A TAGGED PHOTON SOURCE AT THE FRASCATI BEAM-TEST FACILITY (BTF*)

B. Buonomo†, G. Mazzitelli, F. Murtas, L. Quintieri, INFN-LNF, Frascati (Roma), Italy
P. Valente, INFN-Roma, Roma, Italy
E. Vallazza, INFN-Trieste, Trieste, Italy
L. Foggetta, S. Hasan, A. Mozzanica, M. Prest, Univ. Insubria and INFN-Milano, Como, Italy

Abstract

The DAFNE Beam-Test Facility (BTF), operating at the Frascati National Laboratory of INFN (LNF), provides electron or positron beams with tunable energy from 25 MeV to 750 MeV, while the intensity can be varied from 10^{10}/pulse, down to a single particle per pulse.

Recently a tagged photon source has been designed, built and tested. The photons are produced by bremsstrahlung of electrons, on a pair of x-y silicon micro-strip chambers, placed at the inlet of the last bending magnet of the BTF transfer line. The photons are tagged in energy using the same bending dipole, whose internal walls have been covered by 10 modules of silicon micro-strip detectors. Depending on the energy loss in the photon production, the electrons impinge on a different strip once the dipole current has been set to the nominal value. The correlation between the directions on the electron measured by silicon chambers and the impinging position on the tagging module inside the magnet allows the tagging on the photons. In this paper the configuration of the system is presented with some results obtained during the latest test-beams.

BTF PHOTON TAGGING

The DAFNE BTF can provide electron or positron beams with variable energy (up to 750 MeV) and intensity (down to single particle/pulse) at a maximum repetition rate of 50 Hz [1, 2]. The tipical beam spot size is of the order of σ=2 mm (both in x and y coordinates) and the divergence can be kept as small as 5 mrad. This is crucial for an efficient operation of the photon tagging.

The concept of the tagged photon source is sketched in Fig. 1. The beam-pipe inside the last bending magnet has two sections, the beam can exit from either of the two, according to the magnet settings: from the straight section when the dipole is off, or from the 45° curved section when the field is set to the proper value, given the momentum selected by the upstream dipole+collimators system (with a spread better than 1%).

The beam can be intercepted, before the last bending, by a target, made by two couples of silicon micro-strip detectors, 8.9×8.9 cm^2, 380 μm thick, with a pitch of 228 μm. The two x-y couples of detectors are placed at distance of 15 mm and are inside a aluminum box, movable on a rail system (in and out from the beam-line) and are shown in the left pane of Fig. 2. The point resolution is of about 40 μm, corresponding to an angular resolution of 2 mrad.

When an electron radiates a bremsstrahlung photon by interacting on the silicon chambers (the total thickness corresponds to ≈ 1.5% of a radiation length), thus loosing part of its energy, will curve more inside the magnetic field of the bending magnet, thus hitting the beam-pipe in the 45°

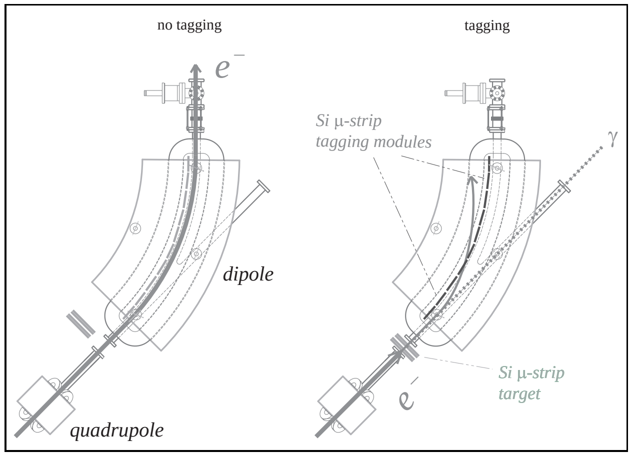

Figure 1: **Left:** layout of the final part of the BTF beamline; the electron beam can exit either from the straight section (bending off), or from the 45° curved section (bending on). **Right:** layout of the photon tagging; the electron irradiates a bremsstrahlung photon on the silicon micro-strip target, and impinges on one of the 10 silicon micro-strip tagging modules outside the wall of the curved section of the beam-pipe.

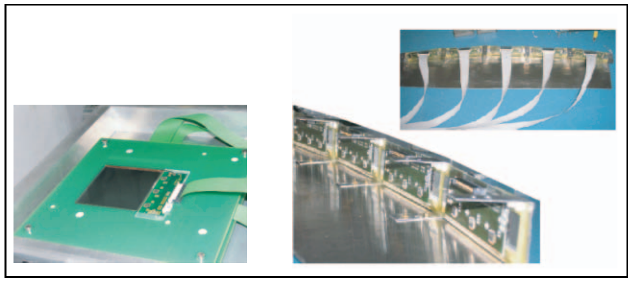

Figure 2: **Left:** silicon micro-strip chambers, acting as active target for bremsstrahlung; **right:** silicon micro-strip tagging modules.

* http://www.lnf.infn.it/acceleratori/btf/
† bruno.buonomo@lnf.infn.it

section. On the external wall of the beam-pipe we have placed two boxes containing 10 modules of silicon micro-strip detectors with an active area of 2 cm heigth, 384 strips each, following the curvature. The strip pitch is of 300 μm in the central region of each module, and 600 μm in the last 3 mm. One supermodule of 5 such detectors is shown in the right pane of Fig. 2.

The 5736 strips of the entire silicon detectors system are read-out by the TAA1 sample-and-hold ASICs (from Ideas, Norway), 128 strips/chip, and multiplexed with a 5 MHz clock by a custom-built VME sequencer. The multiplexed analog signals are then fed to two CAEN sampling ADC VME modules (two channels CAEN V550). All the data acquisition is integrated inside the VME system of the BTF diagnostics.

Further details on the silicon detectors can be found in Ref. [3]. An example online plot of the 4 silicon target planes and of the 10 tagging modules is shown in Fig. 3.

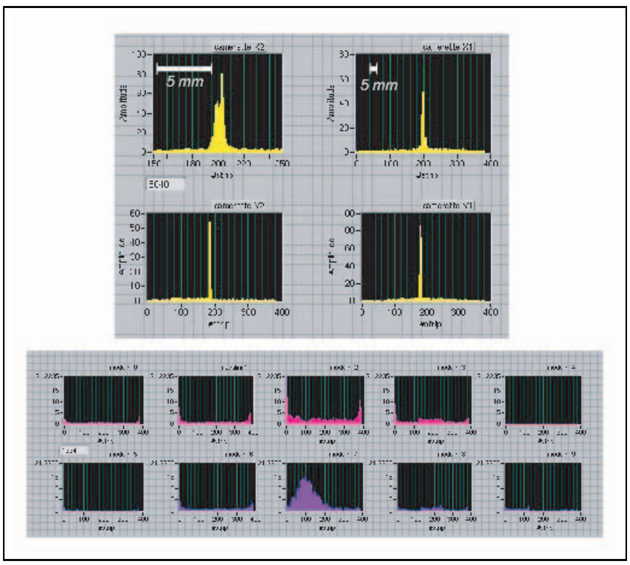

Figure 3: **top:** beam spot on the four silicon micro-strip chambers (x-y views); **bottom:** electron beam on the silicon micro-strip tagging modules (divided in 2 supermodules, 5 detectors each) with magnetic field double with respect to nominal value.

The wall of the aluminum beam-pipe has been thinned to 1 mm in order to reduce the multiple scattering of the electrons before reaching the detectors. Those silicon modules act as tagging system, since from the impact point in the curved section, the bending radius and thus the momentum loss of the electron can be reconstructed, corresponding to the energy of the radiated photon.

The photon will undergo a small ($1/\gamma$) angular deviation from the electron original directions, and thus will exit from the straight beam-line. In order to check the performances of the tagging system, the photon beam has been measured by means of a sodium iodide calorimeter (15 radiation lengths thick). In Fig. 4 the correlation between the photon energy reconstructed from the electon impact point on the tagging modules and the energy measured in the test calorimeter, is shown; the energy of the primary electron beam was of 424 MeV, while he target silicon planes have been used to select single electron tracks on the target itself: a clean linear relationship can be easily seen.

The lower band of events corresponds to reconstructed photons going outside the calorimeter acceptance, essentially due to the beam divergence.

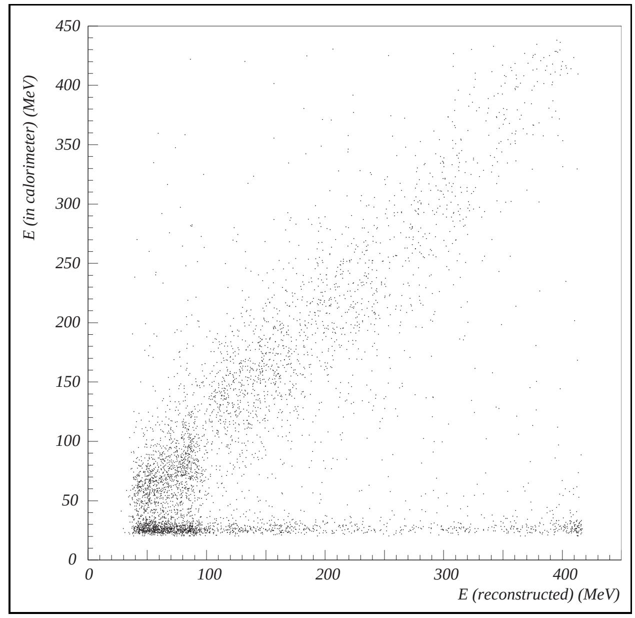

Figure 4: Energy of the photon measured by a calorimeter as a function of the energy reconstructed by the tagging system (energy of primary electrons of 424 MeV).

This has been checked by extrapolating the expected photon position using the reconstructed electron positions and angles in the silicon target planes. The distributions of the x and y (horizontal and vertical) angles of the electron tracks inside the target planes are shown in Fig. 5, while the x and y reconstructed positions are shown in Fig. 6.

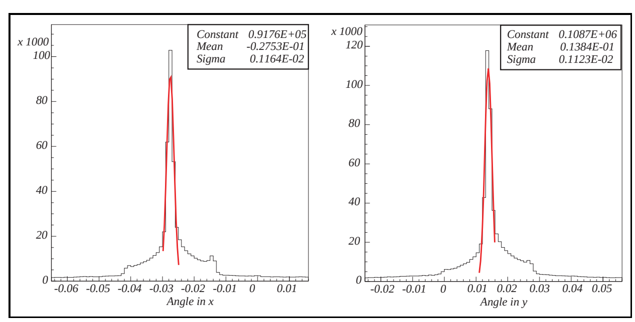

Figure 5: Horizontal and vertical angles of the electron tracks measured inside the target silicon micro-strip planes (energy of incoming electrons of 424 MeV).

In order to estimate the energy resolution of the tagging system, one can use the difference between the estimated (reconstructed) and measured energy in the calorimeter (as

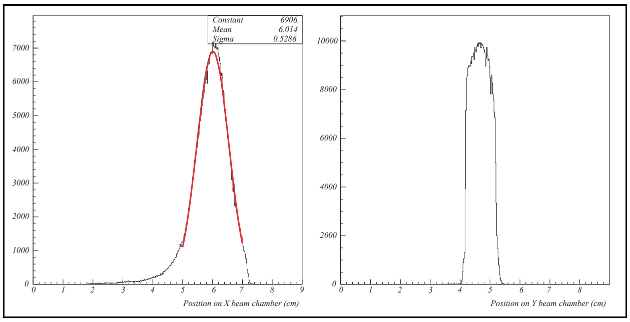

Figure 6: Impact point of the incoming electrons in the horizontal and vertical coordinates measured by the target silicon micro-strip planes (energy of incoming electrons of 424 MeV).

in Fig. 7): the width of the distribution is largely dominated by the intrinsic resolution of the calorimeter (from 6% at maximum energy to about 20% at 100 MeV).

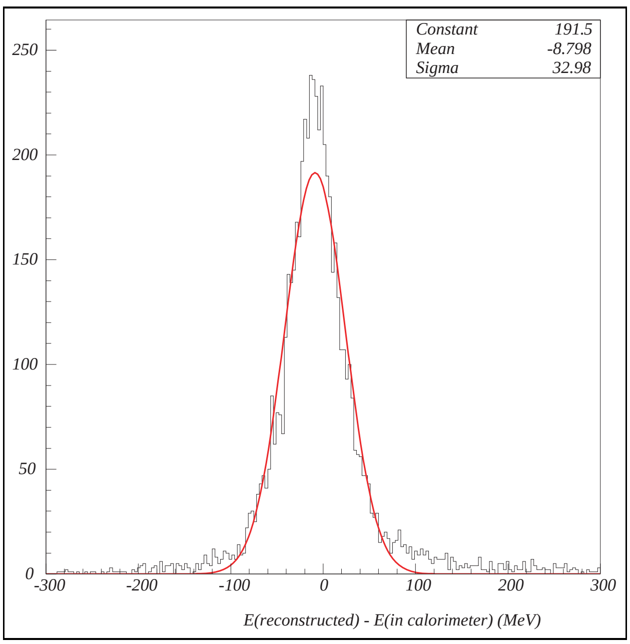

Figure 7: Difference between the photon measured by a test calorimeter and the energy reconstructed by the tagging system (energy of incoming electrons of 424 MeV).

RECENT TESTS AT THE BTF

Recently, a triple-GEM detector [4] has been tested at the BTF, using both electron and photon beams, in order to measure its efficiency for both type of particles. The aim of the project is to realize a couple of segmented detectors, with millimetric spatial accuracy, to be used as a Bhabha detectors for the luminosity measurement of the DAFNE collider (together with a calorimetric measurement of the electron energy).

Photons from radiative Bhabha events and from gas-bremsstrahlung indeed constitute a background for the Bhabha process, so that is crucial to determine the detection efficiency for both photons and electrons.

The triple-GEM has a 3×3 mm^2 pad readout, for a total of 64 pads on a active area 2.4×2.4 cm^2 (over a total area of 10×10 cm^2), read by 4 ASDQ chips and fed to the BTF data acquisition. In Fig. 8 the online distribution of the electron beam spot reconstructed by the 64 pads is shown.

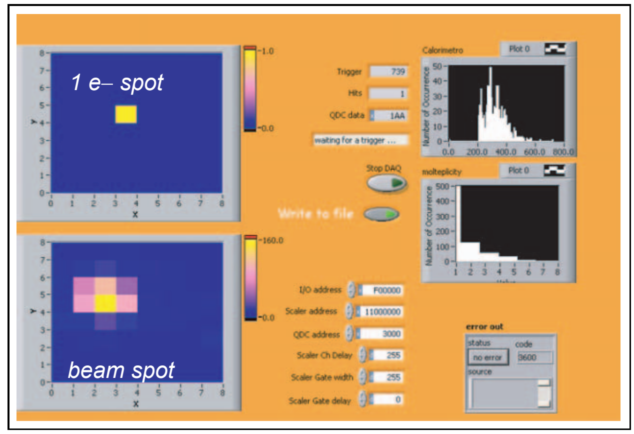

Figure 8: Online panel of the triple-GEM pads readout, showing the beam profile for one electron peak (top) or for the total beam spot (bottom).

The overall detection efficiency measured by this detector has been of 99% with 500 MeV electrons and 1% for photons up to 500 MeV energy; thus showing that this kind of detector is suitable for a precision measurement of the DAFNE luminosity with Bhabha events, with low sensitivity to the radiative Bhabha background.

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