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A Photon Tag Calibration Beam for the AGILE Satellite

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Abstract

The AGILE satellite will be launched in 2006 for the study of gamma rays in the energy range 30 MeV-50 GeV. The satellite has to be calibrated using gamma rays of known energy. The calibration facility is being developed at the Beam Test Facility (BTF) at the INFN Laboratories in Frascati. The photons are produced by bremsstrahlung of electrons with a maximum momentum of 750 MeV/c. The electrons are tagged using a dipole magnet whose internal walls are covered by microstrip silicon detectors: depending on the energy loss, they impinge on a different strip once the dipole current has been set to a given value. The correlation between the direction of the electron measured by a pair of *x-y* silicon chambers and the impinging position on the tagging module inside the magnet allows the tagging of the photon. The paper describes the calibration layout and tests and the results, compared with the Montecarlo simulation, in terms of production rate and energy resolution.

1 Introduction

The AGILE mission [1] will provide a powerful Observatory for γ -ray astrophysics in the energy range 30 MeV-50 GeV, during the years 2006-2008. AGILE will be launched by the Indian launcher PSLV on a equatorial orbit at 550 km with Malindi as ground base. The scientific instrument is light (≈ 100 kg) and will be able to detect and monitor γ -ray sources within a large field of view ($\approx 1/4$ of the whole sky). Given that its launch is foreseen for the beginning of 2006, the calibration of the scientific payload has to be performed before the end of this year.

The calibration facility is being developed at the Beam Test Facility (BTF) of the INFN Laboratories in Frascati. Its working principle and the experimental setup are described in Section 2, while Section 3 presents the results of the commissioning of the beamline and the comparison with the simulation.

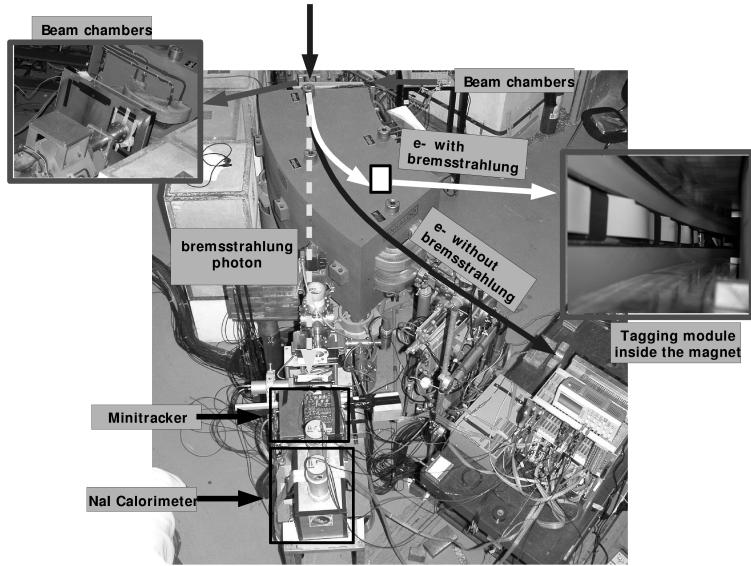


Figure 1: Working principle of the photon tag calibration beamline.

2 The calibration facility

The DAFNE Beam Test Facility (BTF)[2] is a beam transfer line for bunches of electrons and positrons in the energy range tens of MeV - 750 MeV in a wide range of multiplicities down to the single electron mode. The pulse duration is 10 ns and the pulse rate is 50 Hz. Fig. 1 shows the basic idea of the photon tag beamline. Photons are produced in the bremsstrahlung process by the impinging electron beam. The last dipole magnet in the

line is used as a “tagger” of the electrons that have undergone bremsstrahlung in the silicon beam chambers positioned before the magnet itself. These electrons have lost part of their energy in the photon and thus they curve towards the inner walls of the magnet itself, which is completely covered by silicon microstrip detectors.

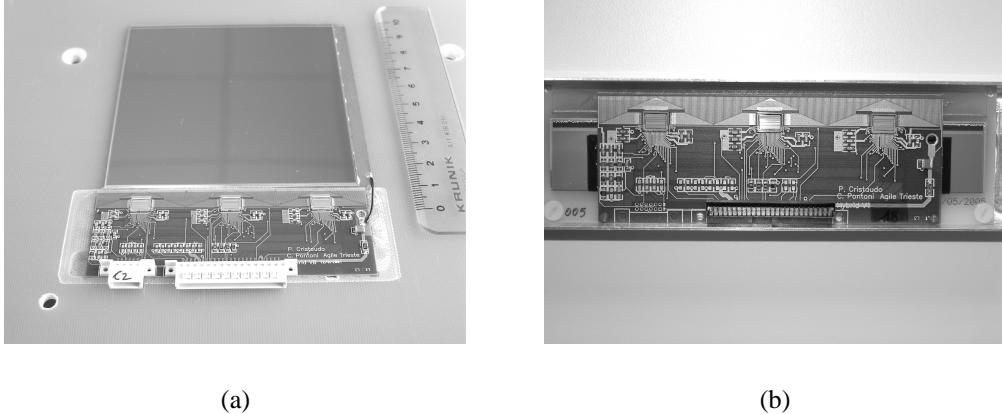


Figure 2: (a) One of the silicon detectors of the beam chambers. (b) One of the tagging modules located inside the bending magnet; the frontend PCB and the silicon detector are clearly visible. The maximum clearance for the modules is 4 cm.

The silicon beam chambers (Fig. 2(a)) before the magnet are the medium for the bremsstrahlung process and they have to reconstruct the direction of the primary beam. They consist in two pairs of $8.9 \times 8.9 \text{ cm}^2$ $380 \mu\text{m}$ thick strip detectors (Micron Semiconductor ltd) with a pitch of $228 \mu\text{m}$. Each tile is readout by 3 TAA1 ASICs (IDEAS, Norway). The two tiles of each pair are positioned in a x - y configuration and the distance between the two pairs is 15 mm. Given the pitch and the analog readout, the spatial resolution is $\approx 40 \mu\text{m}$ while the angular one is $\approx 2 \text{ mrad}$.

Fig. 2(b) presents one of the tagging modules, which is a 12 cm long $300 \mu\text{m}$ thick silicon detector with a strip pitch of $100 \mu\text{m}$ and a readout pitch of $300 \mu\text{m}$ in the central region and $600 \mu\text{m}$ in the outer 3 mm. The tagging system consists in 12 tagging modules positioned in the 4.1 cm gap of the bending magnet. Given this value, a very compact design has been chosen: the frontend electronics (3 TAA1s per module) is located above the silicon detector and is connected to a pitch adapter which in turn is bonded to the silicon strips. The 12 modules are organized in 2 boxes.

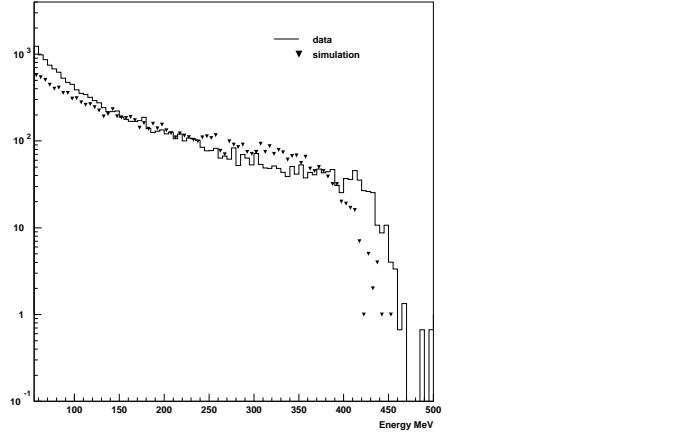


Figure 3: Bremsstrahlung spectra for a primary beam energy of 424 MeV. The results from the Geant 3.21 simulation (triangles) are in good agreement with the data measured by the NaI calorimeter (full line).

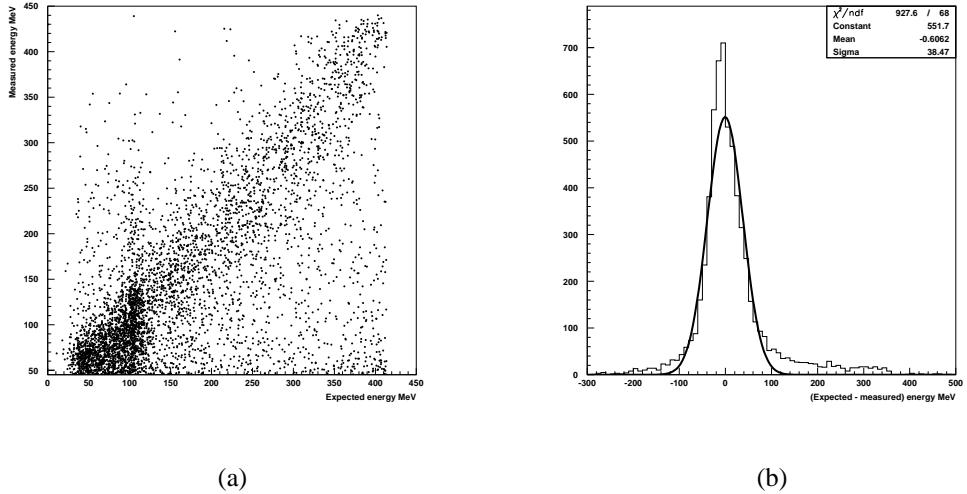


Figure 4: (a) Relationship between the value of the photon energy as computed using the tagging modules (X axis) and the one measured by the NaI calorimeter (Y axis). (b) Difference between the expected (tagging modules) and measured (NaI)photon energy.

3 Results

In the commissioning phase, the bremsstrahlung spectrum and the tagging system response have been verified using a 15×10^{-3} NaI(Tl) calorimeter. Fig. 3 shows the bremsstrahlung spectrum measured by the calorimeter when one of the tagging modules has detected an

electron. The data are compared with the simulation obtained from the code written with Geant 3.21. The minimum threshold for the calorimeter is of the order of 50 MeV.

Fig. 4(a) presents the relationship between the value of the photon energy as measured by the NaI(Tl) calorimeter and the value given by the tagging system. Fig. 4(b) shows the residuals of the same distribution. The system energy resolution is limited at the moment by the calorimeter one, which is of the order of 6% from 424 MeV down to 100 MeV and then increases up to 18%. The system allows to compute the photon energy both when there is a single track in the beam chambers and for multi track events (the maximum allowed multiplicity is around 5 electrons per bunch). In this case, the entrance angle of the electron in the magnet is computed with a weighted average of the track positions in the chambers.

4 Conclusions

A photon tagged beam facility has been commissioned at the BTF (LNF, Frascati). Photons are produced with a bremsstrahlung spectrum from 750 MeV electrons and their energy is measured tagging the interacting electron with a silicon spectrometer inside the last bending magnet. The energy resolution is limited at the moment by the calorimeter used in the system calibration phase. The photon production rate strongly depends on beam multiplicity and is of the order of 1 Hz.

References

- [1] G. Barbiellini et al., Nucl. Instr. and Methods A 490, 146-158, 2002.
- [2] G. Mazzitelli *et al.*, Nucl. Instr. and Meth. in Phys. Res. A 515, 524-542 (2003).