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The AIV quick look and health monitoring system of the AGILE payload

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ABSTRACT

AGILE is an ASI (Italian Space Agency) Small Scientific Mission dedicated to high-energy astrophysics which was launched on April 23 2007 from Satish Dawan Space Centre (India) on a PSLV-C8 rocket. The AGILE Payload is composed of three instruments: a Tungsten-Silicon Tracker designed to detect and image photons in the 30 MeV-50 GeV energy band, an X-ray imager called SuperAGILE that works in the 18-60 keV energy band, and a Minicalorimeter that detects gamma-rays or particle energy deposits between 300 keV and 200 MeV. The instrument is surrounded by an anti-coincidence (AC) system. We have developed a set of Quick Look software tools in the framework of the Test Equipment (TE) and the Electrical Ground Support Equipment (EGSE. This s/w is required in order to support all the assembly, integration and verification (AIV) activities to be carried out for the AGILE mission, from data handling unit level to payload integrated level, calibration campaign, launch campaign and in-orbit commissioning. These software tools have enabled us to test the engineering performance and to perform a health check of the Payload during the various phases. We have used an incremental development approach and a common framework to rapidly adapt our software to the different requirements of the various phases.

Keywords: AGILE, AIV (Assembly Integration and Verification), EGSE (Electric Ground Support Equipment), Calibration, Science Console

1. INTRODUCTION

AGILE is an ASI (Italian Space Agency) Small Scientific Mission dedicated to high-energy astrophysics. The AGILE instrument is designed to detect and image photons in the 30 MeV-50 GeV and 18-60 keV energy bands, with excellent spatial resolution, good timing capability and an unprecedented large field of view covering $\sim 1/5$ of the entire sky at energies above 30 MeV. The primary scientific goals include the study of AGNs, Gamma-Ray Bursts, Galactic sources, unidentified gamma-ray sources, diffuse Galactic gamma-ray emission and high-precision timing studies. AGILE was launched on April 23 2007 from the Satish Dawan Space Centre (India) on a PSLV-C8 rocket into an equatorial orbit of about 530 Km.

The AGILE Payload is composed of three instruments.[1] A Tungsten-Silicon Tracker (ST),[2,3] with a large field of view, good time resolution, sensitivity and angular resolution; a Silicon based X-ray detector, Super-AGILE (SA),[4] for imaging in the range 18 keV - 60 keV and a CsI(Tl) Mini-Calorimeter (MCAL)[5,6] that detects gamma-rays or particle energy deposits between 300 keV to 200 MeV. ST and MCAL form the so called Gamma-Ray Imaging Detector (GRID) for observations in the gamma ray energy range 30 MeV - 50 GeV. The instrument is surrounded by an anti-coincidence (AC) system,[7] made by plastic scintillator layers for the rejection of charged particles. These detector subsystems are controlled by the Payload Data Handling Unit (PDHU),[8] which interfaces their analogue and digital front ends in order to perform all the required signal and data on-board processing and generate the Payload telemetry. In turn, the PDHU interfaces the Satellite Data Handling (called On-Board Data Handling, OBDH) in order to transmit the payload telemetry data and receive the payload telecommand data.

In the context of the AGILE project we have developed the software system presented in this paper.

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2. CONTEXT

In the context of the AGILE project we have developed a software framework that has been extensively used for the Test Equipment (TE) and the Electrical Ground Support Equipment (EGSE) required in order to support all the assembly, integration and verification (AIV) activities to be carried out on the AGILE satellite, from unit level to payload integrated level, launch campaign and in-orbit commissioning.

A first preliminary version of the software has been developed for the AIV phase of the MCAL.[9]

We have decided to develop a stand-alone software due to some constraints and requirements of the AGILE project. First of all, our main task was to analyze the scientific telemetry of the payload; this has required a high level of specialization of our software, due to the unique characteristics of the AGILE Data handling and of the P/L, and as we have not found such a specialized software available "off-the-shelf". In addition, starting from the AIV phase of the P/L, the industrial partners (Thales Alenia Space Italia and Gavazzi Space) have considered the Science Console (see next section) and the related software installed on it the only interface with the scientific and instrument developer community.

This led to adopt for the development of Quick Look tools an incremental software life cycle, where:

1 the requirements of the Quick Look software system have been collected from many people within the scientific community. All the engineering tasks have been developed within this framework; the more specialized scientific tests of the SuperAGILE and MCAL subsystems have been provided by the instrument developers with more specialized software. The approach for the Silicon Tracker was different: the greater part of the scientific verification tasks has been developed directly into the Quick Look system;

2 most of the requirements of the Quick Look have been collected during the development of the instrument itself.

Some C++ libraries have been adopted (root CERN libraries 5.14,[10] VTK libraries 4.2 and CFITSIO 3.006) as the basis for our development. On top of these libraries the Quick Look software has been developed for the visualization of data coming from the P/L. This design concept allows to rapidly add new views of the data and new functionalities.

3. MAIN TASKS OF THE QUICK LOOK SOFTWARE SYSTEM

The Quick Look (QL) software system is a set of software tools that displays the data coming from the AGILE instruments in LV1 format. The LV1 data level is the conversion of the raw telemetry data (LV0 level) into FITS files.

The Quick Look software system runs on the Science Console[11–13] - a workstation PC with Linux - which is connected through the LAN to the rest of the Test Equipment and the EGSE procured by industry. The main purpose of the Science Console is to support the scientific community during the various phases of the AIV of the AGILE satellite, providing a set of scientific-oriented tools that enable the analysis and the verification of the PDHU functionalities and performances. The Science Console receives the echo of the telemetry data and the telecommand data exchanged by these equipments with the P/L, and it processes, converts and archives the telemetry data into NASA/FITS files. The LV1 archive generated by this system is the main input for the QL.

The Quick Look software is able to perform the following functions:

1 to process and display the scientific data coming from the AGILE instruments (as output of the PDHU) for engineering verification purposes. This information has been organized as views and grouped by detector;

2 to perform the health assessment of the detectors and of the overall P/L by means of the HK displays;

3 to display the ratemeters of each instrument;

4 generally speaking, to check the correct working of the P/L in all the phases of the AGILE project, from the PDHU AIV phase up to the commissioning.

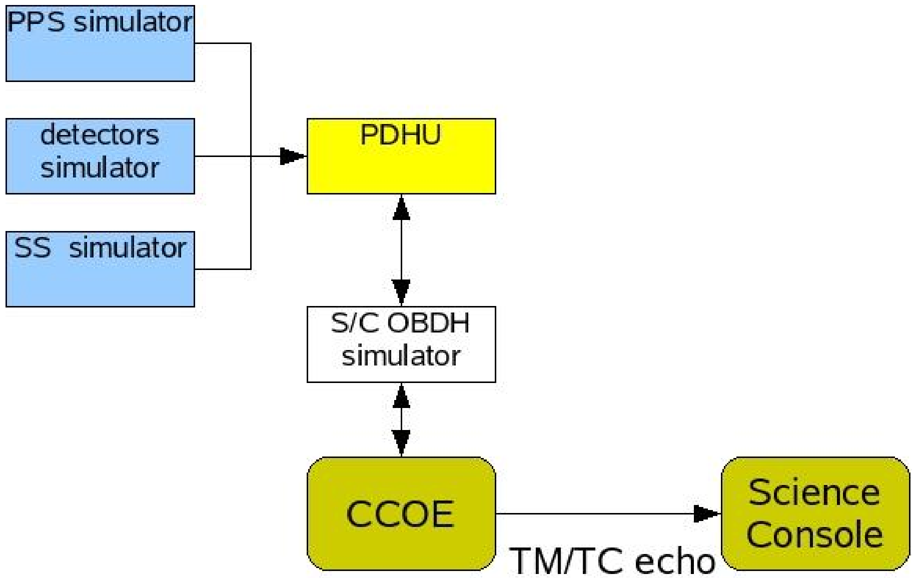

Figure 1. AGILE PDHU AIV phase: this phase has involved the integration of the different electronic boards of the AGILE Data Handling. Some simulators have been developed for this purpose (SS = Star Sensor, PPS = AGILE timing system, OBDH = On Board Data Handling of S/C, CCOE = Central Checkout Equipment). The CCOE is the system provided by industry to command the PDHU. The Quick Look runs on the Science Console.

The Quick Look can be operated in both near-real time and off-line mode. Its functionalities have been provided mainly in near-real time, where the data are displayed during the acquisition from the satellite system: this has enabled the AGILE team and the industrial partners to check the status and the health of all the subsystems of the AGILE satellite during the various tests performed in the clean room and to stop the test immediately if something is malfunctioning.

4. AIV AND CALIBRATION CAMPAIGNS

The Quick Look software system has been used by the AGILE Team during the following phases:

1 the PDHU AIV phase: this phase has involved the integration of the various electronic boards of the AGILE Data Handling. See Figure 1;

2 the P/L AIV campaign: this was the most challenging phase, which followed the integration and test campaigns carried out by the different instrument teams at s/s level. In this phase, all the subsystems (Silicon Tracker and its front end boards, SuperAGILE, MCAL and AC) has been integrated and connected with the PDHU;

3 the P/L calibration, as engineering support for the calibration pipeline of the scientific team, see Figure 2;

4 the satellite integration phase: in this phase the P/L was integrated into the bus and connected with the OBDH (On-Board Data Handling) of the S/C;

5 the launch campaign: the satellite was connected on top of the PSLV launcher and the P/L was switched on for the last verification before the launch;

6 the commissioning phase performed after the launch.

In any configuration the only essential requirement of the Science Console is to receive in near real time the echo of the Payload telemetry. Optionally, the echo of the telecommands produced by the data handling

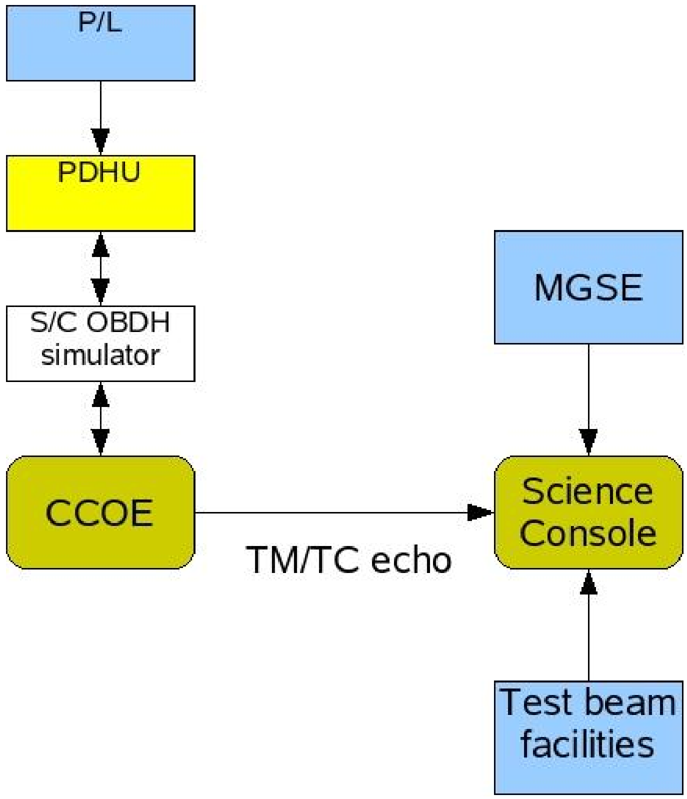

Figure 2. AGILE P/L calibration phase: this phase has involved many different subsystems. First of all, the CCOE commands the P/L by means of the S/C OBDH simulator. The Science Console is the central gateway of the data acquisition of all the calibration subsystems. The MGSE subsystem[14] has the main purpose of moving and positioning the P/L in front of the beam, the test beam facility is compound by a Photon Tagging System (PTS) that acquires the data of the beam. A specialized QL software for calibration purposes has been developed.

enables the Science Console to automatically close the current data file every time a Enter Observation/Enter Idle command is detected.

The Quick Look software developed for any phase are the following:

1. GRID/AC QL + Ratemeters/HK QL: this tool shows all the data coming from the GRID scientific telemetry, those acquired from Anticoincidence system (AC) and the ratemeters and housekeeping telemetry related to all the Payload subsystems;
2. MCAL QL: this QL software is specialized for data coming from the Minicalorimeter subsystem;
3. SA QL: this QL software is specialized for data coming from the SuperAGILE subsystem;
4. Calibration QL: this QL has been developed only for the AGILE GRID calibration activities performed in 2006: the main task of the software is to show the number of gamma-rays and related energy of the beam. Its main interface was the data acquired from the PTS (Photon Tagging System).

Each QL software is organized in views; a view is a way to display the data.

5. DESCRIPTION OF THE GRID QUICK LOOK

As an example we describe the main functionalities of the GRID Quick Look. The main task of this software is to show the content of the data coming from the AGILE P/L in GRID configuration mode. The AGILE Data Handling provides two main configurations:

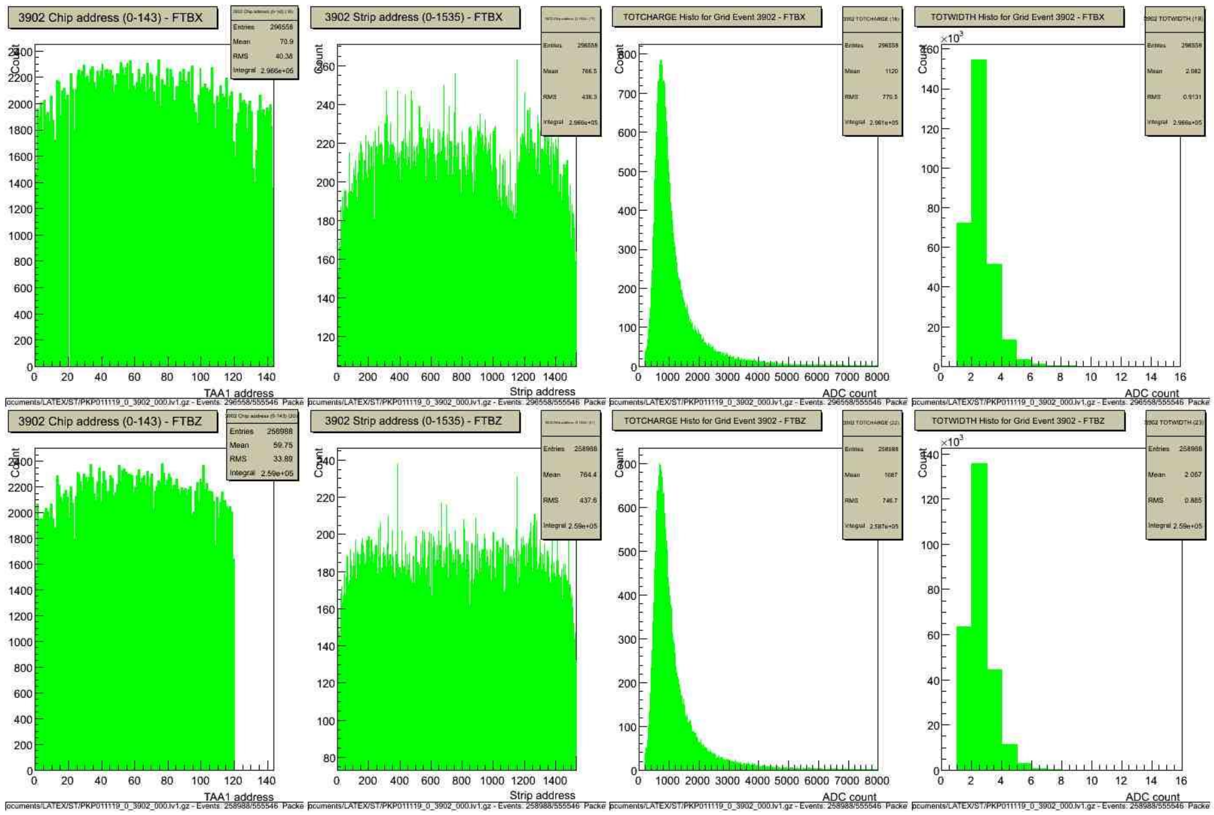

Figure 3. This view shows some histograms related to the main parameters of the GRID cluster. The first row shows the data of the side X of the Silicon Tracker, the second row shows the data of side Z. The first column shows the number of triggers of each chip of a side (labeled from 0 to 147). The second column shows the number of triggers of each strip, labeled from 0 to 1535. The third colum shows the total charge of each cluster acquired and the last column shows the total width (the number of strips) of each cluster. The data shown in this view is related to the launch campaign. The unit of the charge is ADC count.

1 *observation mode*: with this configuration the GRID subsystem is configured to acquire photons in the energy band 30 MeV-50 GeV. A set of different on-board triggers enables the discrimination of background events (mainly muons on ground or particles in the AGILE Low Earth Orbit) from gamma-ray events. This is the acquisition mode used during the calibration activities and in-flight;

2 *physical calibration mode*: in this configuration mode only some basic level triggers have been enabled. This data acquisition mode has been used extensively during the various AIV activities.

The GRID Quick Look works with both these data acquisition modes. The content of the telemetry is the same. Each telemetry packet contains a GRID event that is formed by:

a the set of triggered strips for each plane of the Silicon Tracker. The Silicon Tracker is divided in 2 sides (called X and Z that provide the coordinates (x,y) of each cluster); each side is controlled by an electronic board called FTB (Front End Board) and it comprises 12 plans; each plane is composed of 12 acquisition chips (called TAA1) and each chip is composed of 128 readout strips. In addition for each readout strip a floating strip (a strip not connected to the readout chip) is present*. Finally, a view is a set of 2 planes. A cluster is a set of contiguous readout strips that have passed the trigger logic implemented into the PDHU.[8] For each cluster the telemetry contains:

*This configuration has been chosen in order to have an excellent spatial resolution while keeping under control the number of readout channels and hence the detector power consumption

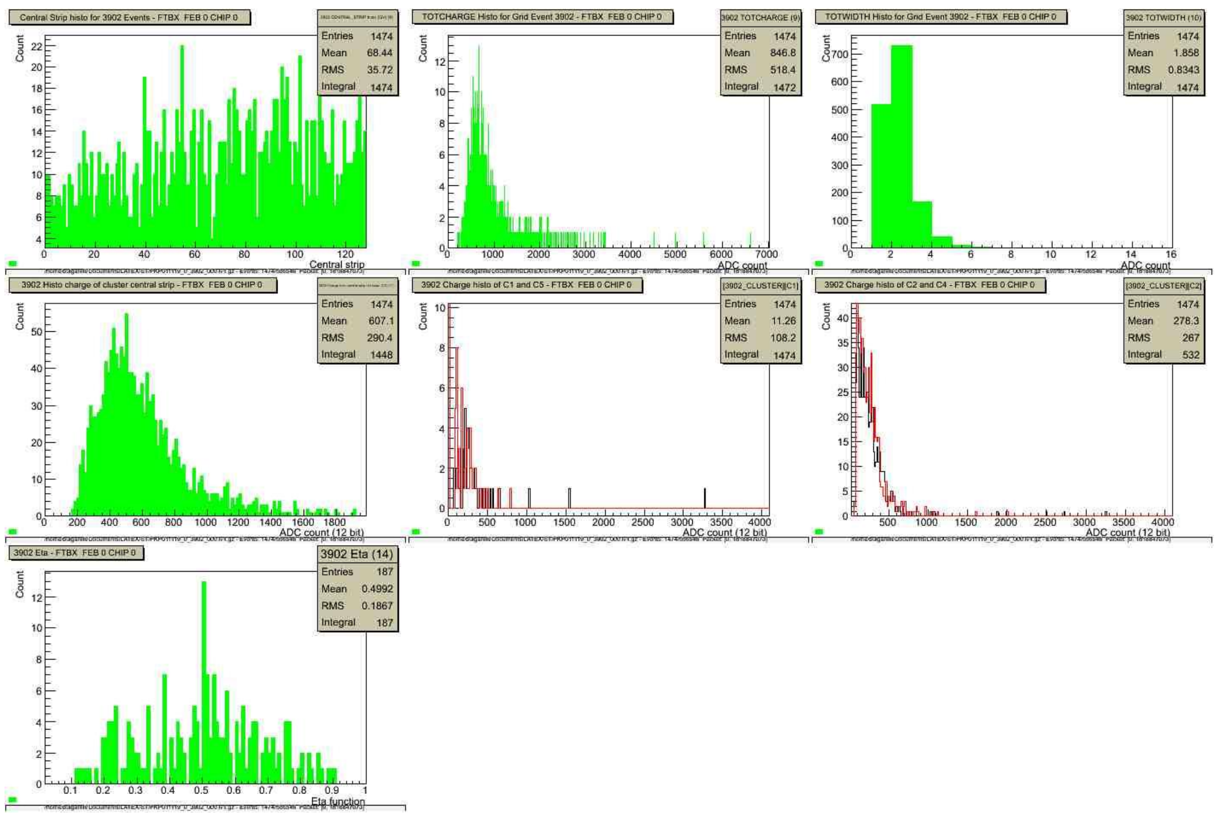

Figure 4. This GRID QL view shows the main data of a single chip (in particular, in this view we show the first chip of the first plane of the side X). The data shown in this view is related to the launch campaign. From top to bottom, from left to right: (i) histrogram of all the triggered strips of the chip for this run; (ii) histogram of the total charge of each cluster; (iii) the total width (number of strips) of each cluster; (iv) the distribution of the charge of the central strip (C3) of the cluster; (v) the distribution of the charge of the strips C1 and C5 (see text), when presents; (vi) the distribution of the charge of the strips C2 and C4 (see text), when presents; (vii) the Eta function.[15] The unit of the charge is ADC count.

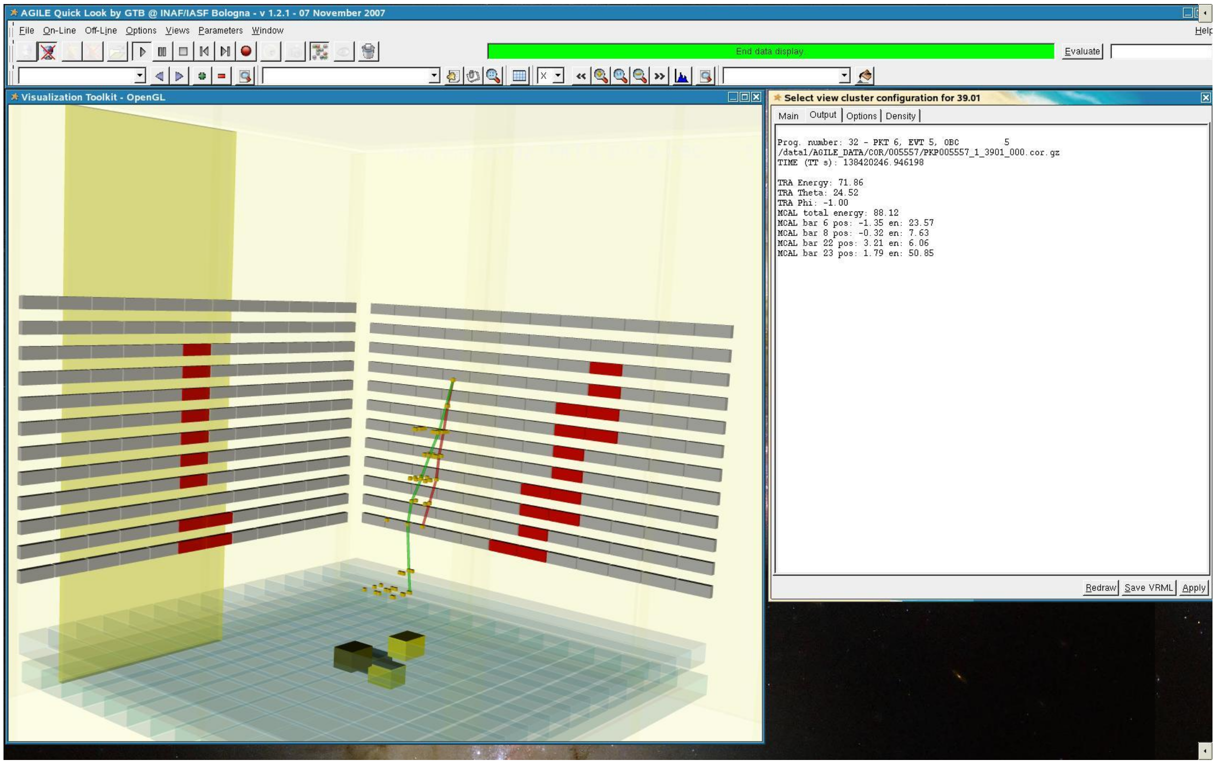

Figure 5. A 3D view of the AGILE that show the full topology of a single GRID event acquired in-flight. The grey horizontal blocks are the Silicon Tracker chips not fired, the red horizontal blocks are the fired chips (a fired chip is a chip with one or more clusters that has passed the trigger level logic[8]). The two tracks (red and green) are the converted electron and positron of the initial gamma-ray and the small yellow boxes are a 3D projection of the clusters. On bottom is shown the MCAL (cyan bars) and the hit on MCAL generated by the converted electron and positron (yellow blocks into the cyan bars - the gradient of this blocks is proportional to the energy deposit). Finally, the big vertical box is a fired lateral panel of the AC system.

- a.1 total charge (the sum of all the charges of the cluster);
- a.2 total width (the number of strips) of the cluster;
- a.3 the charge of the 5 central strips of the cluster, reduced to 8 bits (the least significant bits are removed). In this paper the central strip is called C3, the left side strips are called C1 and C2, and the right side strips are called C4 and C5.

b the energy deposited in each Minicalorimeter bar;

c the configuration of the fired AC panels;

d the time of the event;

e the extra fired chip index: for each view of the Silicon Tracker the max number of triggered chips that are acquired is 8. If more than 8 chips triggers, only the index of the additional triggered chips are sent to ground with the telemetry.

The views of the Quick Look enable us to show all the data coming from the Silicon Tracker. Figure 3 shows the main parameters of the Silicon Tracker clusters. This view has been extensively used for a fast check of the health status: when a strip becomes noisy this view immediately reveals this problem. With our software it is possible to go from all integrated events (with the main data collected into histograms) down to a single strip. Figure 4 shows the data collected for a single chip. In addition, a 3D view of AGILE has enabled us to show

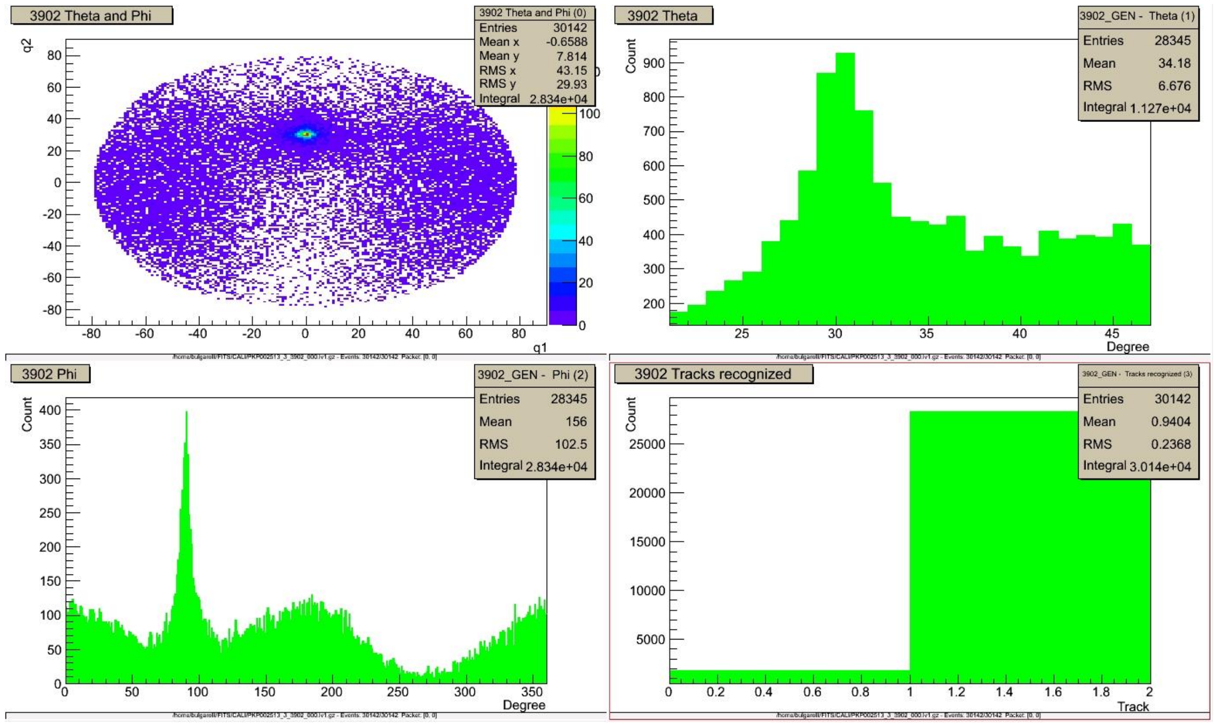

Figure 6. A specialized GRID QL view used during the GRID calibration campaign activity. From top to bottom, from left to right: (i) the GRID field of view with the spot of the calibration beam (red); (ii and iii) the reconstructed angles of incoming photons, into detector reference frame; (iv) the number of reconstructed tracks.

the full topology of each single GRID event acquired. Figure 5 shows this 3D view with a gamma-ray acquired in-flight.

Some specialized views have been developed for the calibration campaign performed at INFN of Frascati (Rome) in 2006. In Figure 6 a snapshot of a calibration run of a gamma-ray beam is shown.

About 250 views related to the GRID, AC, housekeeping and ratemeters have been developed for this Quick Look.

6. CONCLUSIONS

The approach for the development of the Quick Look AIV software presented in this paper has allowed us (i) to focus on the scientific aspects of the data coming from the P/L, as the engineering aspects of P/L commands are covered by industry with its TE and EGSE; (ii) to build a flexible system, which is easily customized for different test phases, and which is upgradeable in order to cope with new requirements arising during the utilization.

In addition, our approach enables us to easily customize our Quick Look software for other different P/Ls for different missions. The basic requirement of the Science Console is to receive the echo of telemetry and, possibly, of the telecommands produced by the P/L data handling during the various phases. This basic data interface enables a fast and simple integration with different systems and contexts.

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