Results and perspectives from Alteino and Si-Rad experiments

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Current and future detectors

Sileye-3/Alteino       Lazio       Altea

Pamela               Sirad
Observations at the minimum of 23° solar cycle

Satellite

Mir

ISS
Alteino Long Term cosmic ray measurements on board the ISS

• In response to AO 2004 ESA (AO2004-067)

• ESA opportunity to start operations in the framework of the ESA LDM (Long Duration Mission) – 4/5/2005

• Replanned on increment 12 (Dic 2005-Mar 2006)

• Next operations on increment 13 (Apr 2006 – Oct 2006)
ALTCRISS Collaboration

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Dr. Christer Fuglesang, EAC
Dr. Cesare Lobascio, Aleniaspazio
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Sileye/Alteino institutions

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Scientific Objectives

• Measure of cosmic ray abundances and radiation environment on board the ISS (p-Fe >50-100MeV/n)

• Long term monitoring of solar modulation and solar particle events.

• Study of the effectiveness of different shielding materials on board the ISS – in parallel to Monte Carlo and Beam Test studies

• Measures with passive dosimeters (JAXA, DLR, Fed II, INFN)

• Joint measures with Matroska, Pamela and Altea
Why Shielding?

• A vast number of studies have been devoted to the subject of radiation shielding.
• Different materials have been proposed. Hydrogenous materials have the best characteristics.
• Active (superconducting magnets) shielding has also been proposed (ESA TT 2002).
• Needed for interplanetary or lunar missions outside the magnetosphere.
Sileye-3 Alteino

- Placed on ISS in 2002 (ISM-1): operational for 6 days
- Reswitched on in 2005 (ISM-2): operational for 4 days
- Long term measurements (ALTCRISS): 3 months until now
Silicon detector:

- 8 silicon planes \((4x, 4y)\)
- 32 strips strip pitch 2.5 mm, 8x 8 cm\(^2\), thickness 380 µm
- Total 256 Independent channels
- Triggered by two scintillators \((E_{\min} = 40\text{MeV/n})\)
- Geom Fact: 24 cm\(^2\) sr
- Bidirectional
- Max Field of view 39\(^o\)
- The front-end is a developed version of two 16 channels CR1 chip with a peaking time of 2 µs; a sensitivity of 5 mV/MIP and a maximum counting rate of 30 kHz.

Left: AST detector tower open (without readout electronics): it is possible to see the stack of silicon detectors and the top scintillator (the detector is upside down). The bottom scintillator has been removed for clarity. Right: One of the 8 silicon detector boards (X view). It is possible to see the segmentation of the 32 strips of the detector. (Photos taken during assembly in the clean room facilities of Tor Vergata.)
Single track (Ne) event
(ADC Channels)

Shower event (ADC Channels)
Mission timeline

- 24 Dec 2005  Begin measurements – PIRS module – no shield
- 26 Dec 2005  Data sample received
- 06 Gen 2006  Poliethilene shielding inserted
- 08 Gen 2006  Data sample received
- 26 Gen 2006  Moved in the Service Module – no shield
- Feb 2006     Shielding in the Service Module

- Mar 2006     Rotate Instrument
- Apr 2006: End increment 12    Rientro dati e dosimetri con Soyuz 11S
- Apr 2006: Launch new dosimeters with    Progress 21P
  - New orientation in crew cabin,
  - New position close to DB-8 (IBMP) detector
  - Command module?
- Autumn 2006: Joint measurements within Matroshka-2
Shielding and radiation measurements with active and passive detectors

TLD, CR39 to measure charged particle and neutron dose

Alteino  Jaxa  DLR  Napoli Fed. II INFN-LNF
Precursor measurements with Lazio-Sirad (ISM-2: April 2005)

• Study of the effect of different shielding materials on the cosmic radiation
• 4 different shielding materials (5g/cm^2):
  Air, Kevlar, Poliethilene, Nextel/Kapton

*In use in ALTCRISS with passive detectors*
Shielding bag

Polietilene shielding: \((5\text{g/cm}^2)\):

(Same thickness of the US section of the station)
Dosimeter arrangement

Each Package:
2 Napoli TLD
6 DLR TLD (diff. Material)
1 Napoli CR-39
2 DLR CR-39
1 JAXA Padles
ALTEINO detector
Eschilo tile
+ dosimeters
Cards and Control
dosimeter

Poliethilene Tiles
with dosimeters

PIRS module: PANEL 401
To Progress (nadir)

INCR. 12 PIRS module - PANEL 302

24/12/2005 Configuration
6/1/2006 Configuration: same location - with shielding tiles
Service Module (Crew Cabin)

Ray Tracing Results

Shielding (pathlength in assigned material) along each of 5000 rays is color-coded to the total amount of shielding [g cm$^{-2}$]; thinnest shielding is white, thickest is blue.

Top View

No additional shielding

With 4.67 g cm$^{-2}$ thick polyethylene constructed of TeSS radiation bricks placed in starboard crew quarters.

Incr. 12 preliminary data:
Acquisition rate vs time, min (raw data)
Acquisition rate vs time, min (raw data, zoom)
All-Particle count world map
Heavy nuclei world (Z>6) world map
Nuclear abundances

26-12-2005 data sample
PIRS Module (2gg) – No Shield
Comparison with/without shielding

Black – 26/12/2005 No shield \ O/C=0.9
Red – 6/1/2006 5 g/cm^2 poliet \ O/C=0.75
Data normalized to Carbon
(preliminary analysis based only on sample data)
Nuclear abundances 2002
Difference PIRS – Service Module

Nero – PIRS (2672 entries) – 40 hours
Red – Service module (Crew Cabin) – 4319 entries – 45 ore

Higher flux in the crew cabin (according to calculations)
Pirs- Service Module rel. abundance

Nero – PIRS
Red – Service module
(values normalized to carbon)

Higher flux in the crew cabin
(according to calculations)
Number of hits distribution

Number of hits

n. entries

Time (2002)
In High cutoff regions the percentage of straight tracks is lower.
Showers vs straight tracks

Geomagnetic shell L

Percentage of Showers (>16 hits)

Entries: 47
Mean: 3.003
RMS: 1.476
Ground Segment

• Usoc at Mars (NA) (Link with ESA, data reception, ISS orbital parameters) – special thanks to Dario Castagnolo and Raimondo Fortezza

• Local Usoc in Tor Vergata (Built for ISM-2 mission, currently shared for Altea, Pamela and Altniss)
Lazio-Sirad Detector

Built (in 6 months)
In response to opportunity to flight in ISM-2 (April 2005)

• Silicon detector
• SI-PM
• Magnetometer

Lazio Detector assembly
Figure 2b Alteino & Lazio detectors inside PIRS module of ISS
To ISS
To Soyuz
Readout pitch is 110 \( \mu \text{m} \) for the p-side (640 channels) 208 \( \mu \text{m} \) for the n-side (384 ch)
LAZIO-SiRad flight data
Particle rate

Energy release
- Good linearity between two channels
- Proton peak evident

2.5 hours data
SIRAD

• Under construction
• 16 double silicon planes
• Trigger with scintillator
• Self Trigger
• Calorimeter on bottom
CPU

- Prototype integrated with FPGA and front-end
- CPU 144 Mhz, 280 Mips
- 2 Mbyte flash 4 RAM
- 2 usb
- 1 bus esterno 16 bit
- indirizzamento esterno 14 bit

- FPGA actel reprogrammable
- 80kGate 208 pin:
- I/F frontend, alarms reading housekeeping
Front end

Completed ingegnerization of the boards
Low interplanar distance (5mm/2 piani vs a 3 cm/2 piani)
Under integration with power and distribution boards
SiPM’s

SiPM consist of thousands pixels

- Pixel size ~ (20-40) µm
- Working point: $V_{\text{Bias}} = V_{\text{BreakDown}} + V_d (< \sim 70 \text{ V})$
  
  $V_d \sim 3\text{V}$ above breakdown voltage

- Each pixel behaves as a Geiger counter with

  $$Q_{\text{pixel}} = V_d \times C_{\text{pixel}}$$

  $$C_{\text{pixel}} \sim 50\text{fmF} \Rightarrow Q_{\text{pixel}} \sim 150\text{fmC}=10^6\text{e}$$

Electrical inter-pixel cross-talk minimized by:

- decoupling quenching resistor for each pixel
- boundaries between pixels to decouple them

results: reduction of sensitive area and geometrical efficiency

Very fast Geiger discharge development < 500 ps

Pixel recovery time = $(C_{\text{pixel}} R_{\text{pixel}}) \sim 20 \text{ ns - 1\mu s}$

Dynamic range ~ number of pixels
Scintillation detector based on SiPM for LAZIO-Sirad (1*1mm)

The scintillator + wave length sifter (WLS) + SiPM technology was used.

Scintillation detector with SiPM's (each detector consist of 8 tiles)

Single tile = scintillator+WLS+SiPM

Power distributor

WLS used for:
- The light collection from 30x30 cm² scintillator to 1x1 mm² sensitive area of SiPM,
- The shift of scintillation radiation spectrum to yellow-green field, where is maximum of SiPM PDE (Photon Detection Efficiency)
Silicon-Photomultiplier data

Count rates of trigger system signals vs time

Equatore
3x3mm SiPM, 5625 pixels

- Sensitive area: 3x3 mm² # of pixels: 5625
- Depletion region: ~ 1 μm
- Pixel size: 30 μm x 30 μm
- Working voltage: 20…25 V Gain: (1…2) x10**6
- Dark rate: room temperature: 20 MHz
- SiPM noise (FWHM):
  - room temperature: 5-8 electrons
  - -50 C: 0.4 electrons
- Single pixel recovery time: 1 us
- After pulsing probability: ~ 1%
- Optical crosstalk: ~ 30 - 50 %
- ENF: appr. 1.5-2.0 (overvoltage dependent)
SiPM’s long term stability

20 tested SiPM’s worked during 1500 hours

Parameters under control:

• Dark rate
• Efficiency of light registration
• One pixel gain
• Dark current
Some properties of 3x3 mm SiPM’s

3x3 mm$^2$ ($\Delta U = U - U_{bd} = 2V$) $T = -50^0C$
Cosmic Ray spectrum (3*3mm)

Canali ADC

Numero Eventi

1ph 2ph 3ph 4ph

T ambiente
Sipm + Scintillatore
(no wlshifter)

SiPM 2 (a+b)

PMT
SIPM1
SIPM1
PMT
Magnetic Spectrometer
Microstrip detector
Silicon Tungsten Tracking calorimeter
Shower Catcher
Scintillator Neutron Detector
Time of Flight Anticounter System

RESURS DK1 SATELLITE (4.5T)
• 450 kg detector devoted to research of antimatter component in cr
• Protons + nuclei up to O
• Polar orbit
• Currently integration in Baikonur,
• Launch foreseen by Spring 2006
Integration in Baikonur cosmodrome, April 2006
Conclusions: need for joint operations

• **Joint Measurements with different detectors**
  Active/Passive  Different detector response, shielding ecc.
  Of crucial importance to determine particle flux variation in different points of the magnetosphere and ISS.

• **Ground/Space comparison/crosscorrelation**
  accelerator / shielding / calibration

• **Use of space data for operational applications**

• **Models** (trapped population, solar particle events, propagation in the magnetosphere)

• **Monte carlo Simulations** (Benchmarking / ion interactions): Geant 3.21, Geant 4, Fluka, HZTRN, Phits
  More important than HE experiments
Availability of PhD positions (post-graduate) in Roma Tor Vergata University:

http://www.uniroma2.it/postgrad/inglese/applicazioni/instruction.htm

And/or contact casolino@roma2.infn.it or picozza@roma2.infn.it

STEP 1: Please read the Pre-selection for foreign students announcement. Foreign citizens shall submit their application on-line. The on-line application can be accessed on the previous page, www.uniroma2.it/postgrad/inglese/applications.htm.

Note: Foreign citizens may only submit one pre-selection application for the academic year.

STEP 2: If applying for one of the two positions described in the announcement (the positions funded by University scholarships or the supplementary positions) then please proceed to the on-line pre-selection application.

STEP 3: Choose the faculty of which the Doctoral Program you are applying to belongs.

STEP 4: Choose the Doctoral Program which you are applying to. Click here for a translation of Doctoral Program titles from Italian to English.

STEP 5: Click on “Add Undergraduate Degree” and then fill in relevant information. Click "send".

STEP 6: Once you have finished inserting one (or more) undergraduate degrees, click "next".

STEP 7: Click on “insert courses/exams” and make sure to insert all the names and grades of courses you took as an undergraduate. Once you have added all your courses, click on “Save inserted information”.

STEP 8: Click on the appropriate link if you have any graduate degrees, publications or relevant information you would like to insert. *Remember to always save inserted information.

STEP 9: Copy down your Ctrl number and make sure to save it. Print a copy of the application and keep it for your own records.
Thank you!
Energy acceptance

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Table 1