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THE BGO-OD EXPERIMENT AT ELSA*

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Meson photoproduction is a key tool for the experimental investigation of the nucleon excitation spectrum. To disentangle the specific couplings of resonances, in addition to the rather well measured pion and eta photoproduction channels it is mandatory to obtain information on channels involving strange and vector mesons and higher mass pseudoscalar mesons, and the associated multi-particle final states with both charged and neutral particles. In this respect, the new BGO-OD experiment at the ELSA accelerator of the University of Bonn's Physikalisches Institut provides unique instrumentation. We describe the experiment, present its status and the initial program of measurements.

Keywords: Mesons production by photons and leptons; photonuclear reactions.

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1. Introduction

The experimental study of the nucleon excited states through photoproduction requires both high intensity polarizable beams and large solid-angle hermetic detectors. High energy photon beams can be obtained either via *Bremsstrahlung* of electrons in an appropriate radiator, or by exploiting the Compton backscattering process of Laser light off high energy electrons, the latter technique allowing for a better polarization quality at the expense of the beam total intensity. Large solid angle detectors can, in turn, be optimized for the measurement of charged particles (e.g. CLAS detector at Jefferson Lab.[1]) or of neutral (photons) particles (e.g. CB-ELSA detector[2]).

The BGO-OD experiment is designed to use a polarizable *Bremsstrahlung* photon beam with a maximum energy of 3.5 GeV. The detector will provide excellent energy resolution and detection efficiency for neutrals by exploiting the features of the BGO *Rugby Ball* calorimeter, coupled with the *Open Dipole* spectrometer for charged particles in the forward direction. This way, mixed-charge final states will be accurately measured, allowing the study of specific final states that are presently poorly known.

Section 2 will describe the beam characteristics; the detector will be illustrated in section 3, and the present status of the experiment is discussed in section 4, along with the initial experimental program.

2. Photon Beam

The photon beam for the BGO-OD experiment is obtained via the *Bremsstrahlung* of the electrons from the stretcher ring ELSA. ELSA is a three stage electron accelerator situated at the Physikalisches Institut of the University of Bonn. After pre-acceleration in linear accelerators, unpolarized or polarized electron beams are injected into a booster synchrotron that delivers a pulsed beam of 1.2 GeV, which is subsequently transferred to the ELSA stretcher ring. A homogeneous filling of the ring results in a circulating cw-beam of typically 100mA. The beam energy can be further increased to a maximum of 3.5 GeV. The circulating beam is slowly extracted with intensities of typically few nA and fed to one of the two experimental areas.[3]

The beam is tagged in a tagging hodoscope. The tagger, consisting of 120 channels, will cover the energy range $(0.1\div0.9)E_{e^-}$ with variable resolution ($10\div40$ MeV). It is designed to handle a high intensity beam (up to $5 \cdot 10^7 s^{-1}$). Coherent *Bremsstrahlung* is used to produce linearly polarized photons, while circular polarization is obtained via *Bremsstrahlung* of longitudinally polarized electrons.

Two beam monitors are installed at the end of the beam line. The GIM (Gamma Intensity Monitor) is a lead glass detector with a 100% efficiency that measures, at low rates, the total number of photons. At higher rates, the flux is measured by a set of 3 scintillation counters, called FluMo.

3. Detector

The BGO-OD detector (Fig. 1) is geometrically divided in two parts: a central one with excellent calorimetry and high neutron detection efficiency, and a forward one with a magnetic spectrometer for charged particle tracking, with very good momentum resolution.

The central detector of the experimental setup is the large solid angle BGO electromagnetic calorimeter. The calorimeter is combined with two multi-wire proportional chambers (MWPC) for inner tracking and a plastic scintillator barrel for particle identification through the measurement of dE/dx. The calorimeter consists

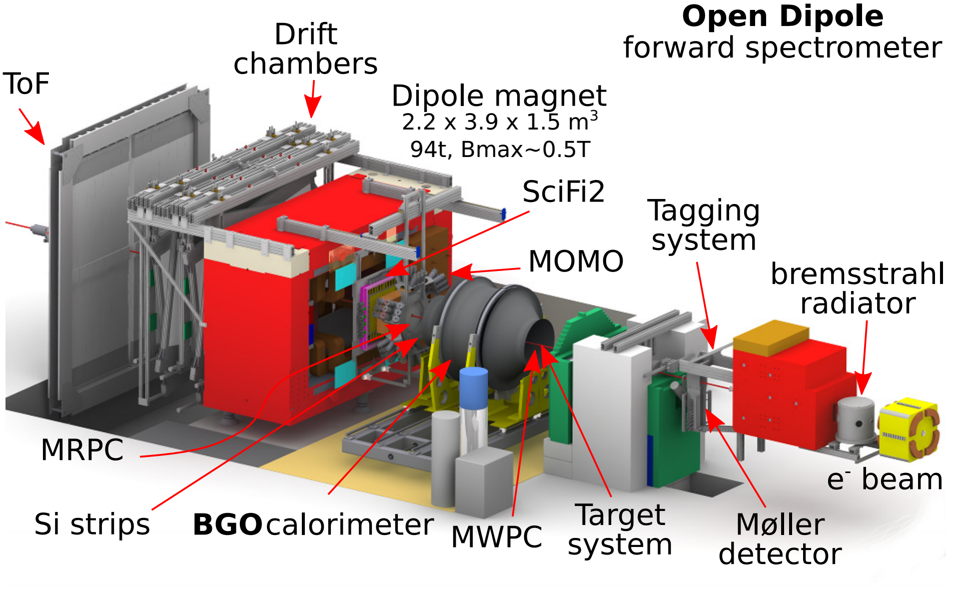

Fig. 1. A schematic view of the BGO-OD experiment.

of 480 BGO crystals, each 24 cm long. The carbon fibre support structure is segmented into 15 polar sectors (25° to 155°), and 32 azimuthal sectors (0° to 360°). The crystals are shaped like pyramidal sectors with a trapezoidal base. Each subset of 32 modules (crystal plus standard photomultiplier) is connected to a mixer, which is equipped with a programmable attenuator. Moreover, the sum of all signals, which is proportional to the total energy deposited in the calorimeter, enters into the general trigger logic. The energy and time information of the BGO is measured for each channel with new sampling AVM16 ADCs from Wiener. The modules have a 160 MHz sampling frequency, 12 bit resolution and feature extraction. The time resolution is about 4 ns.

The detector is ideally suited for photons, with an excellent energy resolution of about 1.3% at $E_\gamma = 1$ GeV.[4] In addition, protons can be detected in a limited range. Up to a kinetic energy of $T_p = 100$ MeV, their energy can be measured reliably, but protons with $T_p \geq 450$ MeV escape the detector.[5] Studies of the neutron detection efficiency were made with the GRAAL setup and show high neutron efficiencies ($\epsilon_n \approx 40\%$).[6]

The scintillator barrel inside the BGO is located between the crystals and the inner tracking detector (MWPC). It consists of 32 scintillators (length ≈ 430 mm, thickness ≈ 5 mm) which are coupled to Hamamatsu H3164-10 sel PMTs. The standard readout is based on two 16 channel Multievent QDC (CAEN V792N) and a 128 channel Multihit TDC (CAEN V1190A).

Inside the BGO calorimeter two cylindrical multi wire proportional chambers (MWPC) allow the reconstruction of trajectories from charged particles. Each chamber is made of two coaxial cylindrical cathodes, segmented into strips and wound helicoidally. The anode array consists of equally spaced wires, stretched parallel to the cylinder axis in the middle of the active area (gas gap ≈ 8mm). The expected resolution is $\Delta z \approx 300$ μm and $\Delta\theta \approx 1°$ The acceptance for particle tracking in the laboratory system is from $\theta = 8°$ to $\theta = 163°$.

Since the laboratory angles θ_{lab} 8÷25 degrees are only partially covered by the MWPC cylindrical chambers, the coverage of this important kinematical region is complemented by an anular MRPC (Multi-gap Resistive Plate Chambers) detector. with a spatial resolution of 1 cm^2 and a time resolution $\sigma_t \approx 50$ ps.

In the forward direction the *Open Dipole* spectrometer is constructed around the dipole magnet. The dipole has an extended gap of 84 cm and the resulting acceptance is ±12° in the horizontal plane and ±8° in the vertical direction. At the maximum current, it provides a field strenght $B_{max} = 0.54$ T. Tracks are reconstructed from the position information given by scintillating fiber detectors (before the magnet), drift chambers and a Time-of-Flight (ToF) scintillator wall (after the magnet).

MOMO is a scintillating fiber detector incorporating 672 channels with readouts through 16-channel Hamamatsu R4760 phototubes. This detector was originally built for the MOMO experiment at COSY and was successfully used there for the detection of pion and kaon pairs.[7,8]

SCIFI2 is a planar detector with an active area of 66×51 cm^2. It is composed by 640 scintillating fibers (dia 3 mm). Groups of 16 fibers are glued together to form a "module". The modules are arranged in two layers twisted by 90 degrees. The signals from each module are read out by a 16-channel photomultiplier (Hamamatsu H6568). The timing resolution of the detectors is about 2ns (FWHM).

The 8 drift chambers are mounted behind the spectrometer magnet. Each contains a double layer of hexagonal drift cells, so that each particle track will hit at least two drift cells in each chamber it passes. The chambers come in four different orientations, two have vertical wires and measure the x-coordinate, two more have horizontal wires and measure the y-coordinate, and the remaininf four have wires tilted by $\pm 9^\circ$ against the vertical, measuring an u- respectively v-coordinate, used to disambiguate between true and false combinations of multiple hits in the x and y chambers. To avoid counting overload by secondary e^+ e^- pairs, insensitivity spots of 5×5 cm^2 are provided at the centre of the chambers by anodizing 6 of the sense wires with gold, thus increasing the total diameter to 100μm in the desired area. The chambers are operated with a mixture of 70% Argon and 30% CO_2. The forward spectrometer is complemented by a time-of-flight (TOF) detector, that provides flight-time information for both charged particles and neutrons; this will cover the polar angular range up to 12° at a distance of 5 m from the target. The wall is formed by four layers of scintillation counters previously used in the SAPHIR and GrAAL experiments.[9,10] The time resolution is $\sigma_t \simeq 500$ ps and the efficiency for neutron detection $\epsilon_n \simeq 15\%$.

Overall, a $\Delta p/p \approx 2\%$ momentum resolution for charged particles is expected.

In a second stage of the experiment other detectors will be added to the setup, to improve performances and allow recoil polarization measurements. An aerogel Čerenkov detector, a tile hodoscope and a vertex silicon strips detector are already planned.

4. Present Status and Initial Experimental Program

All the detector components are installed at ELSA S-beamline, save for the MRPC and MWPC that will be installed by the end of 2013. Tracks are reconstructed in the spectrometer, and π^0 and η signals from their 2γ decays are observed in the *Rugby Ball* with a mass resolution very close to the design value (Fig. 2). Also the K^+ signal in the *Rugby Ball* from the delayed kaon decay[11] was observed. The tagging hodoscope will be completed by september 2013 and commissioned in a dedicated beamtime. With a reduced (60 channels) hodoscope setup, a linearly polarized beam was obtained from coherent *Bremsstrahlung* and optimized with the Stonhenge technique.[12]

The first beam time period for data taking is scheduled in November 2013. The initial experimental program will focus on meson (η, η', ω and ϕ) and strangeness photoproduction off Hydrogen and the study of η-mesic nuclei in a carbon target. A neutron (Deuteron) target will be used in a subsequent stage of the experiment.

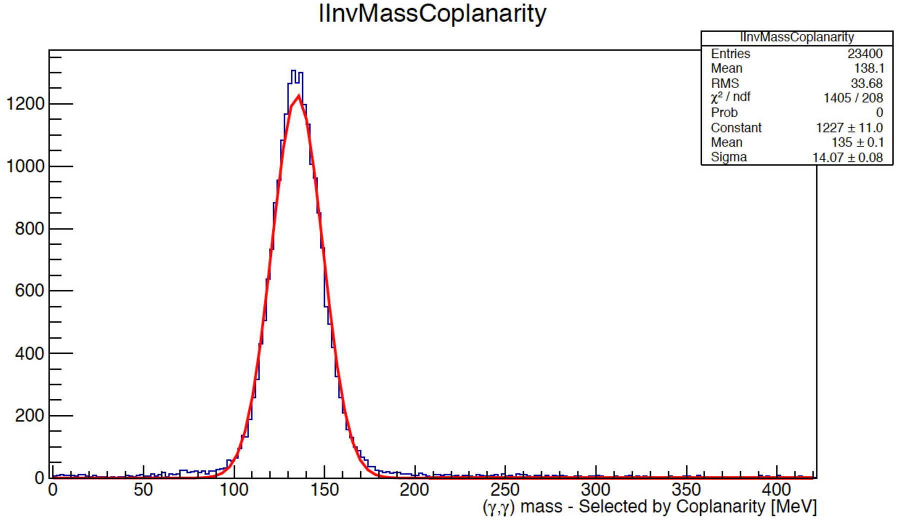

Fig. 2. Two-photon invariant mass spectrum obtained in the *Rugby Ball*.

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