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Cover Letter

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It has been installed in one of the two small-theta angle regions of BEPCII to measure the energy of photons from Initial State Radiation events and is currently taking data together with BESIII.
The detector is a sandwich of Pb and scintillating fibers, the same technique employed for the KLOE calorimeter at the DAFNE accelerator, but the readout is actuated by way of bundles of clear plastic fibers.
We describe here the fabrication, present results from tests with cosmic rays and at the Frascati Beam Test Facility, the installation in BESIII, and preliminary luminosity measurements.

The Zero Degree Detector at BESIII

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Abstract

A small-size calorimeter has been built in the Frascati National Laboratory of INFN for BESIII detector based at the BEPCII storage ring of the Institute of High Energy Physics in Beijing. It has been installed in one of the two small-theta angle regions of BEPCII to measure the energy of photons from Initial State Radiation events and is currently taking data together with BESIII. The detector is a sandwich of Pb and scintillating fibers, the same technique employed for the KLOE calorimeter at the DAΦNE accelerator, but the readout is actuated by way of bundles of clear plastic fibers. We describe here the fabrication, present results from tests with cosmic rays and at the Frascati Beam Test Facility, the installation in BESIII, and preliminary luminosity measurements.

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The experiment BESIII [1] foresees the installation of two zero-degree detectors (ZDD) to measure the energies and directions of photons produced in Initial State Radiation (ISR) processes. They cover cones of a few mrad of aperture around $\theta_{\gamma \mathrm{ISR}} = 0°$ and $\theta_{\gamma_{ISR}} = 180°$ with a design location of 3.5 m from the BESIII interaction region. Their acceptance is comparable to the wide angle one ($20° \leq \theta_{\gamma_{ISR}} \leq 160°$) because ISR processes are peaked at small values of the scattering angle. They operate in a high rate environment of photons produced in the process $e^+e^- \rightarrow e^+e^-\gamma$, much more peaked in the forward region (fig. 1). A 10 mm-wide cut in the detector geometry, slot region in fig. 1, drastically reduces this contamination (2 MHz at highest BEPCII luminosity), still leaving a high efficiency for the signal.

The ZDD detector is composed of two modules $(4 \cdot 6 \cdot 14)$ cm^3 with an empty region in between, 10 mm large, that can be moved in the vertical direction to clear the region of maximum bremsstrahlung yield (fig. 2). Each module is a fine sampling Pb-SciFi calorimeter with photomultiplier (PM) read-out. The structure [2] consists of an alternating stack of 1 mm fibers glued between thin grooved Pb foils. The materials are 0.5-mm thick Pb foils, 1-mm diameter Kuraray SCSF-81 scintillating fibers and Bicron BC-600 optical cement. The final composite has a fiber:lead:glue volume ratio of 48:42:10, a density of 5 g/cm^3 and a radiation length of 1.6 cm (fig. 3).

The light collected is sent through bundles of clear plastic fibers 2 m long to 10 Hamamatsu H10828 photomultipliers that

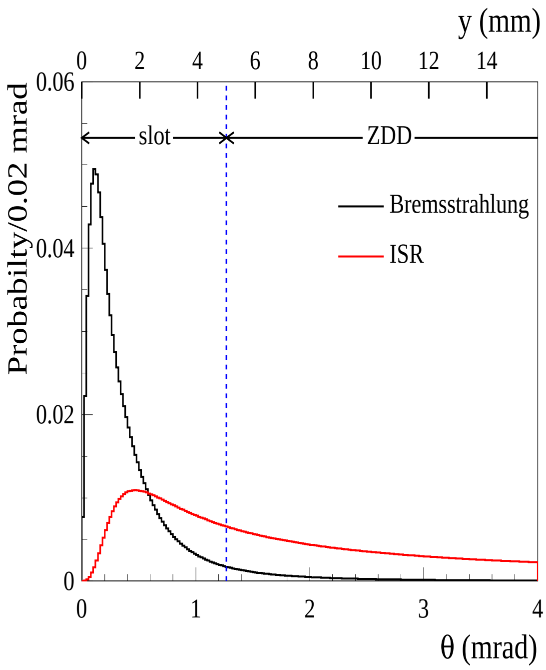

Figure 1: Angular distributions of emitted photons in bremsstrahlung (black histogram) and ISR (red histogram) processes (not in scale). The vertical dashed line indicates the detector angular cut applied (see text). The upper horizontal axis indicates the displacement in the direction *y*, orthogonal to the beam plane. This displacement (±5 mm) defines the empty region (slot) not covered by the ZDD detector.

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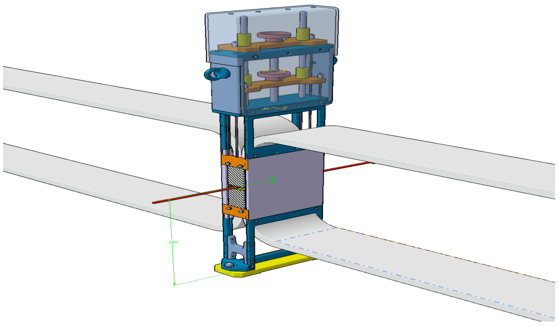

Figure 2: Cartoon showing the ZDD detector mechanical structure used to move the two modules in the vertical direction, to clear the region of maximum bremsstrahlung yield. The four bundles of clear plastic fibers, 2 m long, glued to the modules, to tranfer light to the PM's, are also shown.

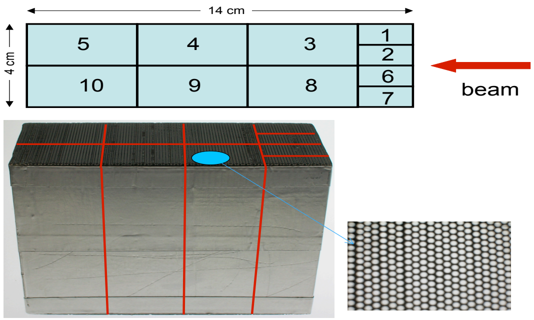

Figure 3: Longitudinal and transversal ZDD module segmentation.

allow a fine definition of the photon impact point (better than 1 mrad) and 4 samples of the shower profile. The ZDD detector has been installed 3.5 m away from the BESIII interaction region, along one of the beam pipes, in front of the first quadrupole, in an area with a low but not negligible magnetic field. For this reason the PM's have been positioned 2 m away from the detector (fig. 4).

The PM charge response has been equalized with minimum ionizing particles that pass through the calorimeter elements. One of the two ZDD modules has been tested at the Frascati Beam Test Facility with 450 MeV electrons. A small scintillator $(60 \cdot 11 \cdot 4)$ mm^3 in coincidence gives a precise measurement

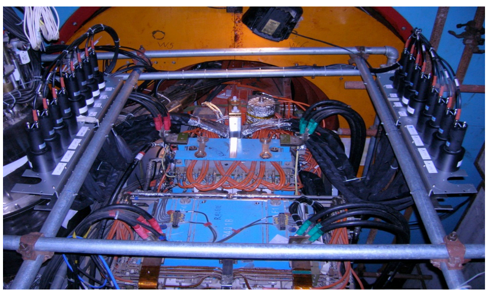

Figure 4: The ZDD detector installed at 3.5 m from the BESIII interaction region, along one of the beam pipes. The ZDD gearbox for vertical movement and the clear fiber bundles connected to the PM's can be seen among many BEPCII accelerator cooling devices.

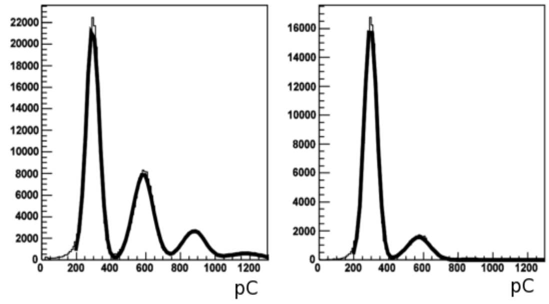

Figure 5: Total charge distribution with 450 MeV electrons (left plot) showing clean 1, 2, 3 electron peaks. When the signal is taken in coincidence with the finger counter described in the text, a background free calibration point is obtained (right plot).

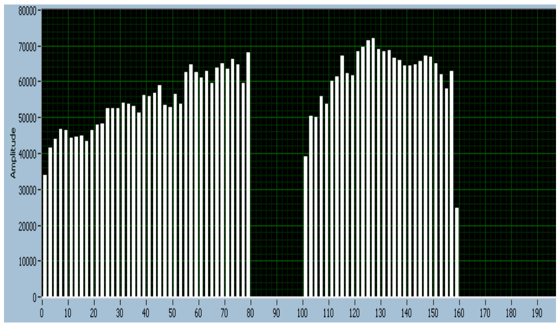

Figure 6: BEPCII bunch structure as seen with the ZDD detector.

of the electron impact point. The total charge distribution with 450 MeV electrons is shown in fig. 5.

The good agreement with Montecarlo of this experimental point allows us to claim the following figure for the ZDD resolution

$$\frac{\sigma(E)}{E} = \frac{0.07}{\sqrt(E)(GeV)} \oplus 0.05 \qquad (1)$$

A complete calibration will be done with photons produced in the process $e^+e^- \to e^+e^-\gamma$ at BEPCII.

The ZDD is a fast detector able to detect the BEPCII bunch structure (bunch separation 8 ns). Time resolution better then 1 ns and signal width smaller than 5 ns have been measured when the PM channels are added together (fig. 6). Single bunches are clearly identified and luminosity measurements with negligible statistical errors should be achieved as demonstrated in [3]. At such high rates a 20% pile up probability is expected for PM sequential pulses. To correct for that, pulse line shapes are stored with a sampling frequency of 500 GHz.

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