A Test of the Gamma Ray Detector for the GDH-Experiment at SPring-8(I. Nuclear Physics)

著者	Daito I., Geso M., Hasegawa S., Horikawa N., Ichihara H., Iwata T., Kondo K., Menze D., Miyachi Y., Nakayama H., Tanoshima S., Wakai A.
journal or publication title	核理研研究報告
volume	34
page range	32-37
year	2001-11
URL	http://hdl.handle.net/10097/30993

A Test of the Gamma Ray Detector for the GDH-Experiment at SPring-8

I. Daito[1], M.Geso[2], S.Hasegawa[3], N. Horikawa[1], H.Ichihara[3], T. Iwata[3], K. Kondo[3], D.Menze[1,4]*, Y. Miyachi[1†], H.Nakayama[3††], S.Tanoshima[3] and A.Wakai[3§]

[1] *CIRSE, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, 464-8602*
[2] *Department of medical radiations science, Royal Melbourne Institute of Technology, PO Box 71, Bundoora, Vic 3083, Australia*
[3] *Department of Physics, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, 464-8602*
[4] *Physikalisches Institut, Universität Bonn, D-53115 Bonn, Germany*

A prototype gamma ray detector for the detection of π^0 in the proposed experiment at SPring-8 to study the GDH sum rule (GDH experiment) has been built and tested. The detector is fabricated with lead-scintillator tiles and wave length shifter (WLS) fiber readout. High detection efficiency (above 85 %) for the gamma rays is the most important requirement for this detector. It has been tested with the tagged photon beam at LNS of Tohoku University. The results of the test alongside some Monte Carlo simulation are presented. The evaluated efficiency ranging in energy above 50 MeV is higher than 90%.

§ 1. Introduction

The proposed experiment [1] at SPring-8 facility aims at measuring the helicity dependent total photoabsorption cross-sections of the proton at photon energies ranging from 1.5 to 2.9 GeV. The results will be employed alongside other proposed measurements at other parts of the world to test the validity of the Gerasimov & Drell-Hearn(GDH) sum rule [2]. The polarized photon beam from the LEP beam line at SPring-8 which is currently operational [3] will be used as a source for circularly polarized photons. Essential feature of the experiment is a complete detection of hadronic final states using a 4π detector setup as displayed in Fig.1. Some detectors will be encompassed inside the bore of the superconducting solenoid magnet of the polarized target.

The gamma ray detector to be installed around the target is required to have a satisfactory efficiency and a large geometrical coverage for gamma rays of energies higher than 70 MeV which mostly originate from π^0. This requirement becomes even harder to fulfill due to (1) limited space (about 60 cm) inside the magnet bore where the detector will be placed and (2) the influence of the high magnetic field (2.5 T) of the superconducting magnet of the polarized target. A sampling calorimeter

* Present address: Physikalisches Institut, Universitat Bonn, D-53115 Bonn, Germany.
† Present address: Physics Department, Tokyo Institute of Technology, 2-12-1, Oh-okayama, Meguro, Tokyo 152-8551.
†† Present address: Department of Physics, Chiba University, 1-33, Yayoi, Inage-ku, Chiba, 263-8522.
§ Present address: Akita Industry Promotion Foundation(AIPF), 3-1-1, Sanno, Akita-city, Akita, 010-8572.

type detector consisting of lead and plastic scintillator tiles with WLS fibers for readout would be a possible solution. The WLS fiber couples into a long light guiding fiber which transmits the secondary emitted light to a photomultiplier tube (PMT). This PMT is placed away from the superconducting magnet to avoid the influence of the magnetic field.

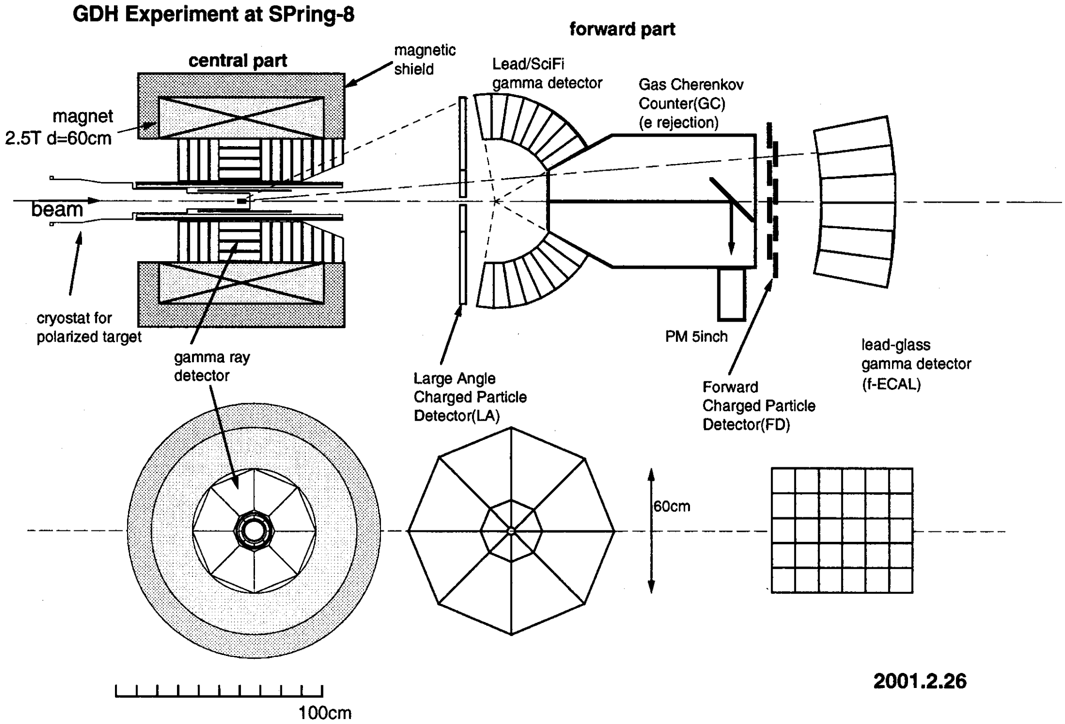

Fig.1. The setup of the GDH experiment at SPring-8.

§ 2. Design of the detector

The design of this detector is based on the following requirements to make suitable for the proposed experimental setup: (1) thickness of the detector along the gamma rays is required to be less than 20 cm; (2) detector's efficiency must exceed 85% for gamma rays of higher energy than 70 MeV; (3) the dead space should be as narrow as possible; and (4) the PMT is to be placed at about 3 meters away from the magnet. One of the major hurdles faced is the requirement for high detection efficiency with such small thickness compared to that of conventional calorimeters. Accordingly, the number of sampling layers and the thickness of the scintillator and lead tiles are appropriately determined.

The number of the sampling layers and the tiles thickness appropriate to obtain high detection efficiency are determined by using GEANT simulation [4]. The efficiency was based on the fraction of the events which are results of an energy deposit higher than the threshold energy of 10 MeV. Then the detection efficiency under the condition of detector's total thickness to be less than 170 mm was obtained as shown in Fig.2 as a function of the number of the sampling layers (n_s) and the ratio of the thickness of the scintillator and lead tiles ($R=t$(scin.)/t(lead)), where the thickness is measured in a unit of mm. The detection efficiency first increases according to n_s and then saturates. On the contrary, regarding R; it seems that there is a nominal R value which gives maximum efficiency.

Our simulation results show that efficiencies above 85% are obtainable with n_s value more than 17 and the ratio R ranging between 3 to 5. Accordingly, n_s value of 18 and the R ratio of 5 were selected for this detector's design. These results lead to the following detector's configuration: t(scin.) = 8.0 mm, t(lead) =1.6 mm and the total detector's thickness of $5.4X_0$ (where X_0 is a radiation length).

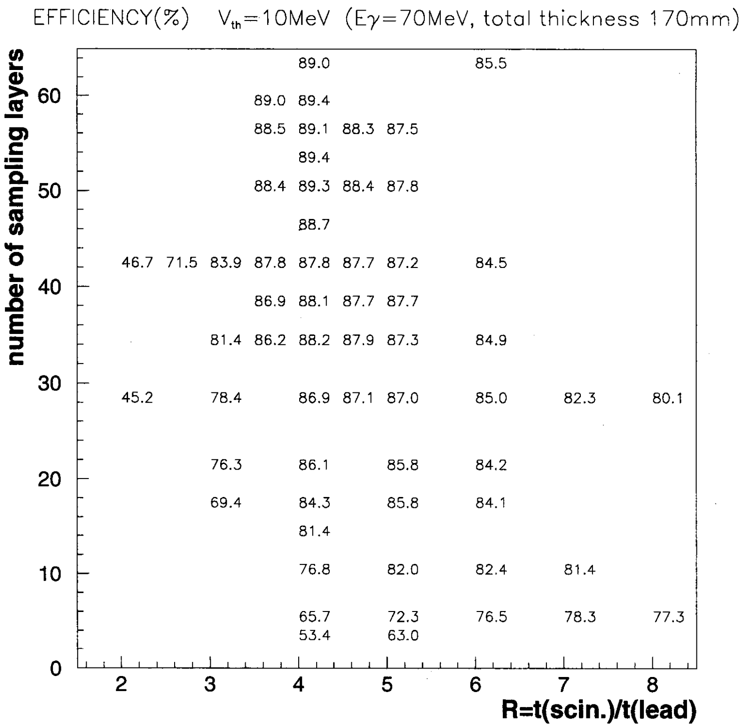

Fig.2. Efficiencies (in %) as a function of number of sampling layers and the ratio R.

§ 3. Description of the detector

This detector has a trapezoidal cross section and covers a 1/8 section ($\Delta\phi = 45°$) in the azimuthal angle as shown in Fig.3. It consists of 18 sampling layers of different areas, the smallest at the top and the largest at the bottom. The smallest layer is No.1 and its area is 75 × 200 mm^2 and the largest is No.18 and it is 210 × 200 mm^2 in area. Each layer consists of a lead tile of 1.6 mm thickness and a scintillator tile of 8 mm thickness. The scintillator tiles are cut from a BC412 Bicron scintillator plate. Grooves were etched on the surface of the scintillator tiles by a round edge cutter. Two different shaped grooves are formed; race-track and S type. The first type is adopted for the large area tiles i.e. from No. 6 to 18. The groove depth around 2.6 mm allows two turns of the WLS fiber to be installed in the tile. The diameter of the groove circles is made as large as possible in order improve the light collection. The second type, S type, allows only a single trace through the S-shaped groove of 1.6 mm in depth. This type is adopted for the first five tiles from No.1 to 5. WLS fiber Y-7(100) of 1 mm diameter from Kuraray is used in all the tiles. A small disc made of an aluminized Mylar sheet is glued on one end of the WLS fiber to form a light reflector. The other end of the WLS fiber is glued to the light guiding fiber 3m long. The other end of the light guiding fiber is directly attached to the PMT (Hamamatsu H1161). The four sides of the scintillator plate are painted with Bicron BC-650 white paint and the top and the bottom sides are covered with aluminized Mylar sheets.

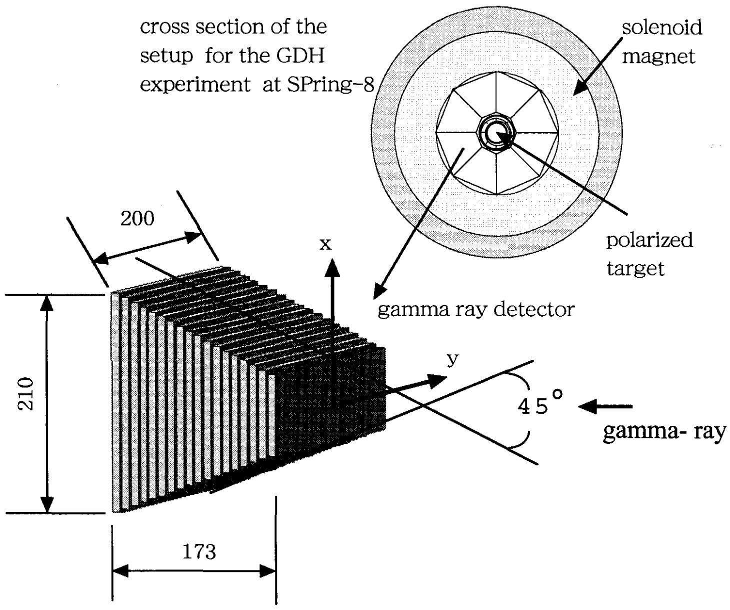

Fig.3. The schematic view of the prototype for the gamma ray detector.

§ 4. Gamma ray detection efficiency

Gamma ray detection efficiency is measured using the tagged photon beam delivered by the booster synchrotron at LNS. The beam energy ranges between 600 to 800 MeV and the energy resolution of the tagging system is about 4.7 MeV. The experimental setup is displayed in Fig.4. To veto charged particles in the beam, scintillation counters, T1, T2 and a Gas Cherenkov counter, C1 are used. The prototype gamma ray detector, Ga, is followed by a lead glass calorimeter, LG which allows calibration of the photon flux. An event selection was made, in order to eliminate photons not reaching Ga, requiring that at least one of Ga and LG gives a significant signal.

The pulse height distribution of the prototype gamma ray detector obtained for photons of 630 MeV shows asymmetric shape with a tail in the lower energy region due to leakage of a shower as displayed in Fig.5. It is well reproduced by our simulation using the GEANT4 package [5]. Setting the threshold at 4 photo electron level, the detection efficiency was calculated to be 97.1 $\pm$0.2%. We evaluated it also at different energies using the Monte Carlo simulation. The results are shown along with the experimental value in Fig.6. It was found detection efficiencies were satisfactorily high for the use of the proposed GDH experiment: above 90% at the energies higher than 50 MeV.

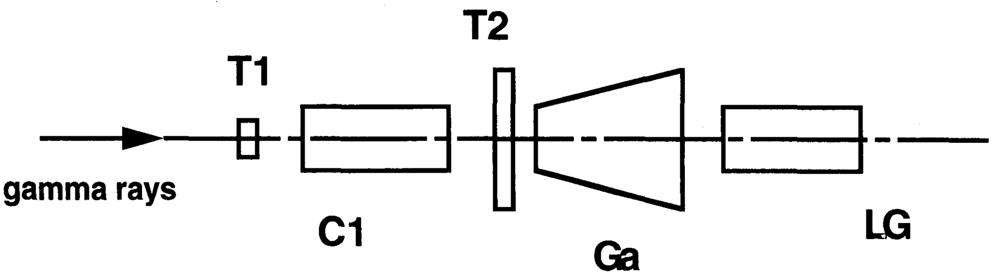

Fig.4. The experimental setup to measure detection efficiencies for gamma rays at LNS of Tohoku University. T1, T2: veto counters, C1: gas Cherenkov counter (veto), Ga: the gamma ray detector on test, LG: lead glass calorimeter.

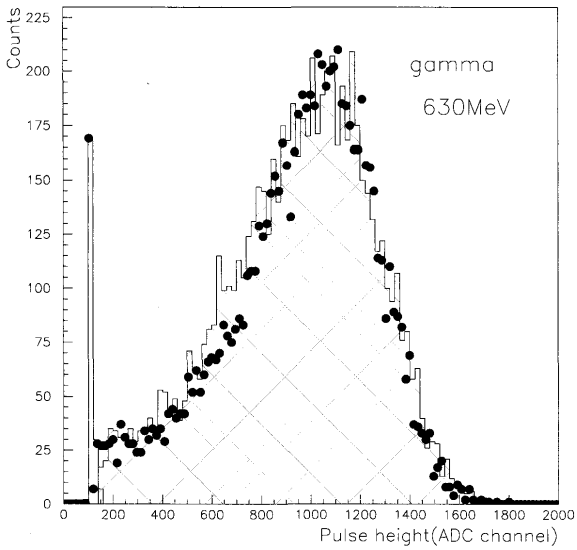

Fig.5. The pulse height distribution for gamma rays at 630 MeV along with the results of the Monte Carlo simulation displayed with the closed circles. The cross hatched area shows the events above the threshold set at 140 channed corresponding to 4 photo electron level. The fraction of the events in the hatched area to the total events gives the detection efficiency, 97.1±0.2%.

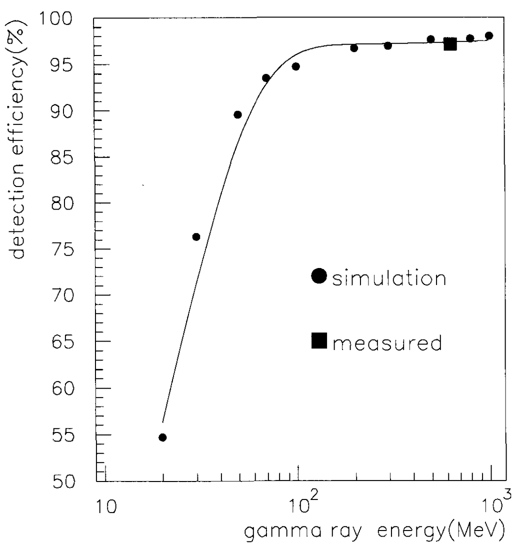

Fig.6. The detection efficiency for gamma rays as a functiion of energy. The closed square is the measured value. The closed circles are obtained in the simulation. The solid line is for an eye guide.

§ 5. Conclusion

The prototype of the gamma ray detector specially designed to be used in the proposed GDH experiment at SPring-8 has been fabricated with lead and scintillator tiles using WLS fiber readout. It has been tested with the tagged photon beam at LNS. The detection efficiency was measured and also evaluated based on the simulation. It was found to be higher than 90% at energies above 50 MeV. This result meets the requirement of the proposed GDH experiment.

Aacknowledgement

We would like to express our gratitude to the accelerator crews of LNS of Tohoku University for their effort to maintain the beam condition. We would like to thank Dr. H. Yamazaki of LNS-Tohoku University for his effort in arrangement of our experiment.

References

[1] T.Iwata : *Symposium on The Gerrasimov-Drell-Hearn Sum Rule and the Nucleon Spin Structure in the Resonance Region, Johannes Gutenberg-Universitaet, Mainz, June 14-17, 2000.*

[2] S.B.Gerasimov : Yad. Fiz. 2 (1965) 598, Sov.J. Nuci.Phys. **2** (1996) 430.

[3] S.D.Drell and A.C.Hearn : Phys. Rev. Lett. **16** (1966) 908.

[4] J.K.Ahn *et al.* : *12th Symposium on Acceierator Science and Technology*, 141-143, 27 Oct.1999, Wako, Japan,P.141.

[5] R.Brun *et al.* : *GEANT3 Users Guide* CERN/DD/EE/84(1987).

[6] K.Amano *et al.* : Nucl. Instr. and Meth. **A 453** (2000) 455.