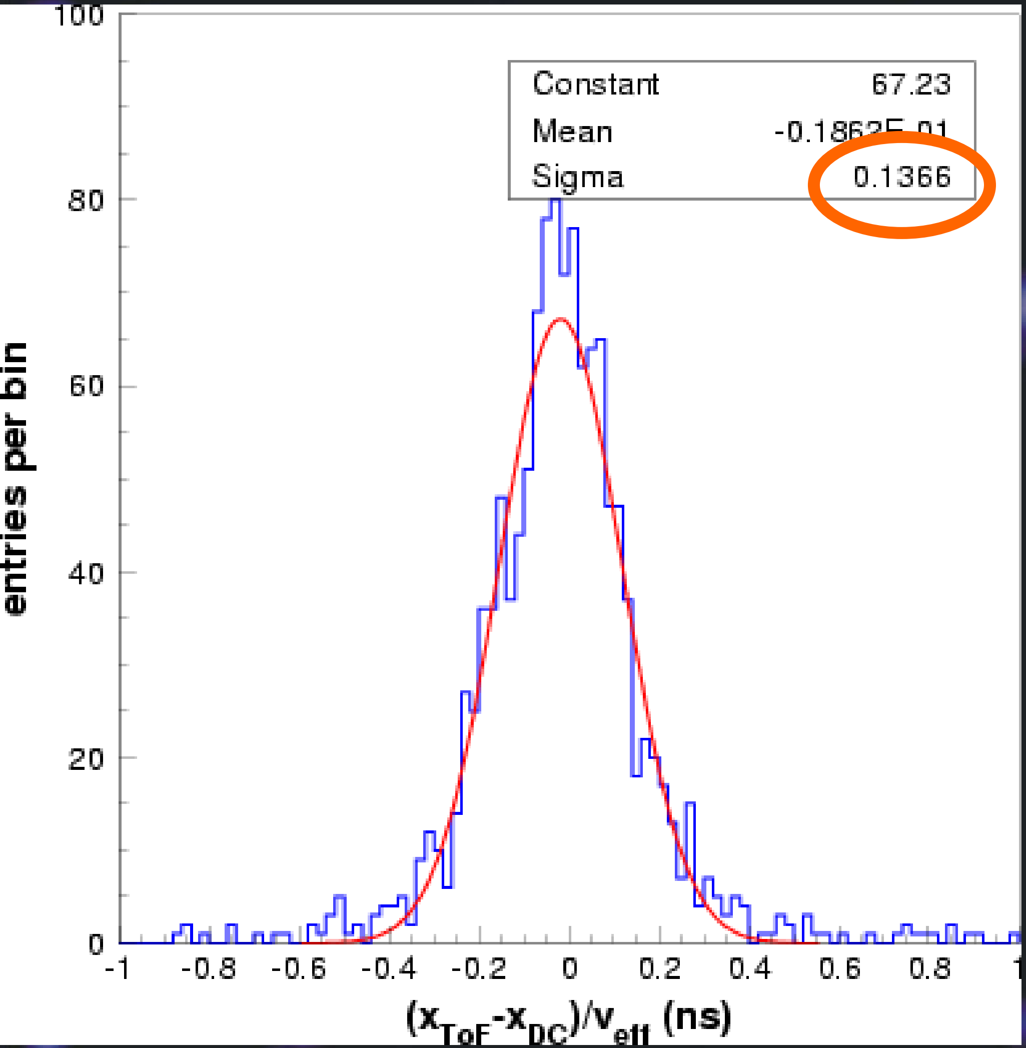
- evaluation of intrinsic time resolution

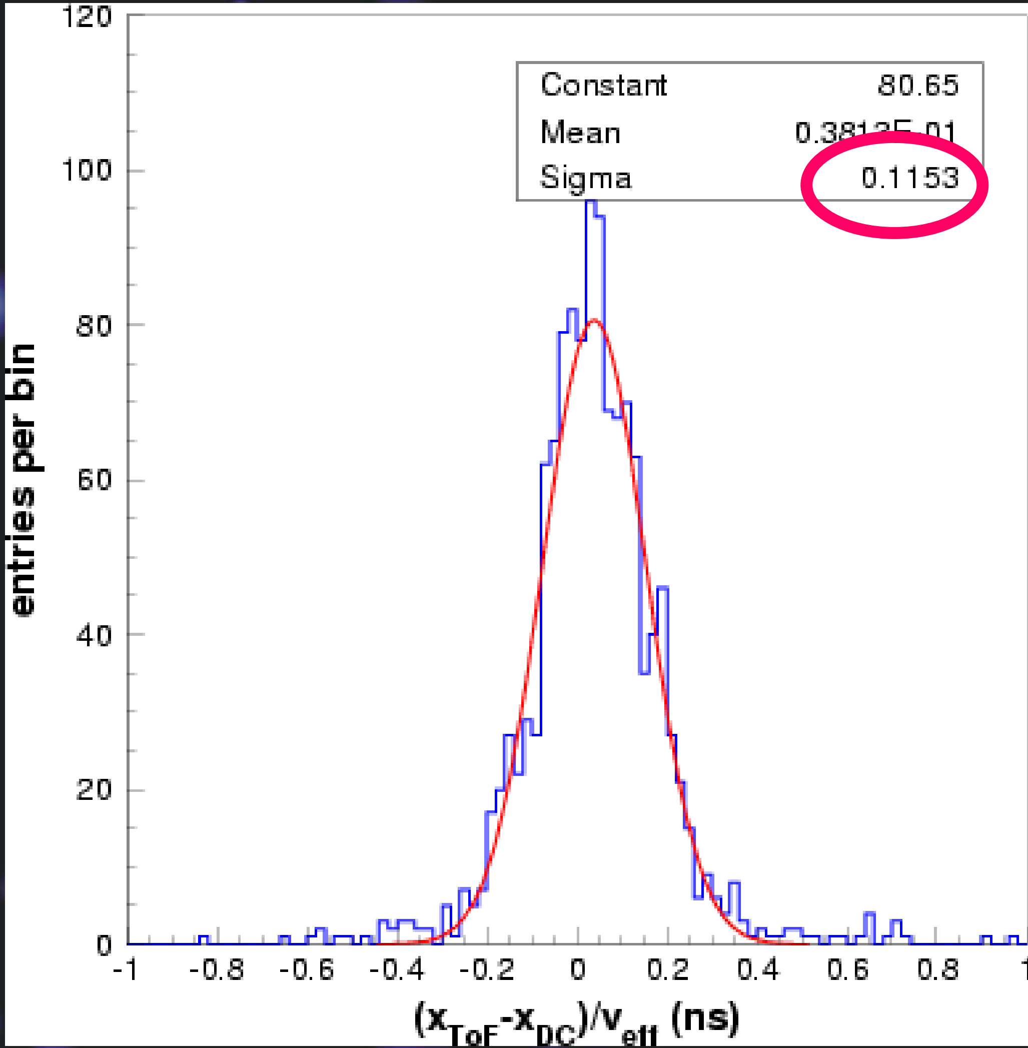
ToF tests – experimental setup



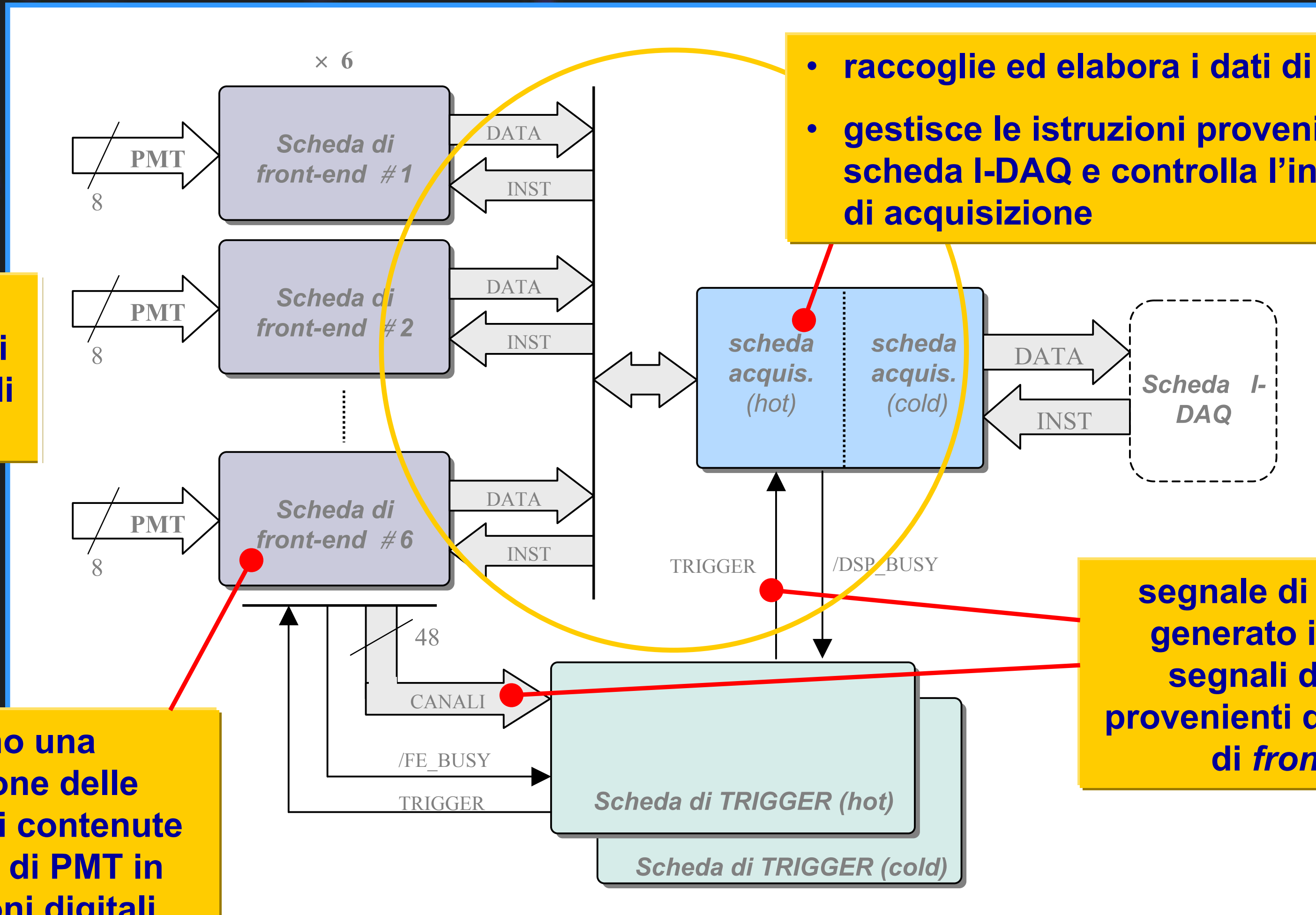
$$\frac{t_1 - t_2}{2} = \frac{x_{DC}}{v_{eff}} + const.$$

ToF tests – time-walk correction





Elettronica ToF (*Time of Flight*)



- **raccoglie ed elabora i dati di evento**
- **gestisce le istruzioni provenienti dalla scheda I-DAQ e controlla l'intero sistema di acquisizione**

48 segnali di PMTsono letti da 6 schede di *front-end*

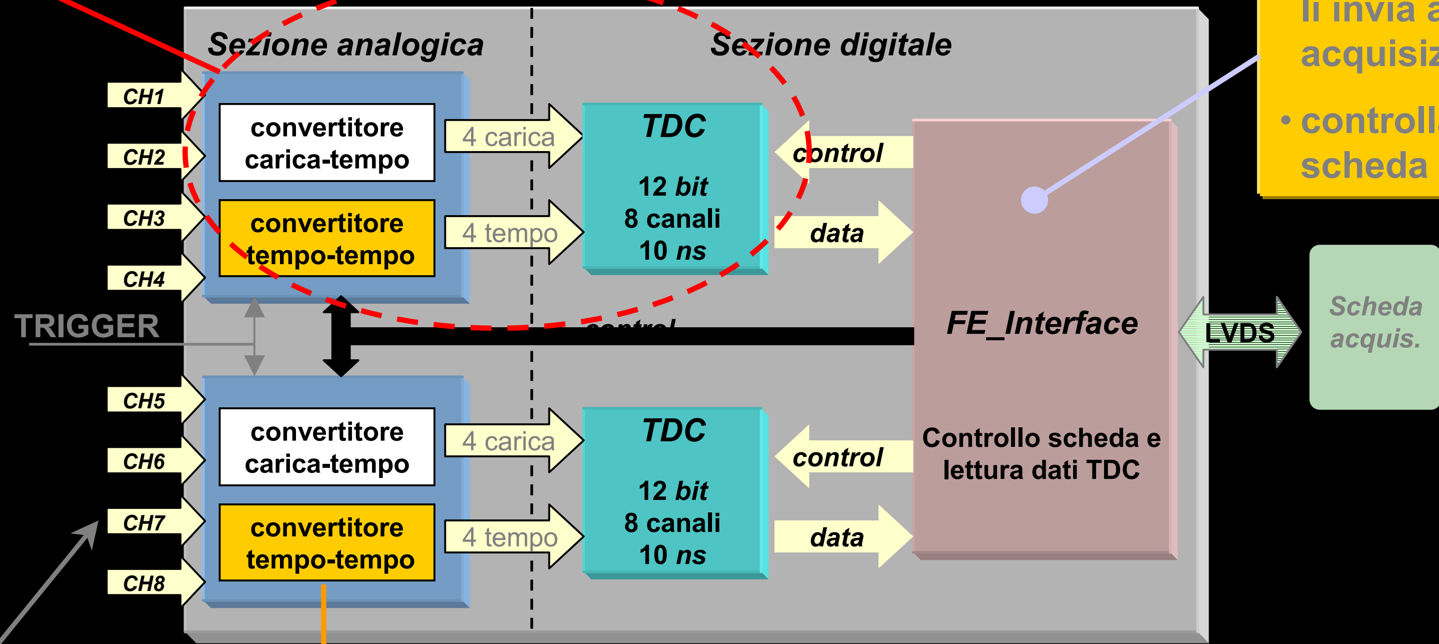
operano una conversione delle informazioni contenute nei segnali di PMT in informazioni digitali

segnale di TRIGGER generato in base ai segnali di canale provenienti dalle schede di *front-end*

- **I segnali tra le schede viaggiano su linee differenziali LVDS (*Low Voltage Differential Signal*): standard per lunghe distanze e ridotto rumore**

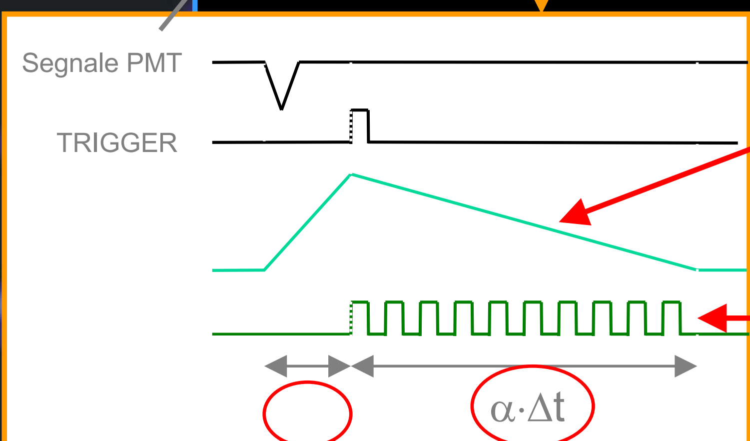
La scheda di *front-end*

Le informazioni di carica e tempo dei segnali di PMT sono digitalizzate



dispositivo di interfaccia

- racccoglie i dati dei TDC e li invia alla scheda di acquisizione
- controlla le operazioni della scheda di *front-end*



Espansore temporale a doppia rampa

coefficiente di espansione: $\alpha \cong 200$

Conteggio TDC

(*Time to Digital Converter*)

frequenza =100 MHz (T_{TDC} =10 ns)

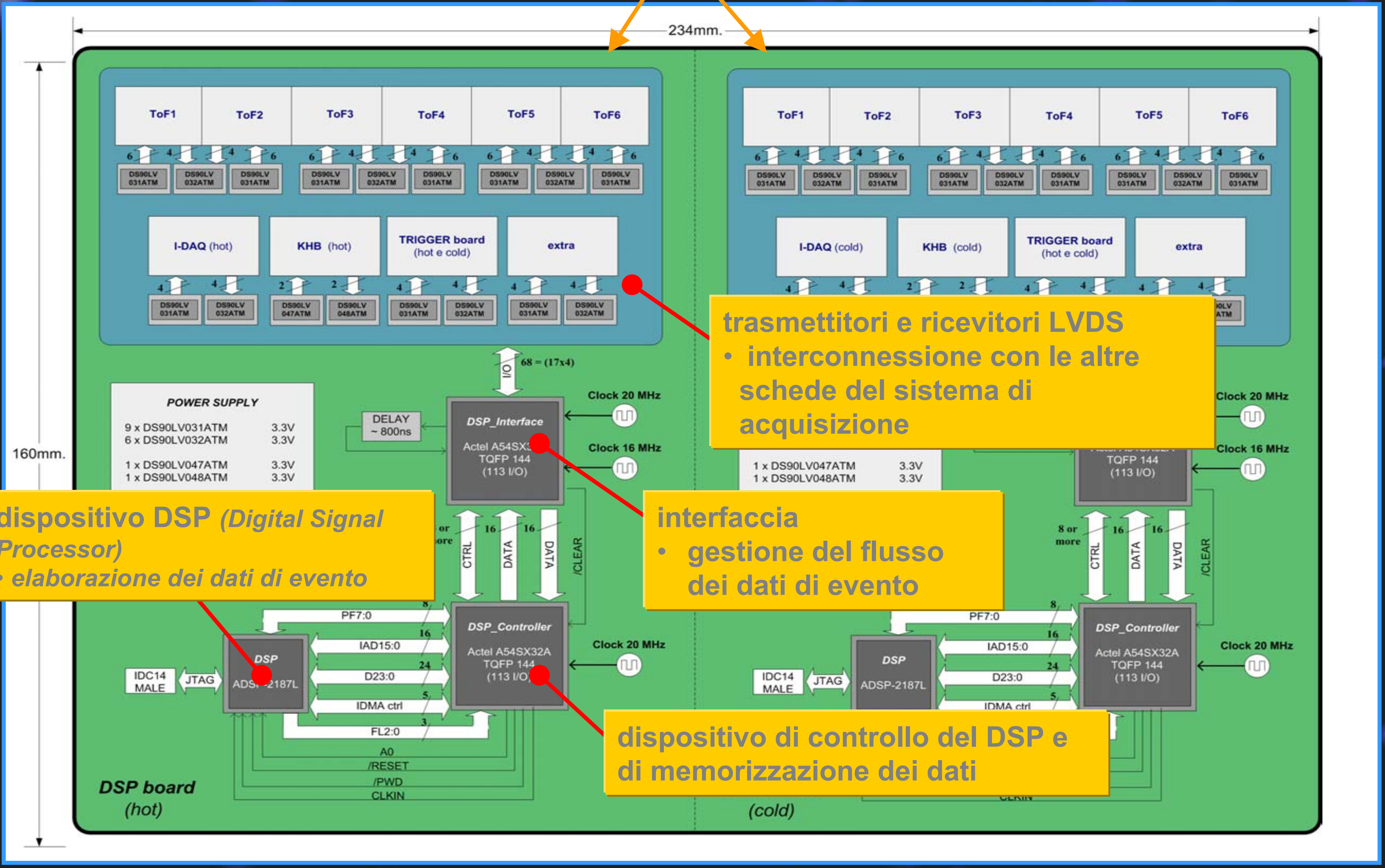
Risoluzione temporale

10 ns /200 $\cong$ 50 ps

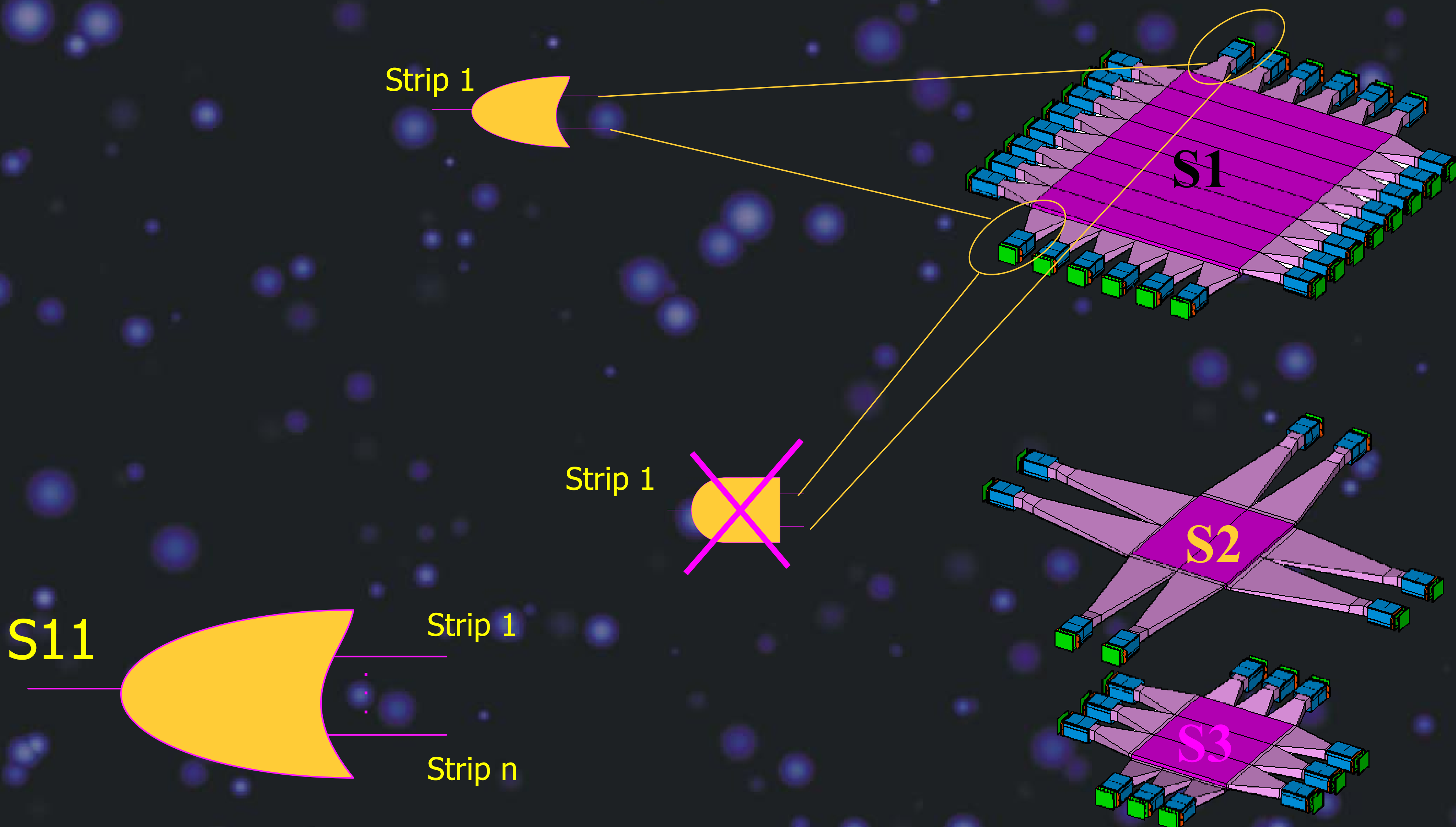
sulla misura di Δt

La scheda di acquisizione del ToF

- **Progettazione architettura *hardware***
- **affidabilità: la scheda è completamente duplicata**



Segnali per il trigger



Il trigger dell'esperimento – 1

le equazioni logiche

(S11 **OR** S12) **AND** (S21 **OR** S22) **AND** (S31 **OR** S32)

(S11 **AND** S12) **AND** (S21 **AND** S22) **AND** (S31 **AND** S32)

20,5 cm² sr

(S21 **OR** S22) **AND** (S31 **OR** S32)

(S21 **AND** S22) **AND** (S31 **AND** S32)

S12 **AND** (S21 **AND** S22)

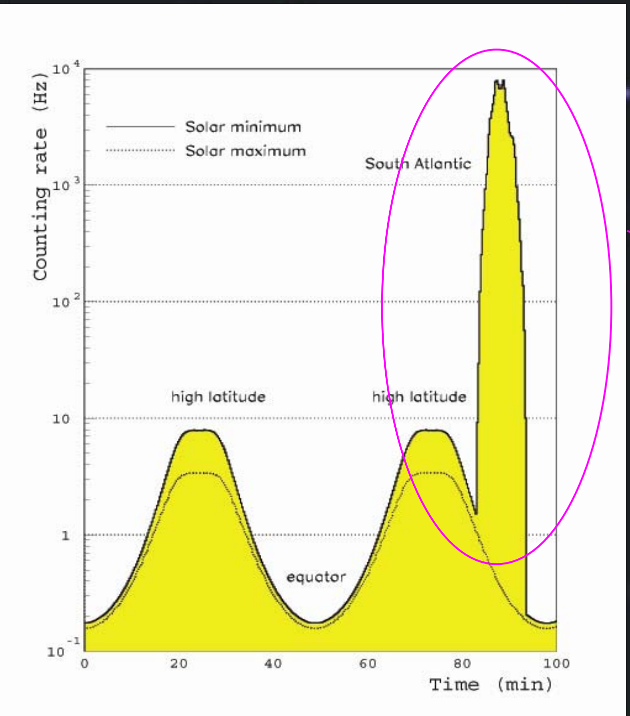
600 cm² sr

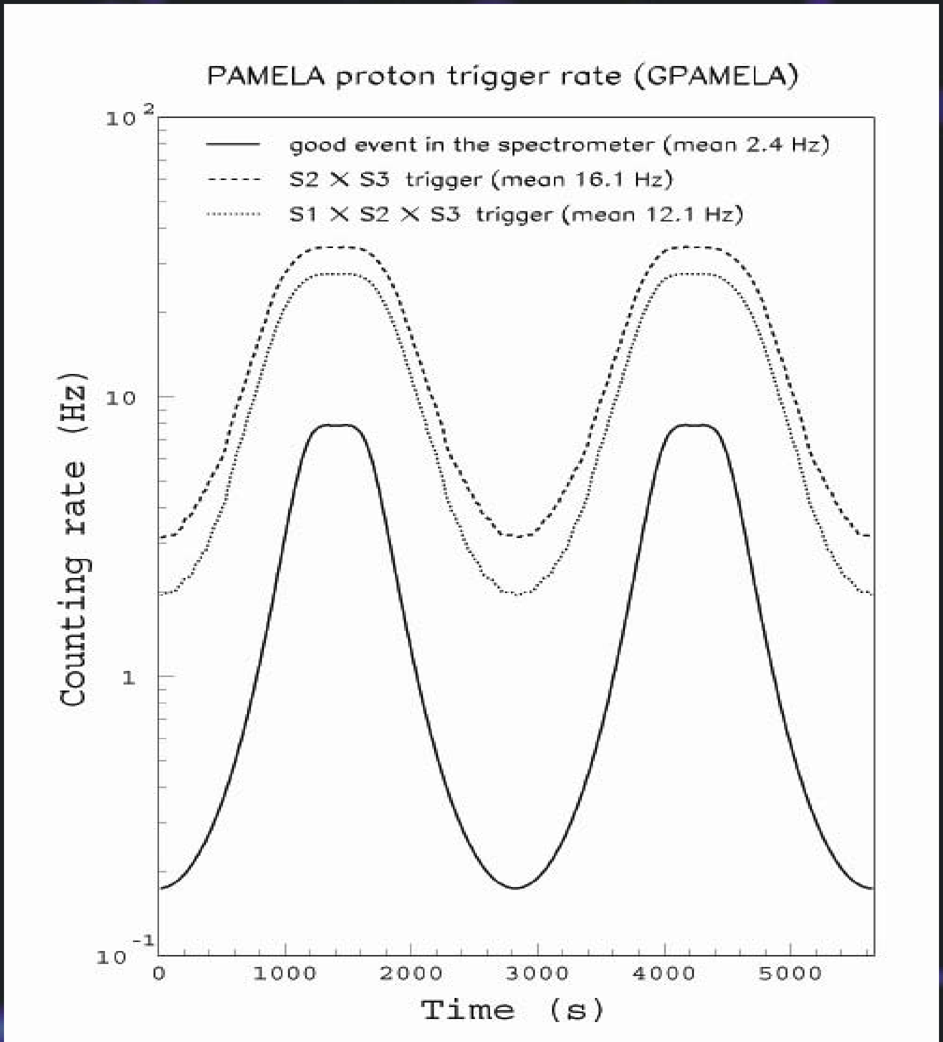
S4

CALORIMETRO (soglia in energia)

TOF + S4 + CALO

Il trigger dell'esperimento – 2
conteggi aspettati





(S11 **OR** S12) **AND** (S21 **OR** S22) **AND** (S31 **OR** S32)

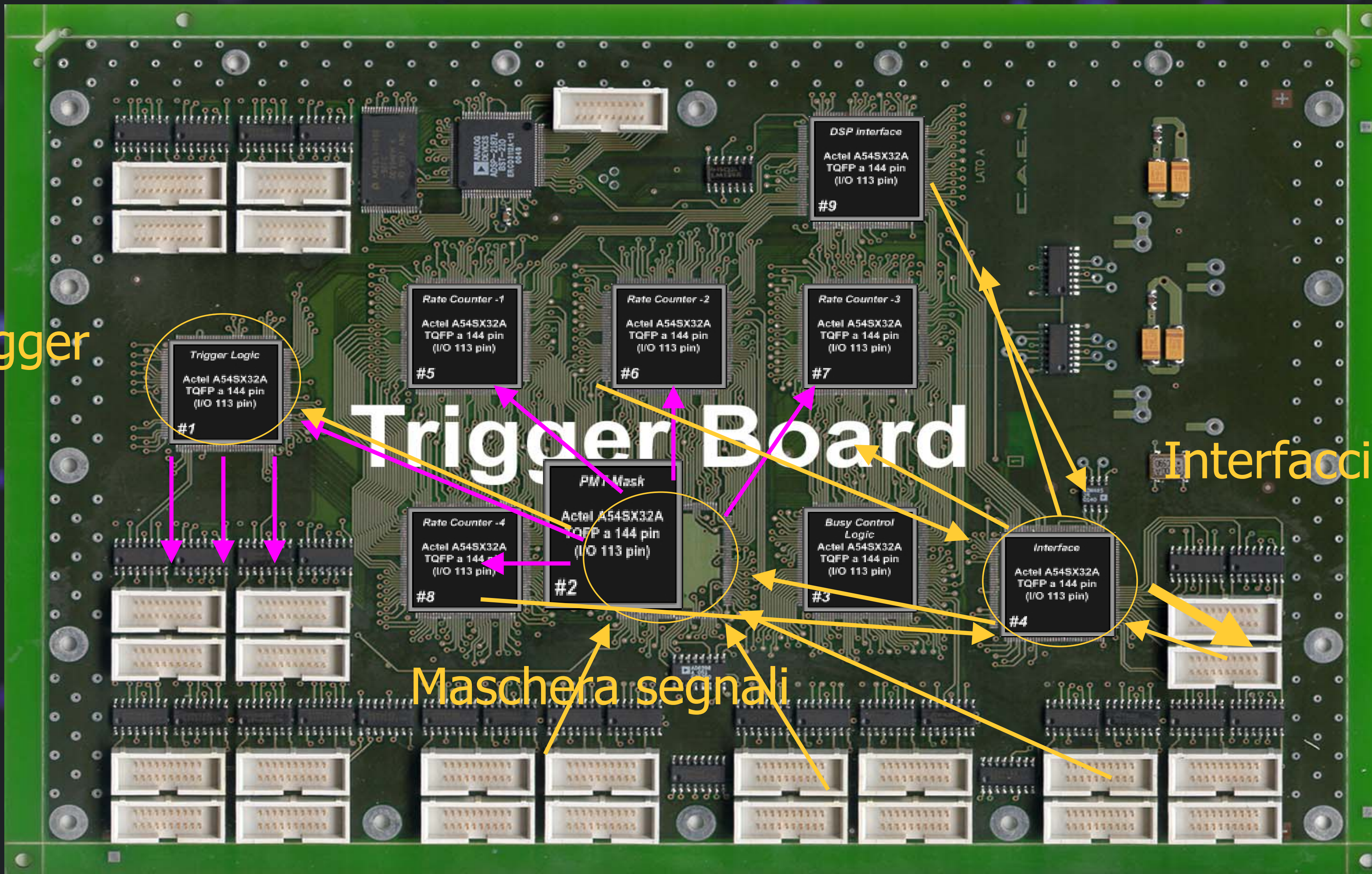
L'elettronica di trigger - 2

I componenti

Acquisizione

Start-up

Trigger



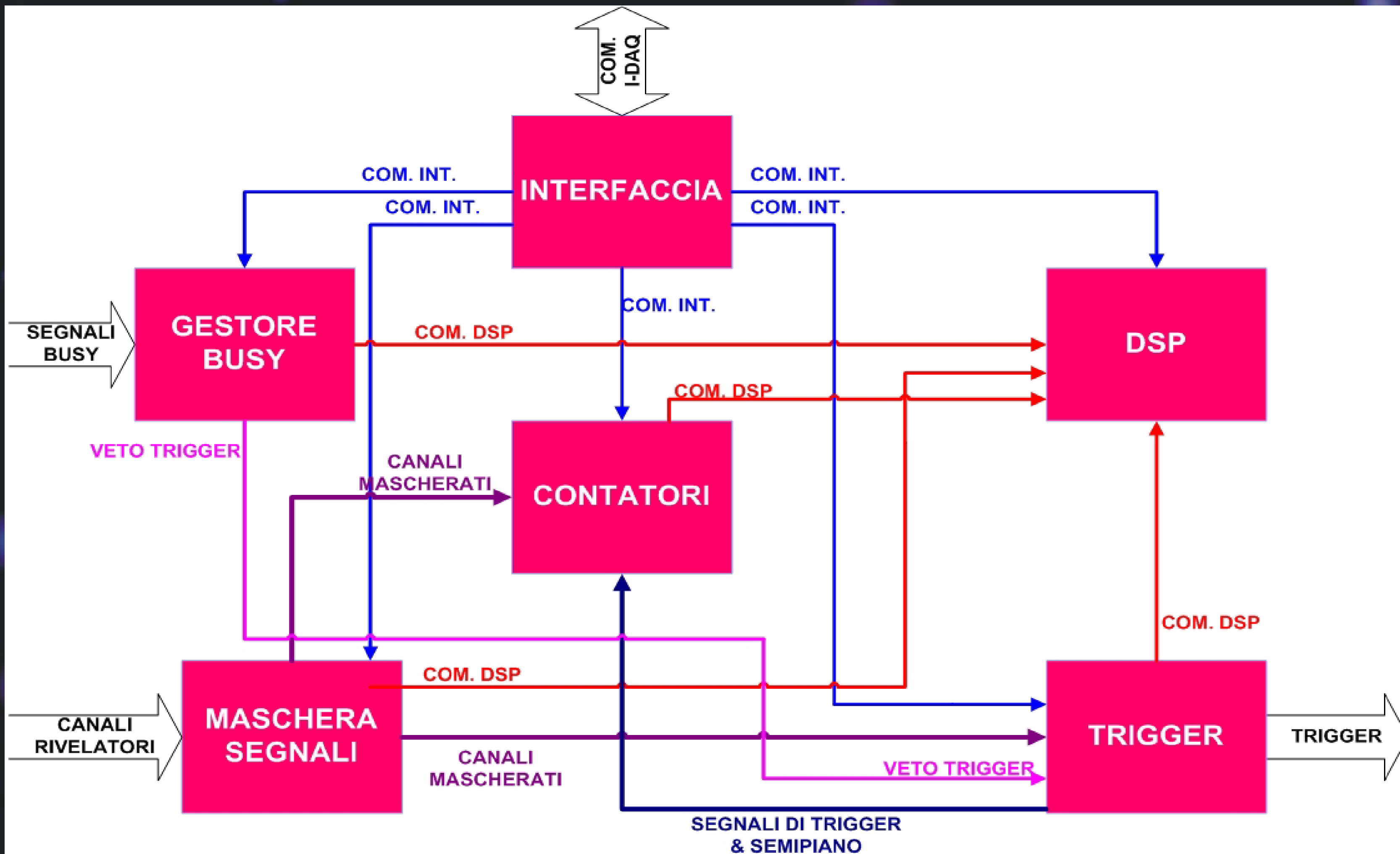
Interfaccia

Maschera segnali

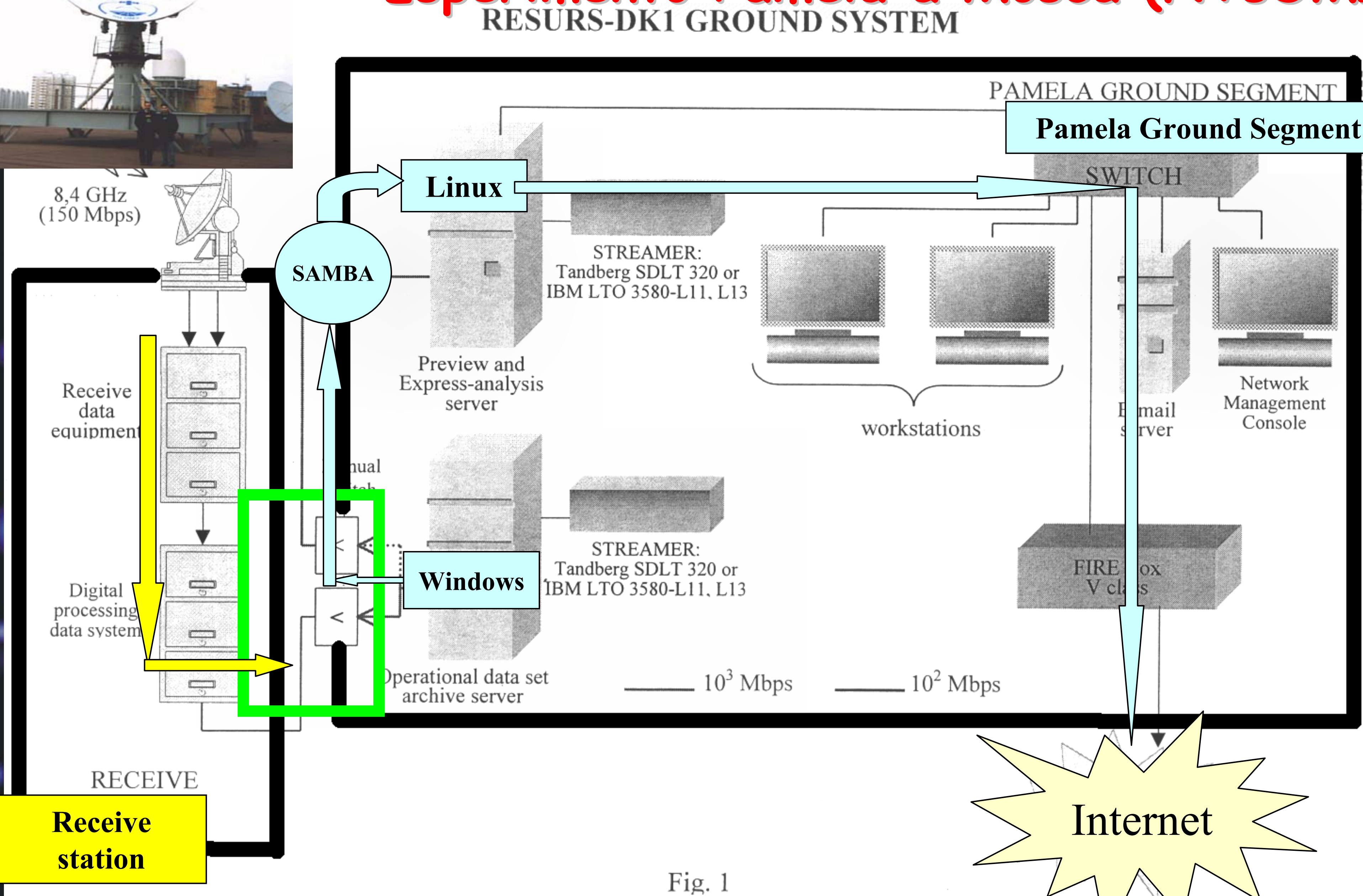
L'elettronica di trigger - 3
Lo schema a blocchi

Modalità DSP

Modalità RAW

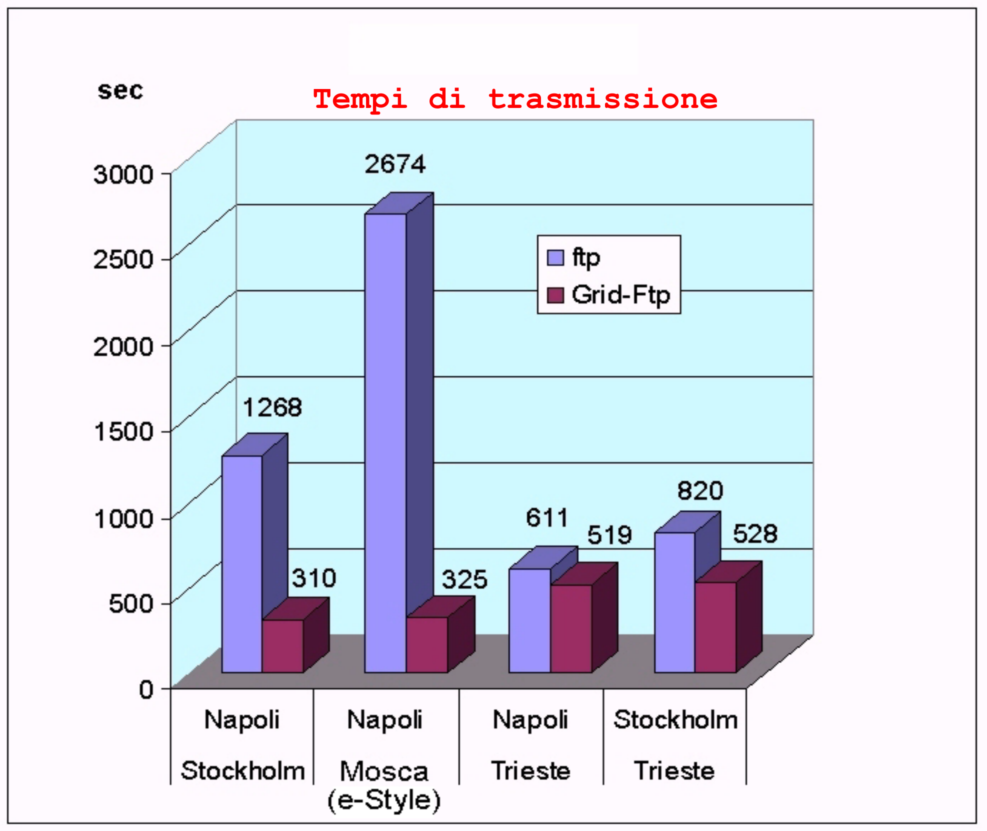


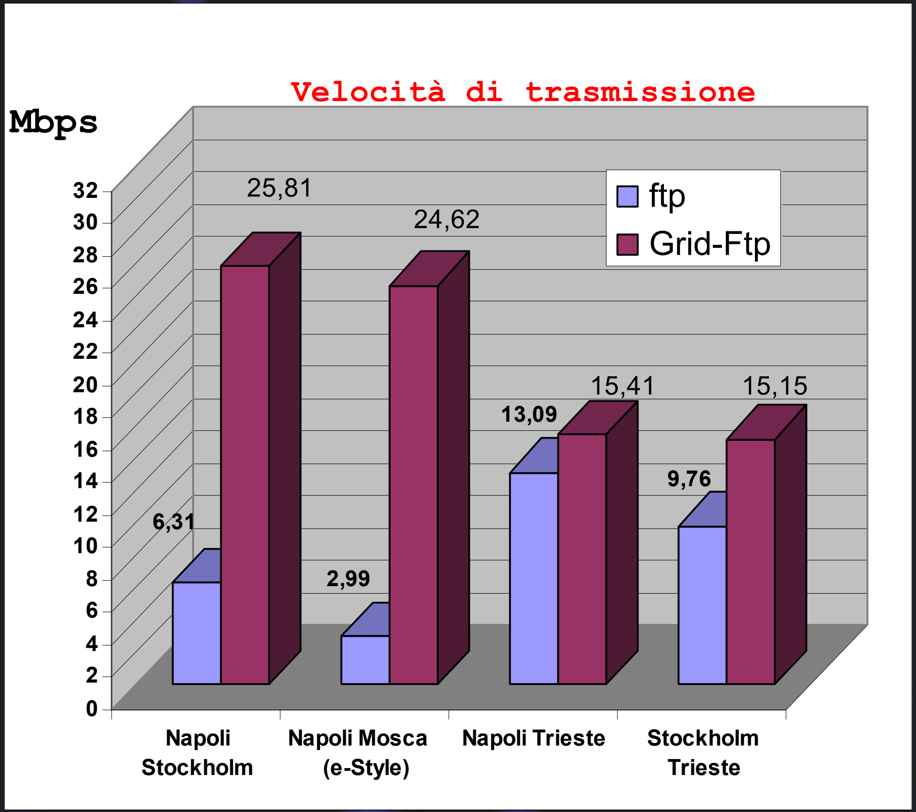
Progetto stazione di ricezione dati Esperimento Pamela a Mosca (NTsOMZ)



Test finali trasferimento file da 1 Gbyte con GridFtp

- 5'25" (contro 44'34" con Ftp) per 1 GByte da Mosca a Napoli
- 5'10" (contro 21'8" con Ftp) per 1 GByte da Stoccolma a Napoli



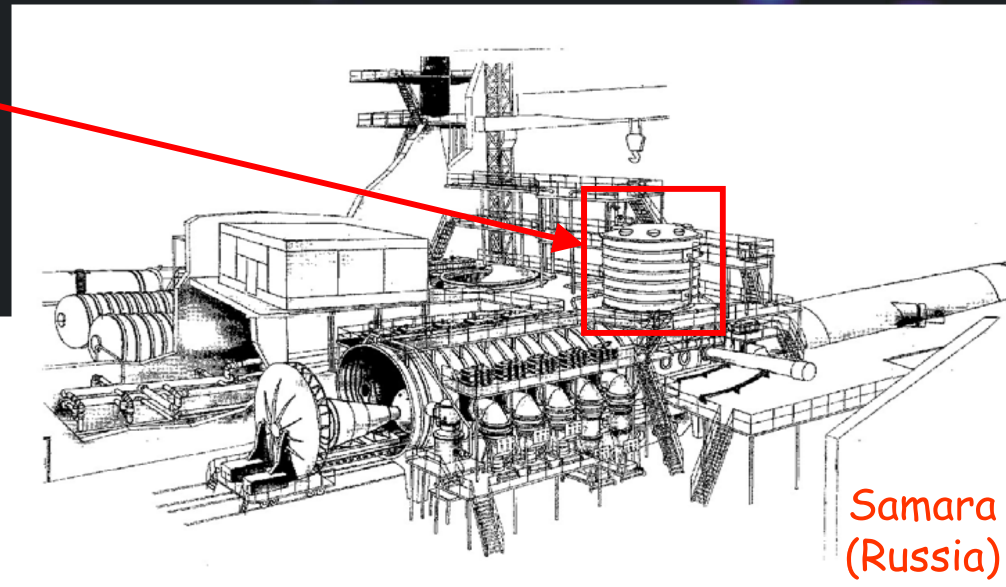


CHEP2003

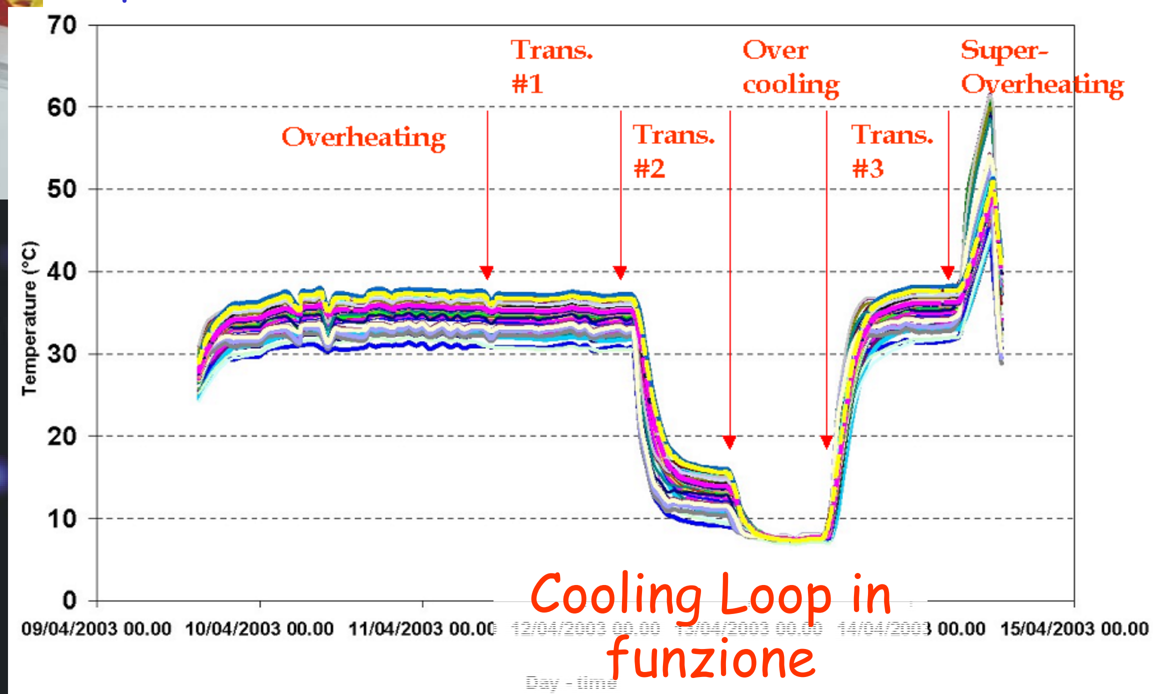
Test Termico

MODELLO di MASSA

La camera del vuoto

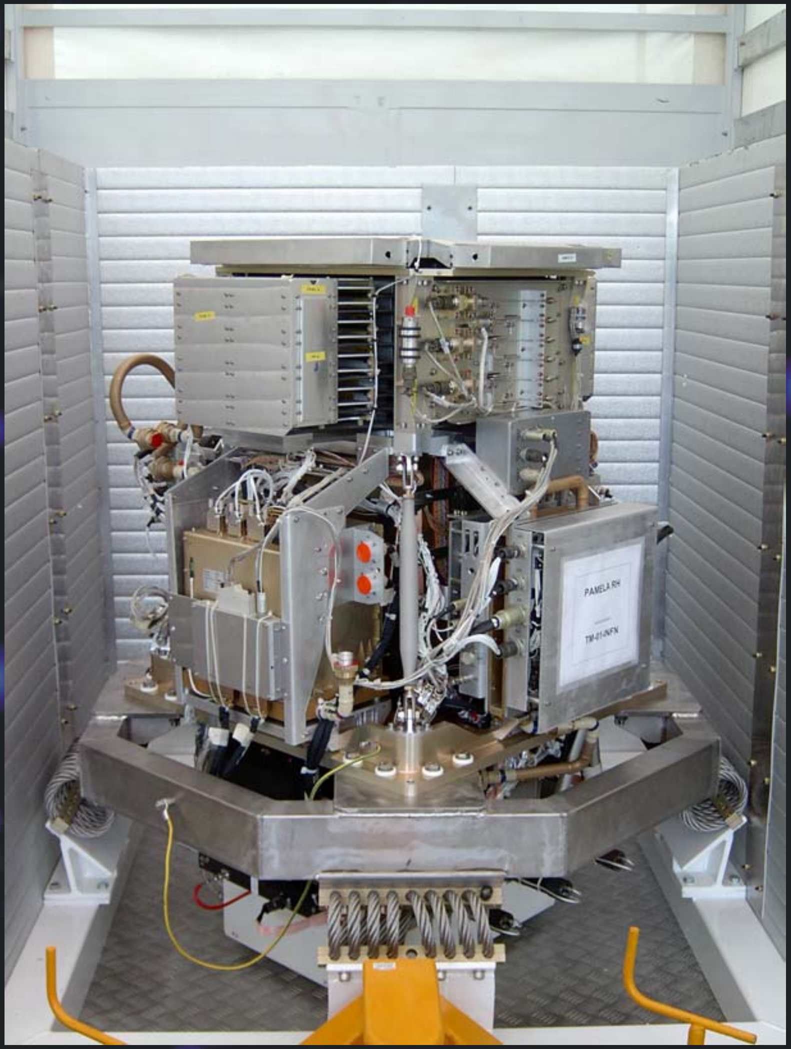


Condizioni di pressione e escursioni termiche simili a quelle di volo!!!

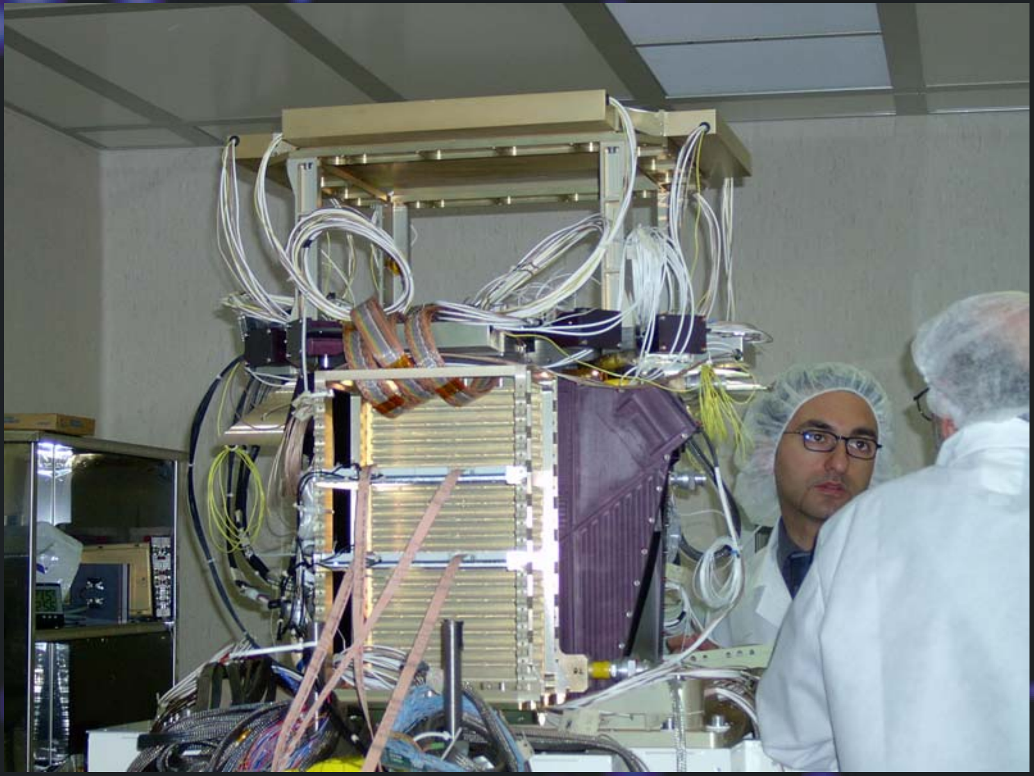


8 < T < 38 °C

Technological Model at "Roma2"
before delivery to Samara [Apr. 2004]



Flight Model at "Roma2" May 2004



Status attività a Napoli

Rivelatore

✓Progettazione e realizzazione Detector

✓Progettazione e realizzazione Meccanica

✓Test ambientali (vibrazioni e temperatura)

✓Performance test (PMT's e scintillatori)

✓Integrazione sul Modello di volo

Elettronica

✓Progettazione Front-end (ADC 12 bit TDC 50 ps)

✓Progettazione interfaccia con DAQ

✓Progettazione trigger

Test e caratterizzazione elettronica

Integrazione sul Modello di volo

Test Trasferimento dati

✓Modello termico e di massa

✓Modello tecnologico

Modello di volo

Attività 2004-2005

- Completamento modello di volo in Italia
- Integrazione modello di volo presso TSKB (Samara)
- Lancio (inizio 2005)
- Presa dati