ЛМФ 2015 (гамма-нуклон)

Лаборатория мезонной физики ОФВЭ

(В.В.Сумачёв)

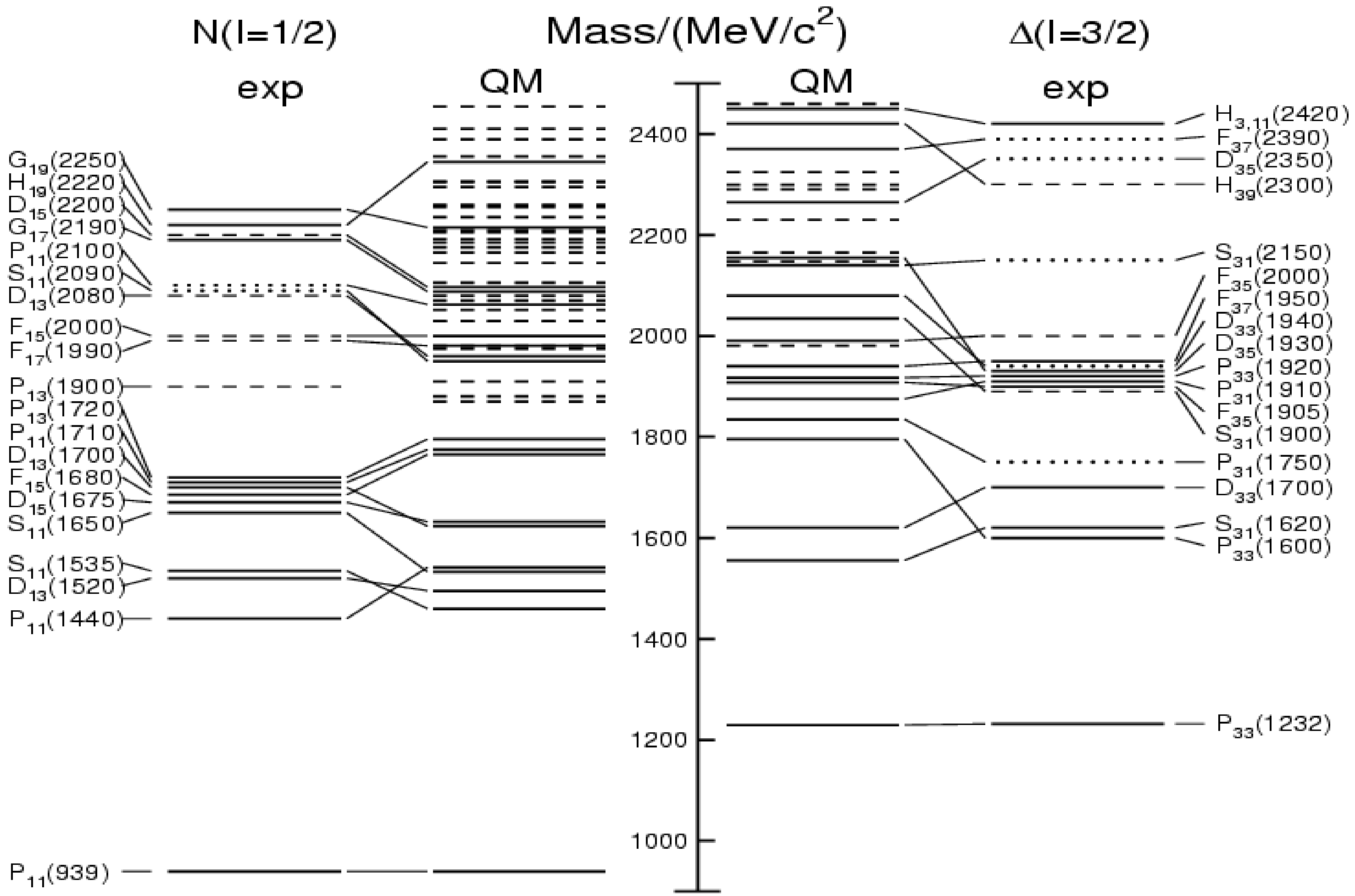
Отчет о ходе выполнения научно-исследовательской работы

«Барионная спектроскопия на фотонных пучках.»

1. **Бонн, CB-ELSA**
2. **Бонн, BGO-OD**

2015 г.

Сравнение предсказаний кварковой модели с экспериментом.



Excitation spectrum of the nucleon. (J.Phys.G37:075021, 2010)

L. Tiator

Сравнение количеств наблюдаемых в «полных» экспериментах по рождению мезонов:

Пион-нуклонное рассеяние – 4 наблюдаемых возможны
4 наблюдаемых нужны для полного эксперимента
0 наблюдаемых можно предсказать

Фотообразование пионов - 16 наблюдаемых возможны
8 наблюдаемых нужны для полного эксперимента
8 наблюдаемых можно предсказать

Возможно, в частности, измерение 16 поляризационных наблюдаемых в фоторождении мезонов (p, h , K, …) при использовании 32 различных вариантов постановки эксперимента.

…L.Tiator….arXiv:0705.3550v1 [nucl-ex] 24 May 2007

…L.Tiator…Zeitschrift fur Phys. A v.352, № 3, p.327 (1995).

ЛМФ 2015 (гамма-нуклон)

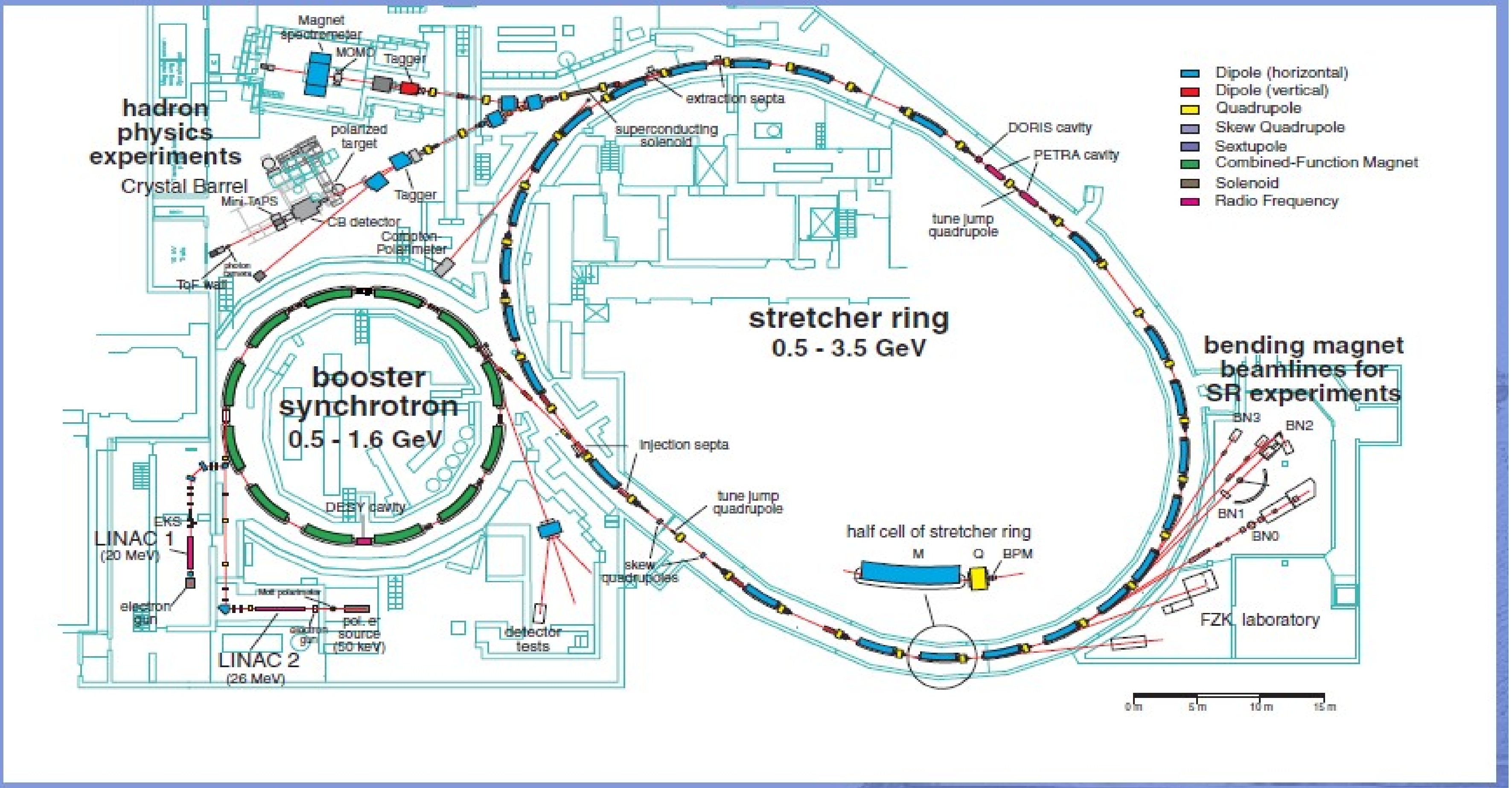
Экспериментальные данные по гамма-протон взаимодействию на установке CB-ELSA (Бонн).

Участники от Лаборатории мезонной физики:

Д.Е. Баядилов, Ю.А. Белоглазов, А.Б. Гриднев, И.В Лопатин, Д.В. Новинский, А.К. Радьков, В.В. Сумачёв.

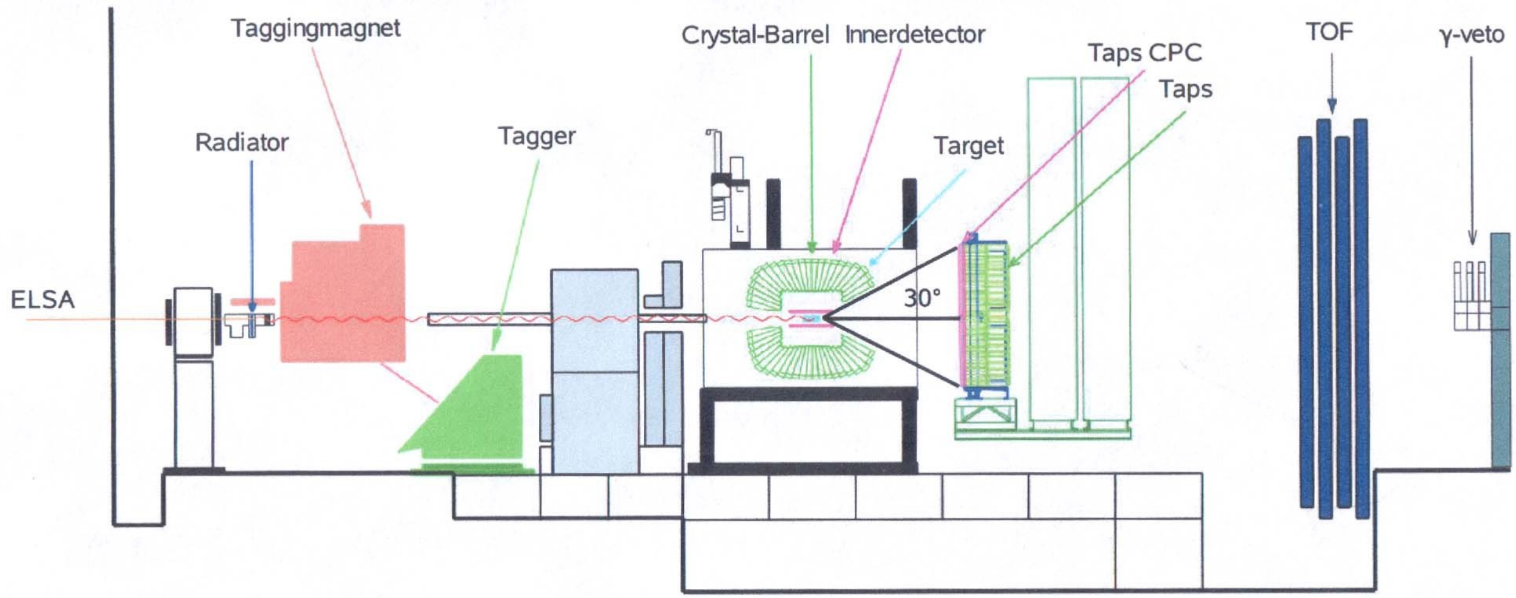
Ускоритель - ELectron Stretcher Anlage (ELSA)

- Energy range 0.5–3.5 GeV
- Max. extracted intensity ∼ 1nA
- Electron polarisation ∼ 60–80%



ЛМФ 2015 (гамма-нуклон)

Experimental Setup

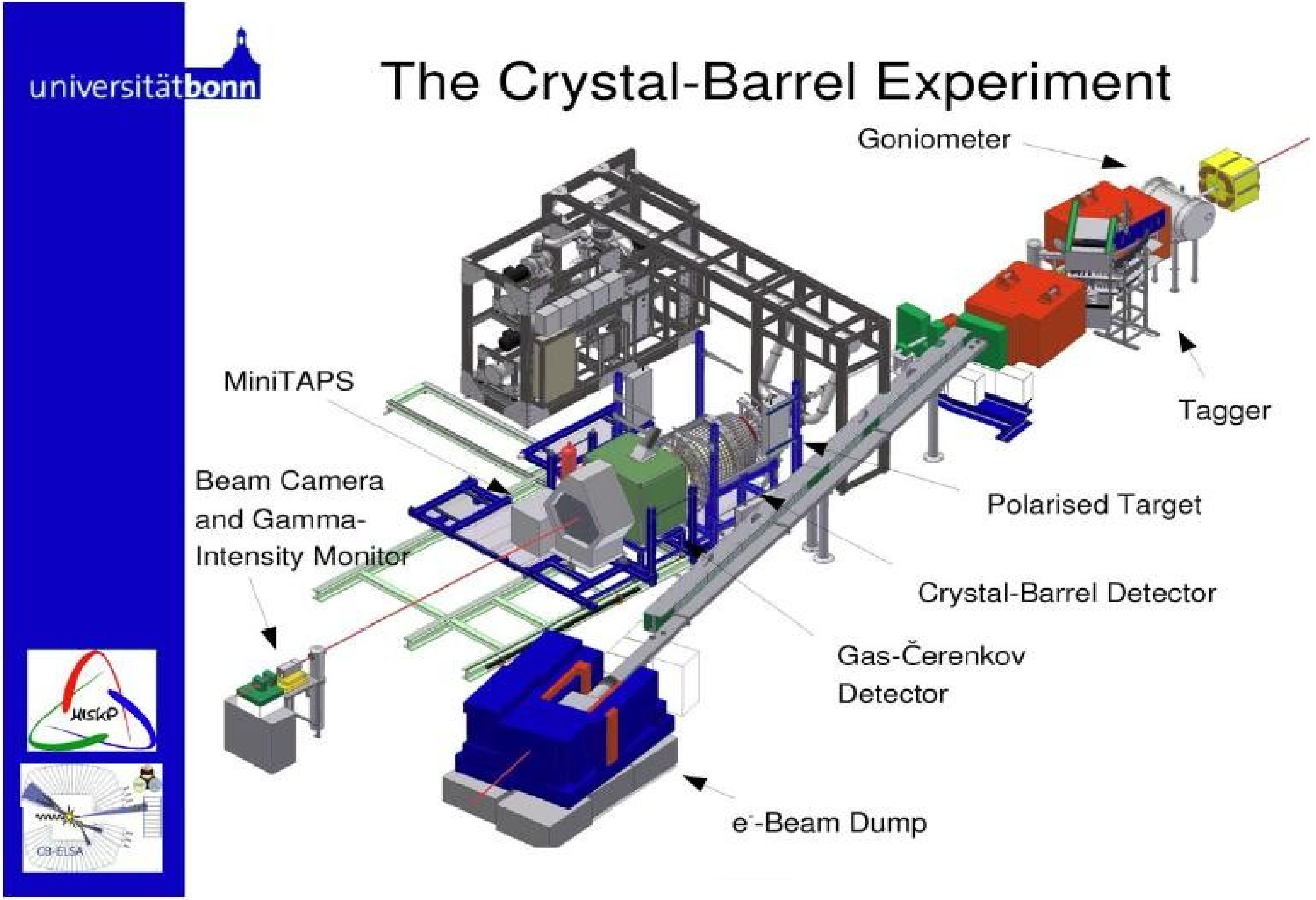


3.3 GeV $E_{electron}$ up to 3GeV photons LH_2/LD_2 1290 CsI crystals 522 BaF crystals

4π geometry, high sensitivity to multiphoton final states
physics aims:
meson production and **baryon spectroscopy**

ЛМФ 2015 (гамма-нуклон)

Схема установки CB-ELSA



ЛМФ 2015 (гамма-нуклон)

Photoproduction of ω Mesons off the Proton☆

A. Wilson[a,b], V. Crede[b,*], A.V. Anisovich[a,c], J.C.S. Bacelar[e], B. Bantes[d], O. Bartholomy[a], D. Bayadilov[a,c], R. Beck[a], Y.A. Beloglazov[c], K.T. Brinkmann[f], R. Castelijns[e], H. Dutz[d], D. Elsner[d], R. Ewald[d], F. Frommberger[d], M. Fuchs[a], Chr. Funke[a], R. Gregor[f], A. Gridnev[c], E. Gutz[f,a], J. Hannappel[d], W. Hillert[d], P. Hoffmeister[a], I. Horn[a], I. Jaegle[g], T. Jude[d], J. Junkersfeld[a], H. Kalinowsky[a], V. Kleber[d], Frank Klein[d], Friedrich Klein[d], E. Klempt[a], M. Kotulla[g,f], B. Krusche[g], M. Lang[a], H. Löhner[e], I.V. Lopatin[c], S. Lugert[f], T. Mertens[g], J.G. Messchendorp[e,f], V. Metag[f], M. Nanova[f], V.A. Nikonov[a,c], D. Novinski[c], R. Novotny[f], M. Ostrick[d], L.M. Pant[f], H. van Pee[a], M. Pfeiffer[f], A. Roy[f], A.V. Sarantsev[a,c], C. Schmidt[a], H. Schmieden[d], S. Shende[e], V. Sokhoyan[a], N. Sparks[b], A. Süle[d], V.V. Sumachev[c], T. Szczepanek[a], U. Thoma[a], D. Trnka[f], R. Varma[f], D. Walther[a,d], Ch. Wendel[a], U. Wiedner[i]

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[g] *Physikalisches Institut, Universität Basel, CH-4056 Basel, Switzerland*
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08.01483v1 [nucl-ex] 6 Aug 2015

Abstract

The differential cross sections and unpolarized spin-density matrix elements for the reaction $\gamma p \to p\omega$ were measured using the CBELSA/TAPS experiment for initial photon energies ranging from the reaction threshold to 2.5 GeV. These observables were measured from the radiative decay of the ω meson, $\omega \to \pi^0\gamma$. The cross sections cover the full angular range and show the full extent of the t-channel forward rise. The overall shape of the angular distributions in the differential cross sections and unpolarized spin-density matrix elements are in fair agreement with previous data. In addition, for the first time, a beam of linearly-polarized tagged photons in the energy range from 1150 MeV to 1650 MeV was used to extract polarized spin-density matrix elements.

These data were included in the Bonn-Gatchina partial wave analysis (PWA). The dominant contribution to ω photoproduction near threshold was found to be the $3/2^+$ partial wave, which is primarily due to the sub-threshold $N(1720)\,3/2^+$ resonance. At higher energies, pomeron-exchange was found to dominate whereas π-exchange remained small. These t-channel contributions as well as further contributions from nucleon resonances were necessary to describe the entire dataset: the $1/2^-$, $3/2^-$, and $5/2^+$ partial waves were also found to contribute significantly.

ЛМФ 2015 (гамма-нуклон)

In this paper, the differential cross sections and spin-density matrix elements for the reaction

$$\gamma p \to p\omega \tag{1}$$

are presented by reconstructing the ω from the neutral decay,

$$\omega \to \pi^0\gamma \to \gamma\gamma\gamma\,. \tag{2}$$

2. Experimental Setup

The CBELSA/TAPS experiment was conducted at the electron stretcher accelerator (ELSA) facility [4] located at the University of Bonn in Germany. A 3.175 GeV electron beam from ELSA interacted with a radiator target and produced bremsstrahlung photons. The radiator target was situated in a goniometer which contained copper radiators of varying thickness along with a diamond radiator for linear polarization. The unpolarized data utilized a copper radiator of thickness $3/1000\,X_R$ (radiation length). The polarized data used a diamond radiator. The bremsstrahlung electrons were deflected by a dipole magnet into the tagging detector system (tagger). The tagger consisted of 480 scintillating fibers on top of 14 scintillating bar counters which partly overlapped. Using the knowledge of the magnetic field strength and the hit position in the tagger, the energy of each electron was determined and used to tag each bremstrahlung photon with energy and time information.

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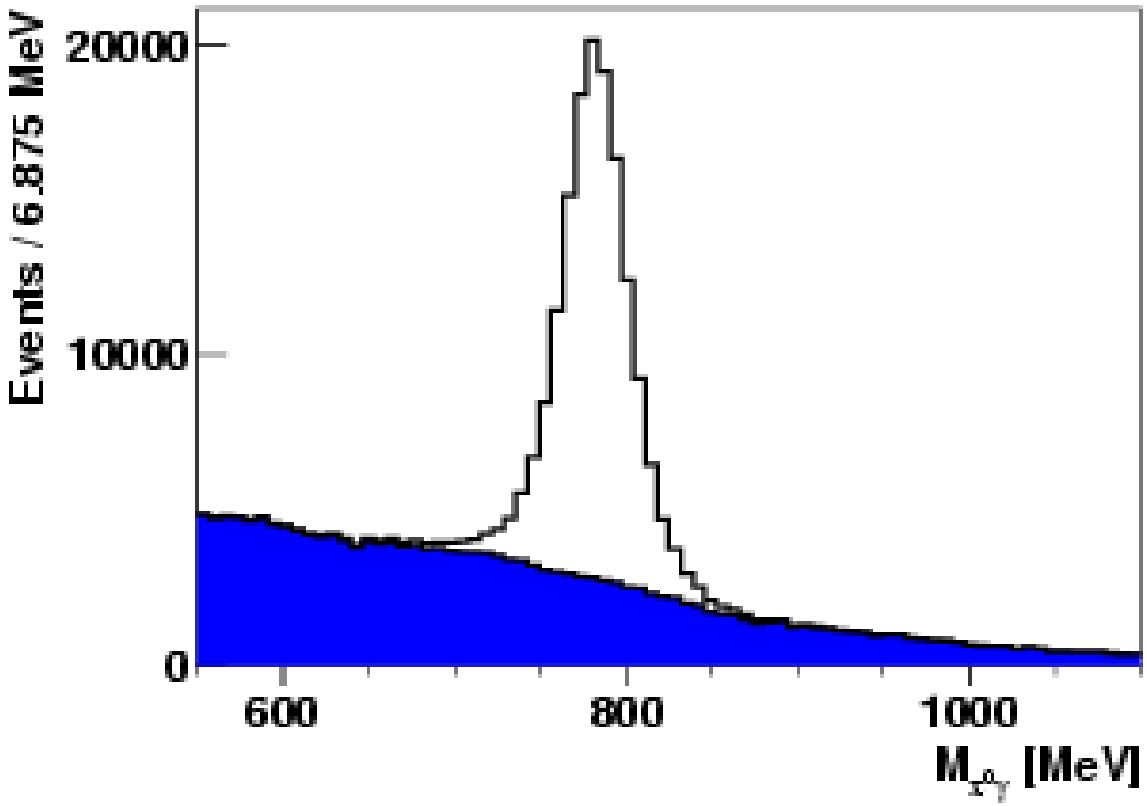

Figure 1: (Color Online) The invariant $\pi^0\gamma$ mass distribution for unpolarized data events which were subjected to the Q-factor fitting (background subtraction). These events survived all kinematic cuts. The solid blue area shows the background subtracted using the Q-factor method. There were approximately 128,000 ω's in this dataset.

ЛМФ 2015 (гамма-нуклон)

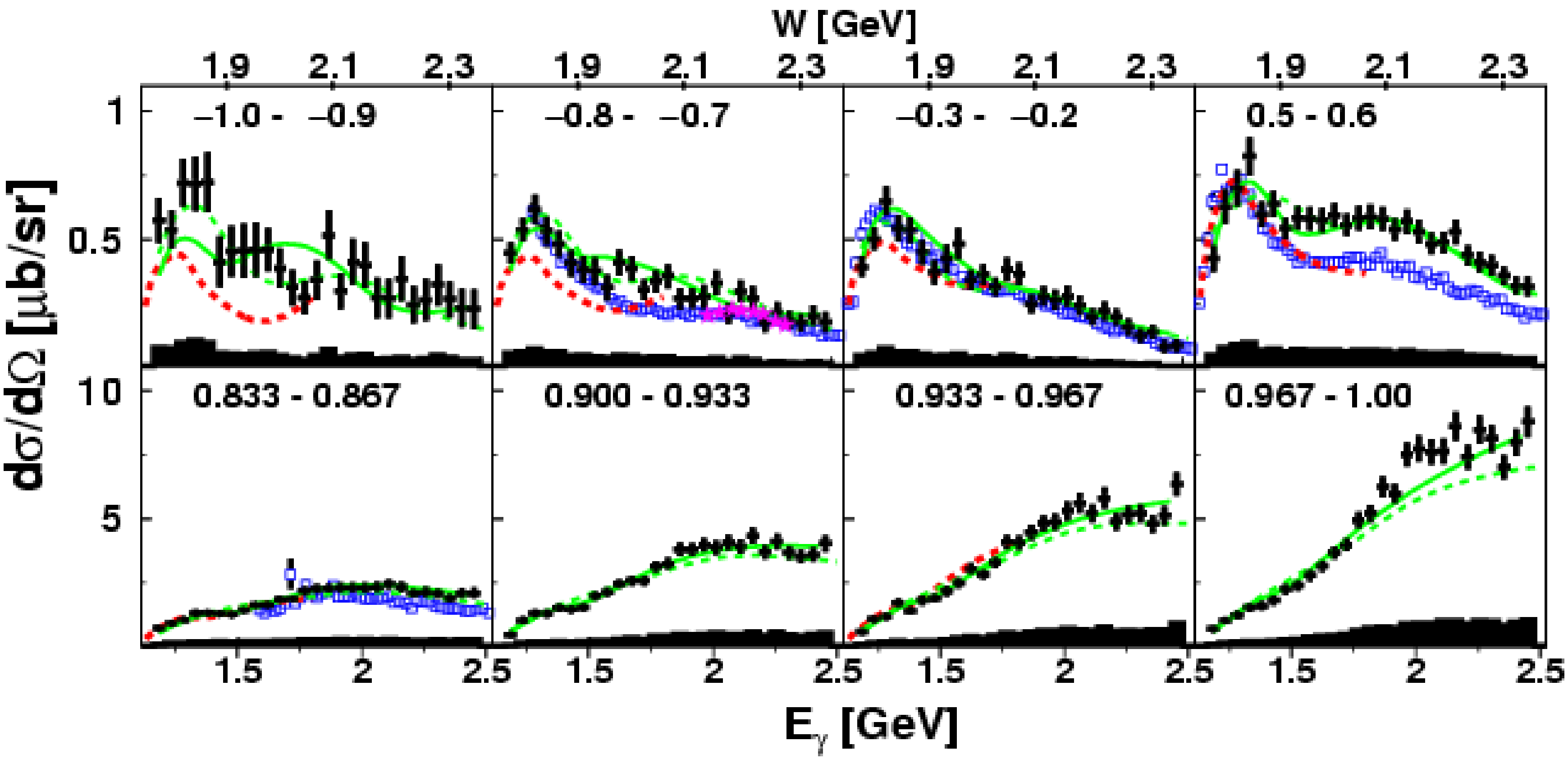

Figure 2: (Color Online) Excitation functions for $\gamma p \to p\omega$ from CBELSA/TAPS (•) for selected angle bins. For comparison, the CLAS data [19] are represented by □, the LEPS data [20] are represented by ★ (for the −0.8 - −0.7 panel), and the Gießen Lagrangian fit in [21] is represented by - - - . The Bonn-Gatchina PWA solutions are represented by green lines: — (full solution), - - - (solution without $3/2^+$ partial wave). Statistical uncertainties are reported as vertical bars on each data point. The total systematic uncertainty for the CBELSA/TAPS data is shown as a black band at the bottom of each plot. Each plot is labeled with its range in cosine of the polar angle in the center-of-mass frame of the ω meson ($\cos\theta^{\omega}_{c.m.}$). The horizontal axis is measured in the energy of the initial photon. An additional horizontal axis at the top of the figure shows the center-of-mass energy.

ЛМФ 2015 (гамма-нуклон)

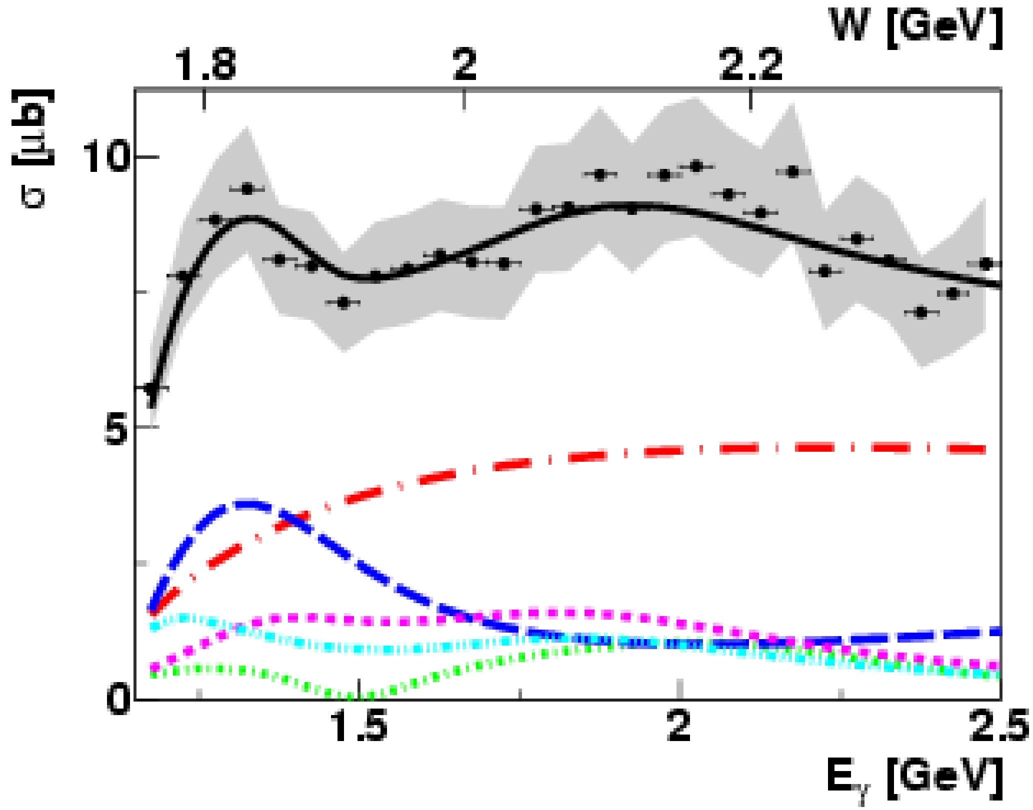

Figure 3: (Color Online) Total cross cection for $\gamma p \to p\omega$ from the CBELSA/TAPS experiment (•) as a function of the initial photon (E_γ) and center-of-mass (W) energy. The error bars represent the statistical uncertainty and the gray band represents the systematic uncertainty. The Bonn-Gatchina fit is represented with a solid black line. The largest contributions to this fit are (listed from largest to smallest at the highest energies) pomeron-exchange (red dash-dot), resonant production of the $J^P = 3/2^+$ partial wave (blue dashed), $3/2^-$ partial wave (magenta dotted), $5/2^+$ partial wave (cyan dotted), and $1/2^-$ partial wave (green dotted).

ЛМФ 2015 (гамма-нуклон)

The $\gamma p \to p\omega$ differential cross sections and spin-density matrix elements detected in the ω meson's radiative decay measured at the CBELSA/TAPS experiment have been presented. The experimentally measured events were obtained by irradiating a liquid hydrogen target with tagged photons ranging in energy from threshold up to 2.5 GeV. The measured cross sections presented here seem to be systematically higher than some previous measurements. This indicates a normalization discrepancy in particular between CBELSA/TAPS and CLAS. The spin-density matrix element, ρ^0_{00}, agrees well with the CLAS measurement and further suggests that the cross section discrepancy is related to an unknown issue with the absolute normalization, either at CLAS or CBELSA/TAPS.

The BnGa PWA solution indicated that the dominant contributions to the cross section near threshold were the sub-threshold $N(1720)\,3/2^+$ resonance as well as the $3/2^-$ and $5/2^+$ partial waves. Toward higher energies, the t-channel contributions increased in strength. They were defined by a dominant pomeron-exchange and a smaller π-exchange. In addition to the t-channel amplitude, further contributions from nucleon resonances were required to describe the data. The $1/2^-$, $3/2^-$, and $5/2^+$ partial waves showed significant contributions to the PWA solution. The $1/2^-$ wave was defined by two sub-threshold resonances interfering destructively with the $N(1895)\,1/2^-$ resonance. The $N(1875)$ and $N(2120)$ resonances created the two-peak structure seen in the $1/2^-$ partial wave in Figure 3. The $5/2^+$ partial wave had sub-threshold contributions along with the $N(2000)$ resonance. In addition, at least one previously unseen higher-mass resonance above 2 GeV was needed to describe the data.

ЛМФ 2015 (гамма-нуклон)

Measurement of double polarisation asymmetries in ω-photoproduction

H. Eberhardt[a], T. C. Jude[a], H. Schmieden[a], A.V. Anisovich[b,c], B. Bantes[a], D. Bayadilov[b,c], R. Beck[b], Yu. Beloglazov[c], M. Bichow[d], S. Böse[b], K.-Th. Brinkmann[e], Th. Challand[f], V. Crede[g], F. Diez[e], P. Drexler[e], H. Dutz[a], D. Elsner[a], R. Ewald[a], K. Fornet-Ponse[a], St. Friedrich[e], F. Frommberger[a], Ch. Funke[b], M. Gottschall[b], A. Gridnev[c], M. Grüner[b], E. Gutz[b,e], Ch. Hammann[b], J. Hannappel[a], J. Hartmann[b], W. Hillert[a], Ph. Hoffmeister[b], Ch. Honisch[b], I. Jaegle[f], D. Kaiser[b], H. Kalinowsky[b], F. Kalischewski[b], S. Kammer[a], I. Keshelashvili[f], V. Kleber[a], F. Klein[a], E. Klempt[b], K. Koop[b], B. Krusche[f], M. Kube[b], M. Lang[b], I. Lopatin[c], Y. Maghrbi[f], K. Makonyi[e], V. Metag[e], W. Meyer[d], J. Müller[b], M. Nanova[e], V. Nikonov[b,c], R. Novotny[e], D. Piontek[b], S. Reeve[a], G. Reicherz[d], T. Rostomyan[f], S. Runkel[a], A. Sarantsev[b,c], St. Schaepe[b], Ch. Schmidt[b], R. Schmitz[b], T. Seifen[b], V. Sokhoyan[b], V. Sumachev[c], A. Thiel[b], U. Thoma[b], M. Urban[b], H. van Pee[b], D. Walther[b], Ch. Wendel[b], U. Wiedner[d], A. Wilson[b], A. Winnebeck[b]

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1v2 [nucl-ex] 1 Sep 2015

Abstract

The first measurements of the beam-target-helicity-asymmetries E and G in the photoproduction of ω-mesons off protons at the CBELSA/TAPS experiment are reported. E (G) was measured using circularly (linearly) polarised photons and a longitudinally polarised target. E was measured over the photon energy range from close to threshold (E_γ = 1108 MeV) to E_γ = 2300 MeV and G at a single energy interval of $1108 < E_\gamma < 1300$ MeV. Both measurements cover the full solid angle. The observables E and G are highly sensitive to the contribution of baryon resonances, with E acting as a helicity filter in the s-channel. The new results indicate significant s-channel resonance contributions together with contributions from t-channel exchange processes. A partial wave analysis reveals strong contributions from the partial waves with spin-parity $J^P = 3/2^+, 5/2^+$, and $3/2^-$.

ЛМФ 2015 (гамма-нуклон)

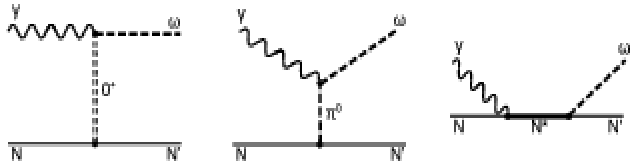


Figure 1: ω production via t-channel 0^+ (Pomeron) exchange (left), t-channel π^0 exchange (middle) and s-channel intermediate resonance (right).

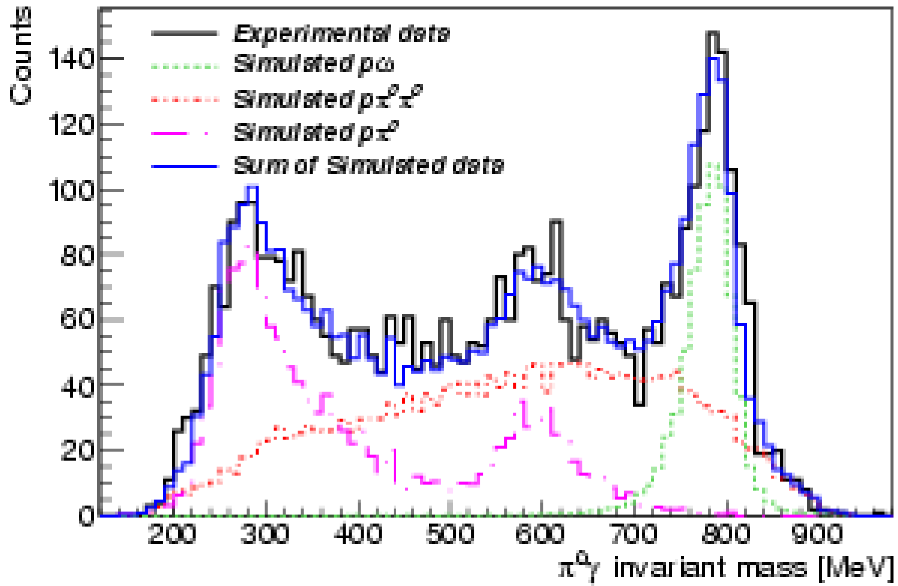


Figure 2: Typical $\pi^0\gamma$ invariant mass distribution of one bin (E_γ = 1300 – 1400 MeV, $\cos\theta^{\omega}_{CMS}$ = (−0.75) – (−0.5)). Experimental and simulated data labelled inset. Colour available online.

ЛМФ 2015 (гамма-нуклон)

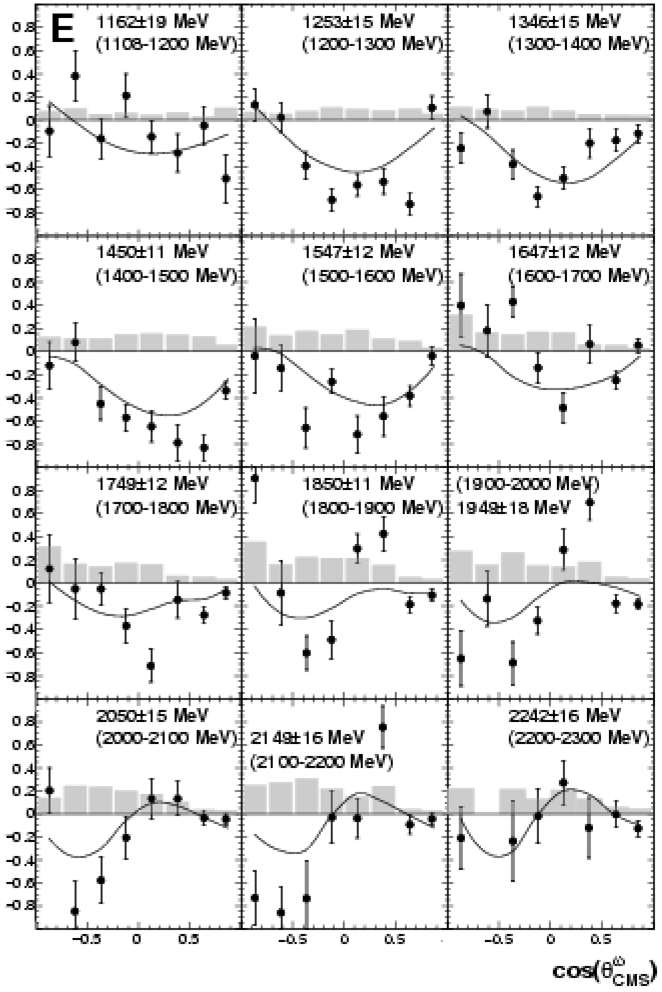


Figure 4: Beam-target-helicity asymmetry, E, as a function of $\cos\theta^{\omega}_{CMS}$. Systematic errors are on the abscissa. The event weighted average beam energy and systematic error is given for each energy interval, with the energy range given in parentheses. The solid line is the result of the Bonn-Gatchina PWA when including this data (see text for details). The data are tabulated in Ref. [34].

ЛМФ 2015 (гамма-нуклон)

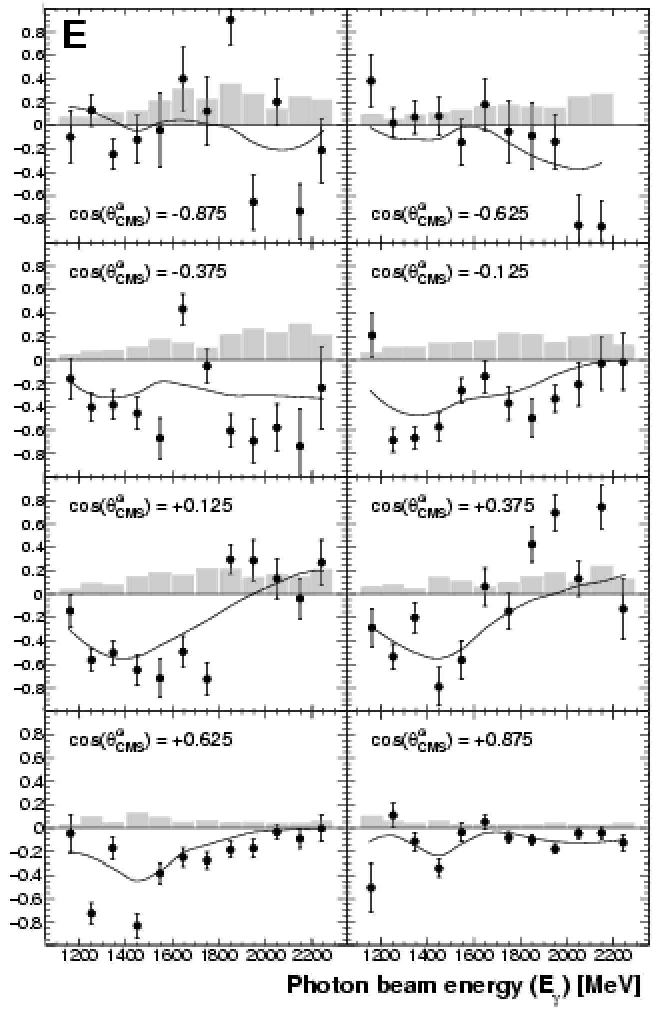


Figure 5: Beam-target-helicity asymmetry, E, as a function of photon beam energy (the same data as in Fig. 4). Systematic errors are on the abscissa. The solid line is the result of the Bonn-Gatchina PWA when including this data (see text for details).

6. Summary and outlook

The first measurements of the double polarisation observables E, G, and G_π for $\gamma p \rightarrow p\omega$ have been reported. The beam-target-helicity asymmetry E was measured from threshold to a photon energy of 2300 MeV, and G and G_π were measured at a single bin in photon energy at $1108 < E_\gamma < 1300$ MeV. The results clearly show that s-channel contributions, in addition to the expected t-channel contributions, have significant importance in ω photoproduction close to threshold.

A fit to the data within the framework of the Bonn-Gatchina partial wave analysis requires significant contributions of the partial waves with $J^P = 3/2^+, 5/2^+$, and $3/2^-$ to ω photoproduction.

A possibility to improve statistics in the ω channel is to exploit the mixed charged decay ($\omega \rightarrow \pi^+\pi^-\pi^0$) with a branching ratio of 89.2 % [4]. This cannot be done within the present CBELSA/TAPS setup but will instead be pursued with the new BGO-OD experiment [40, 41, 21] at ELSA. The BGO-OD experiment will also be used to analyse other vector meson channels (for example ϕ and K^* production) off the proton and neutron, in order to study t-channel exchange processes and the contributions from nucleon resonances in greater detail.

ЛМФ 2015 (гамма-нуклон)

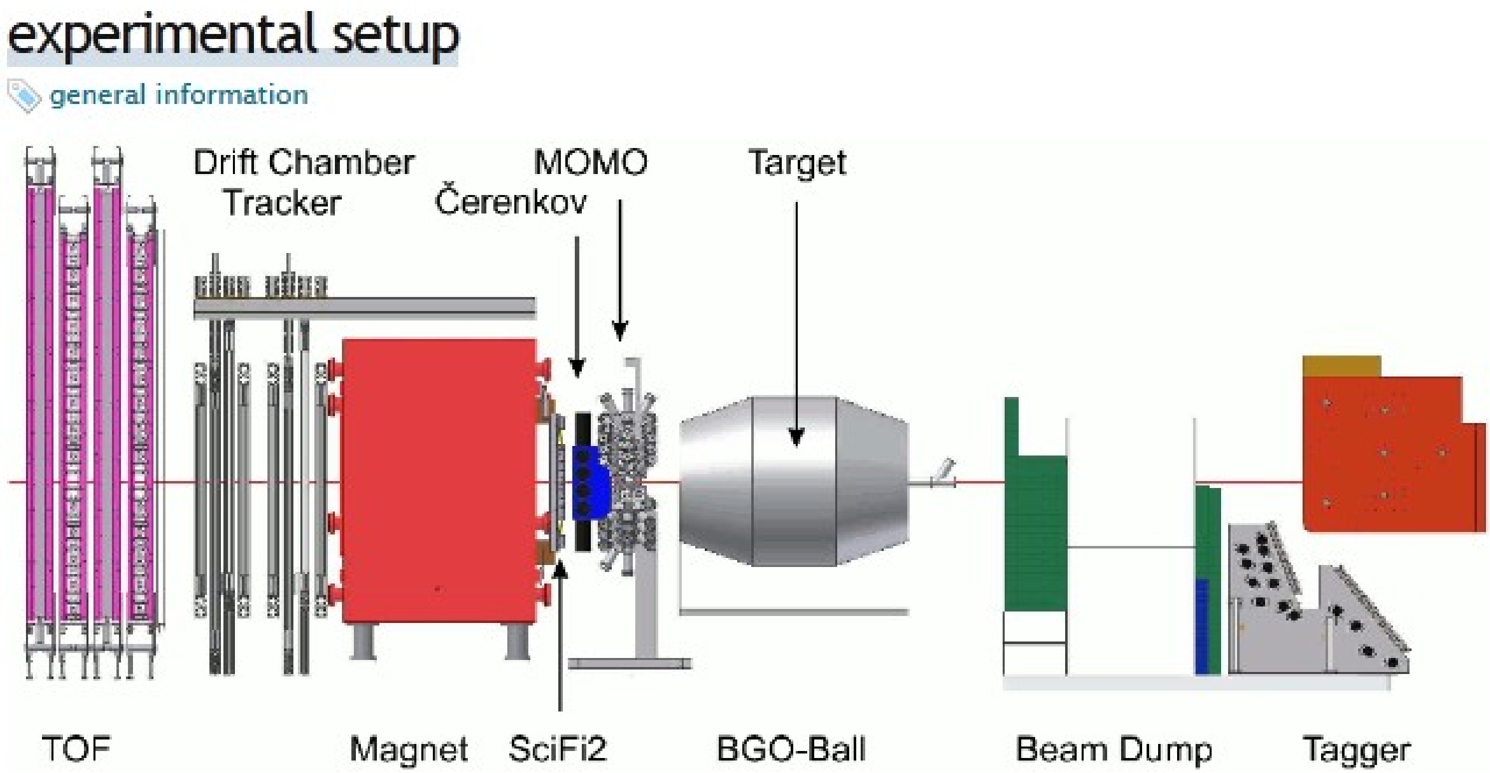
BGO-OD-Kollaboration
Tina Bantes[1], Dair Bayadilov[2], Reinhard Beck[2], Max Becker[2], Andreas Bella[1], John Bieling[1], Sabine Boese[2], Alessandro Braghieri[3], Kai Brinkmann[2], Dmytro Burdeynyi[4], Gordon Diefenthal[2], Rachele Di Salvo[5], Hartmut Dutz[1], Holger Eberhardt[1], Daniel Elsner[1], Alessia Fantini[5], Torsten Frese[1], Frank Frommberger[1], Vladimir Ganenko[4], Gianpiero Gervino[6], Francesco Ghio[7], Giorgio Giardina[8], Bruno Girolami[7], Derek Glazier[9], Stefan Goertz[1], Anatoly Gridnev[10], Daniel Hahne[1], Daniel Hammann[1], Jürgen Hannappel[1], Wolfgang Hillert[1], Alexander Ignatov[11], Fahimeh Jahanbakhsh[2], Oliver Jahn[1], Rainer Jahn[2], Russell Johnstone[1], Rainer Joosten[2], Tom Jude[1], Fritz Klein[1], Karsten Koop[2], Bernd Krusche[12], Alexander Lapik[11], Paolo Levi Sandri[7], Igor Lopatin[10], Giuseppe Mandaglio[8], Francesco Messi[1], Roberto Messi[5], Dario Moricciani[5], Vladimir Nedorezov[11], Dmitry Noviskiy[10], Paolo Pedroni[3], Mariia Romaniuk[8], Tigran Rostomyan[12], Carlo Schaerf[5], Hartmut Schmieden[1], Georg Siebke[1], Victorin Sumachev[10], Viacheslav Tarakanov[10], Valentina Vegna[1], Petr Vlasov[2], Dieter Walther[2], Dan Watts[9], Hans-Georg Zaunick[2] und Thomas Zimmermann[1] — [1]Physikalisches Institut, Nussallee 12, D-53115 Bonn — [2]Helmholtz-Institur für Strahlen und Kernphysik, Nussallee 14–16, D-53115 Bonn — [3]INFN sezione di Pavia, Via Agostino Bassi, 6 - 27100 Pavia Italy — [4]National Science Center Kharkov Institute of Physics and Technology, Akademicheskaya St. 1, Kharkov, 61108, Ukraine — [5]INFN Roma Tor Vergata,Via della Ricerca Scientifica 1, 00133 Rome - Italy — [6]INFN sezione di Torino, Via P.Giuria 1, 10125 Torino Italia — [7]INFN - LNF,Via E. Fermi 40, 00044 Frascati (Roma) Italy — [8]Universita degli Studi di Messina, Via Consolato del Mare 41, 98121 Messina — [9]The University of Edinburgh, James Clerk Maxwell Building, Mayfield Road, Edinburgh EH9 3JZ UK — [10]Petersburg Nuclear Physics Institute, gatchina, Leningrad District, 188300 Russia — [11]Russian Academy of Sciences Institute for Nuclear Research, prospekt 60-letiya Oktyabrya 7a, Moscow 117312 Russia — [12]Institut für Physik, Klingelbergstrasse 82, CH-4056 Basel

Участники от Лаборатории мезонной физики:

**Д.Е. Баядилов, А.Б. Гриднев, И.В Лопатин,
Д.В. Новинский, В.В. Сумачёв.**

ЛМФ 2015 (гамма-нуклон)

Commissioning of the BGO-Open Dipole setup at beamline S of ELSA.



ЛМФ 2015 (гамма-нуклон)

Strangeness Photoproduction at the BGO-OD Experiment

T. C. Jude [1], S. Alef[1], D. Bayadilov[2], R. Beck[2], M. Becker[2], A. Bella[1], P. Bielefeldt[1], S. Boese[2], A. Braghieri[3], K. Brinkmann[4], P. Cole[1], F. Curciarello[6,7], V. De Leo[6,7], R. Di Salvo[8], H. Dutz[1], D. Elsner[1], A. Fantini[8,9], O. Freyermuth[1], S. Friedrich[4], F. Frommberger[1], V. Ganenko[5], G. Gervino[10,11], F. Ghio[12,13], G. Giardina[6,7], S. Goertz[1], A. Gridnev[15], E. Gutz[4], D. Hammann[1], J. Hannappel[1], P. Hartmann[1], W. Hillert[1], A. Ignatov[16], R. Jahn[2], R. Joosten[2], F. Klein[1], K. Koop[2], B. Krusche[17], A. Lapik[16], P. Levi Sandri[18], I. V. Lopatin[15], G. Mandaglio[6,7], F. Messi[1], R. Messi[8,9], V. Metag[4], D. Moricciani[8], A. Mushkarenkov[16], M. Nanova[4], V. Nedorezov[16], D. Novinskiy[15], P. Pedroni[3], B. Reitz[1], M. Romaniuk[8], T. Rostomyan[17], N. Rudnev[16], G. Scheluchin[1], H. Schmieden[1], A. Stugelev[15], V. Sumachev[15], V. Tarakanov[15], V. Vegna[1], D. Walther[2], D. Watts[14], H. Zaunick[2,4] and T. Zimmermann[1]

BGO-OD is a newly commissioned experiment to investigate the internal structure of the nucleon, using an energy tagged bremsstrahlung photon beam at the ELSA electron facility. The setup consists of a highly segmented BGO calorimeter surrounding the target, with a particle tracking magnetic spectrometer at forward angles. BGO-OD is ideal for investigating meson photoproduction. The extensive physics programme for open strangeness photoproduction is introduced, and preliminary analysis presented.

ЛМФ 2015 (гамма-нуклон)

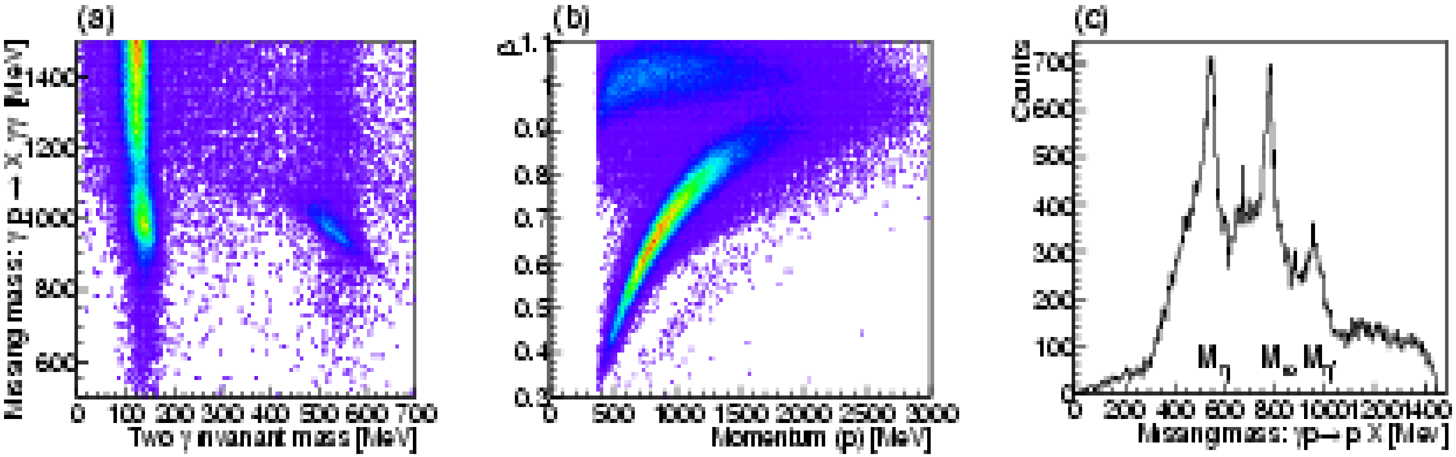


Fig. 1. (a) The missing mass, m_X, from two photons detected in BGO ball versus the invariant mass of the two photons. Peaks correspond to $p\pi^0$ and $p\eta$ final states. (b) β versus the measured momentum of charged particles in the forward spectrometer. Prominent loci of charged pions and protons are visible. (c) The missing (meson) mass from protons detected in the forward spectrometer. Meson masses labelled inset. (All analysis is preliminary, colour online.)

ЛМФ 2015 (гамма-нуклон)

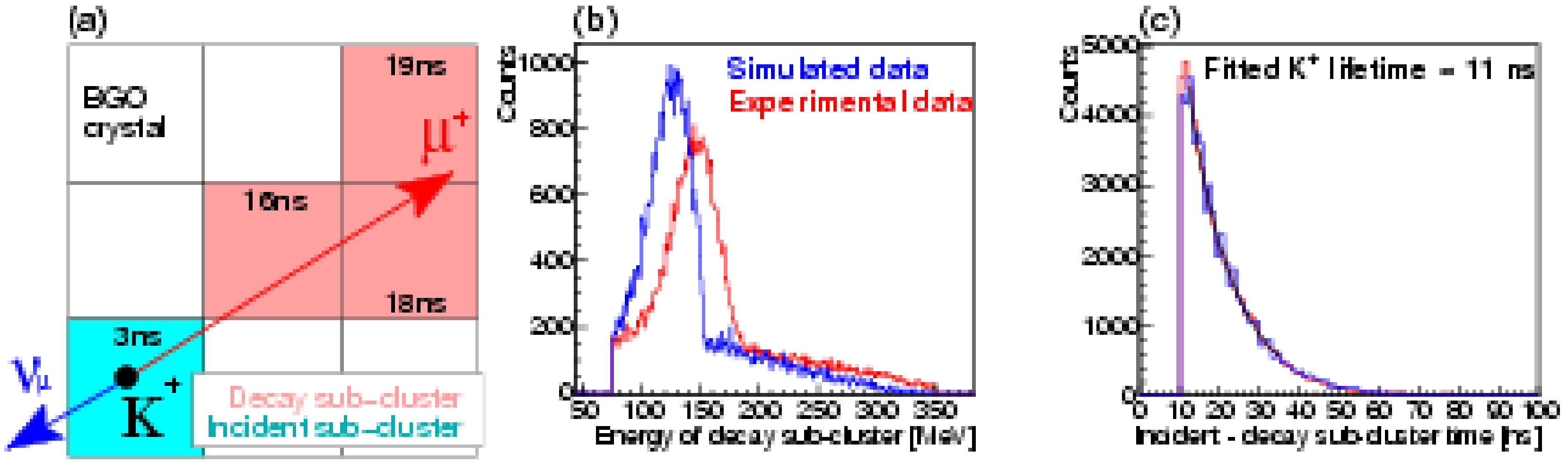


Fig. 2. K^+ identification in the BGO ball (preliminary). (a) An initial cluster is separated by time to an incident sub-cluster of crystals (blue) and decay sub-cluster (red). The time inset each crystal indicates the time of the measured energy deposition. (b) The energy of the decay sub-cluster. The peak at 153 MeV corresponds to the μ^+ energy deposition when the K^+ decays via the $\mu^+\nu_\mu$ mode at rest. The shoulder extending to 350 MeV is due to the $\pi^+\pi^0$ decay mode. The discrepancy between simulated and experimental data is due to the light collection behaviour of the photomultiplier tube not yet implemented in the simulation. (c) The time difference between the incident sub-cluster from stopping the K^+, and the decay sub-cluster from the K^+ decay. An exponential fit yields a lifetime close to the accepted value of 12 ns.

ЛМФ 2015 (гамма-нуклон)

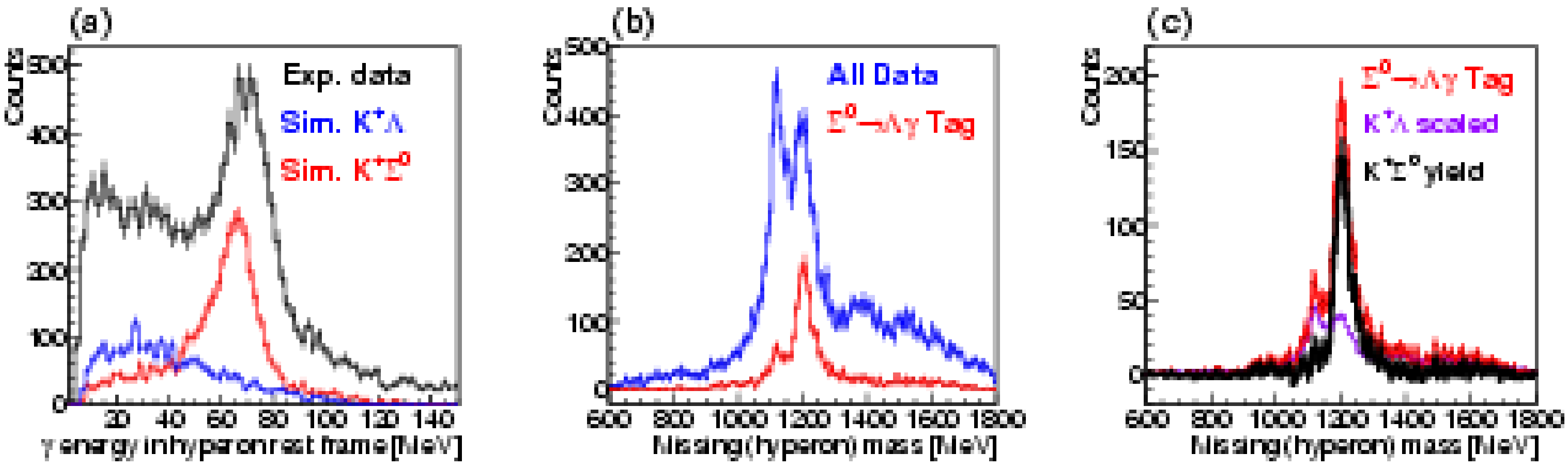


Fig. 3. (a) Photon energy after a Lorentz boost into the missing hyperon rest frame, for experimental data (black line), simulated $K^+\Lambda$ (shaded blue line) and simulated $K^+\Sigma^0$ (shaded red line). (b) The missing hyperon mass from K^+ detected in the BGO for all experimental data (blue line) and events where the $\Sigma^0 \to \Lambda\gamma$ is tagged (red line). (c) Events where the $\Sigma^0 \to \Lambda\gamma$ is tagged (red line), the efficiency scaled background from misidentified $\Sigma^0 \to \Lambda\gamma$ candidates (shaded purple line), and the yield of $K^+\Sigma^0$ after subtraction of background (thick black line). All preliminary.

ЛМФ 2015 (гамма-нуклон)

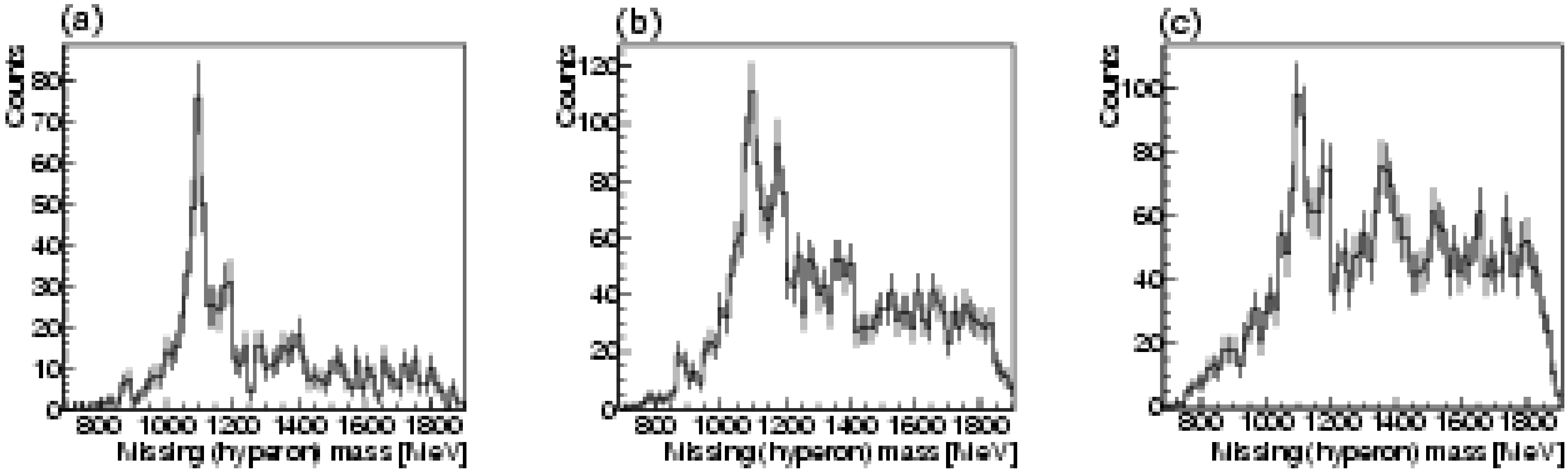
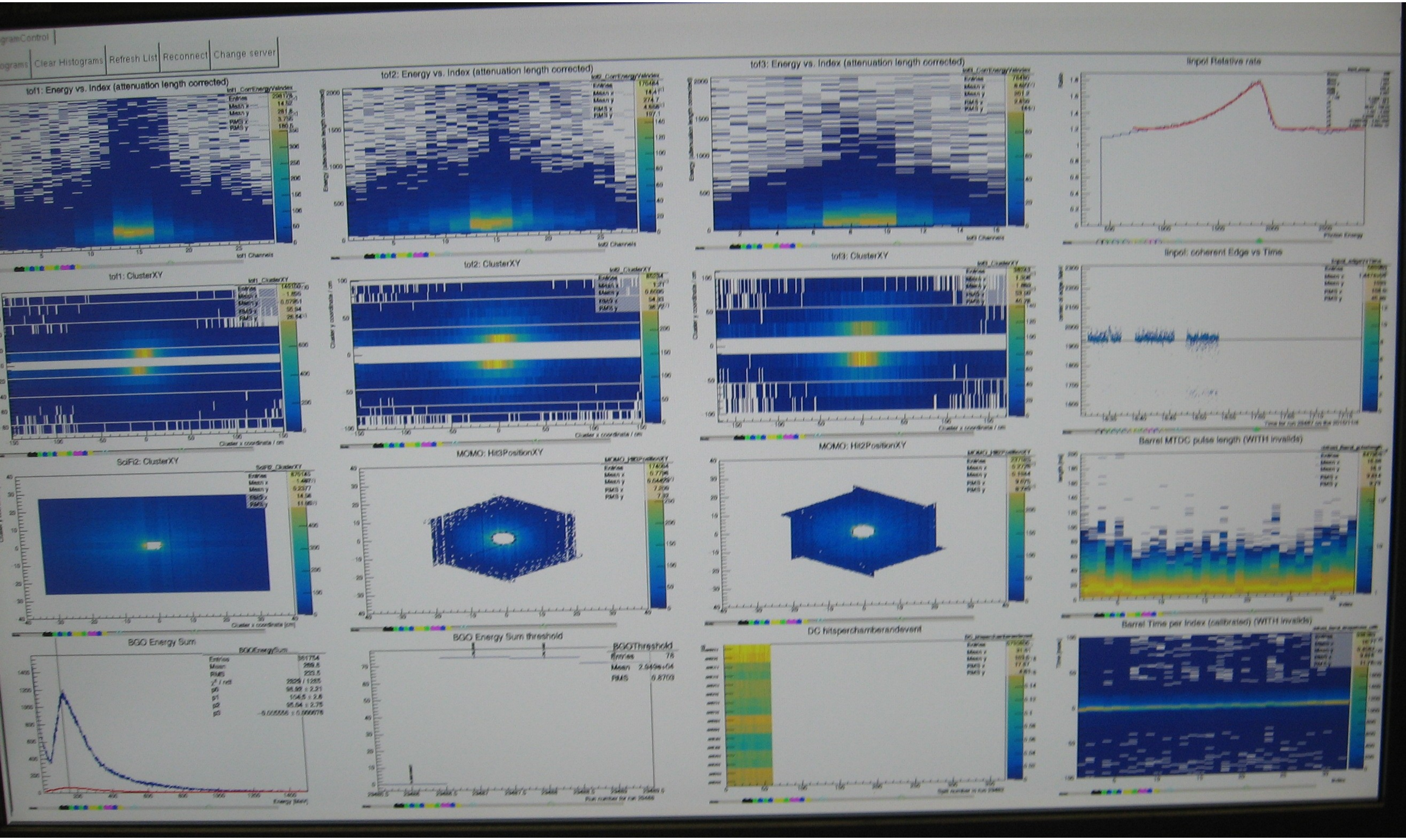


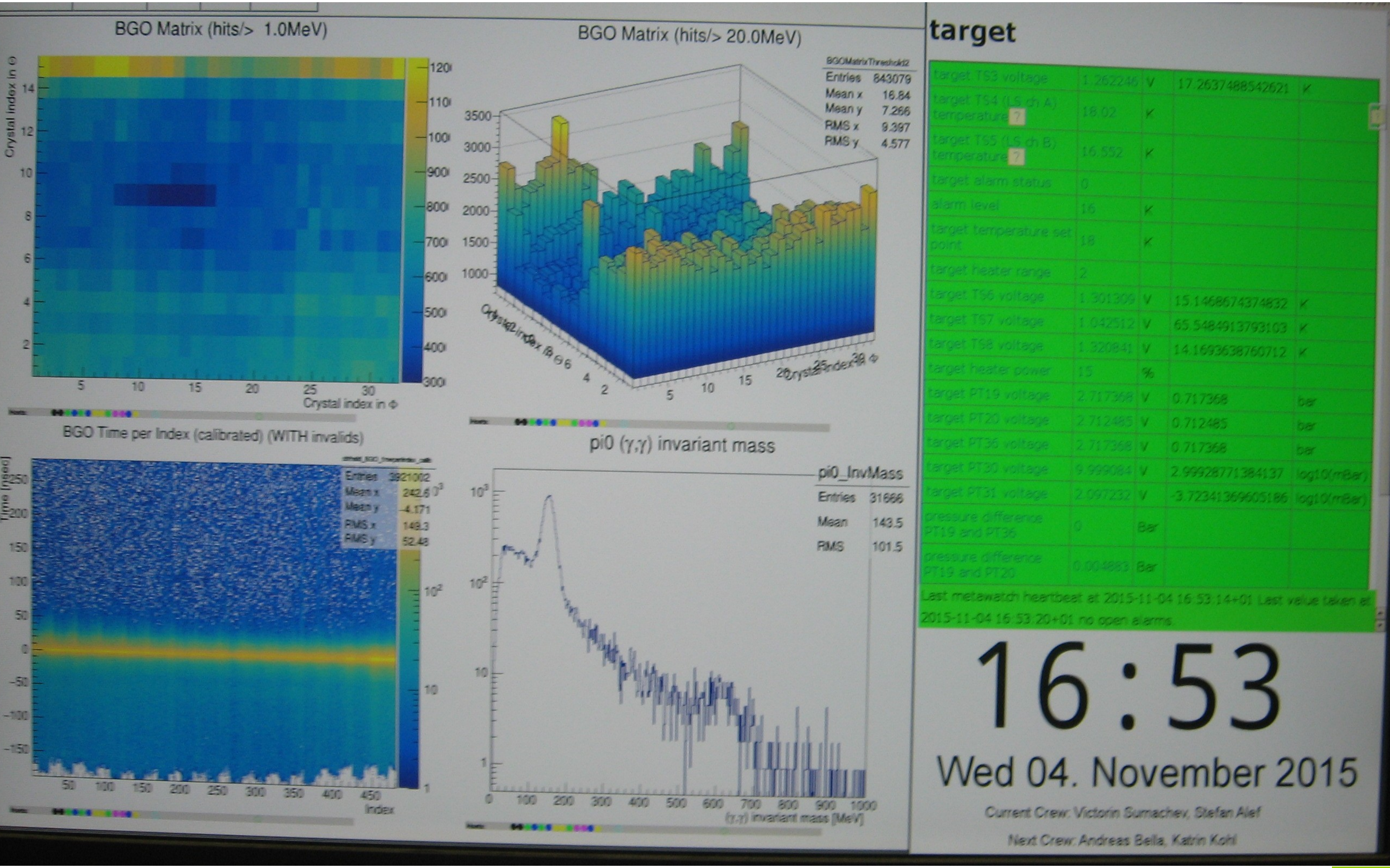
Fig. 4. The missing mass of the hyperon recoiling from the K^+ when identified in the forward spectrometer (preliminary). (a) Requiring an energy deposition less than 250 MeV and a reconstructed π^0 in the BGO ball accentuates the $K^+\Lambda$ states. (b) Requiring only an energy deposition less than 250 MeV accentuates the $K^+\Sigma^0$ and $K^+\Lambda$ final states. (c) Requiring only a reconstructed π^0 in the BGO ball accentuates higher lying Y^* states.

ЛМФ 2015 (гамма-нуклон)

ЛМФ 2015 (гамма-нуклон)

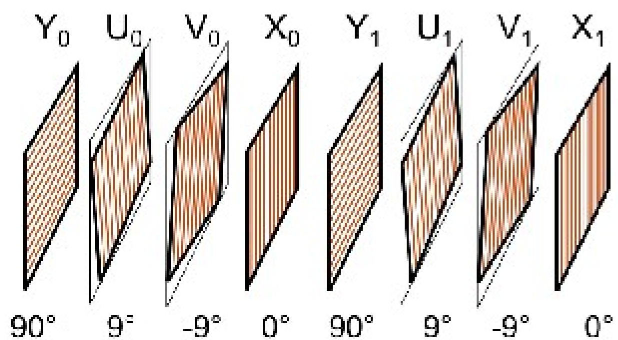


ЛМФ 2015 (гамма-нуклон)

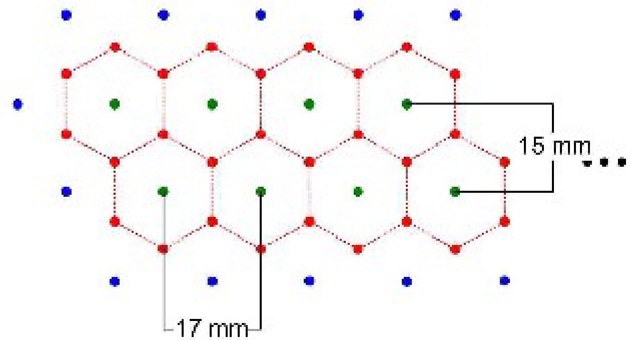


Driftkammer - Aufbau

8 Driftkammern mit je 2 Signaldrahtebenen



Senkrechter Schnitt durch eine Kammer

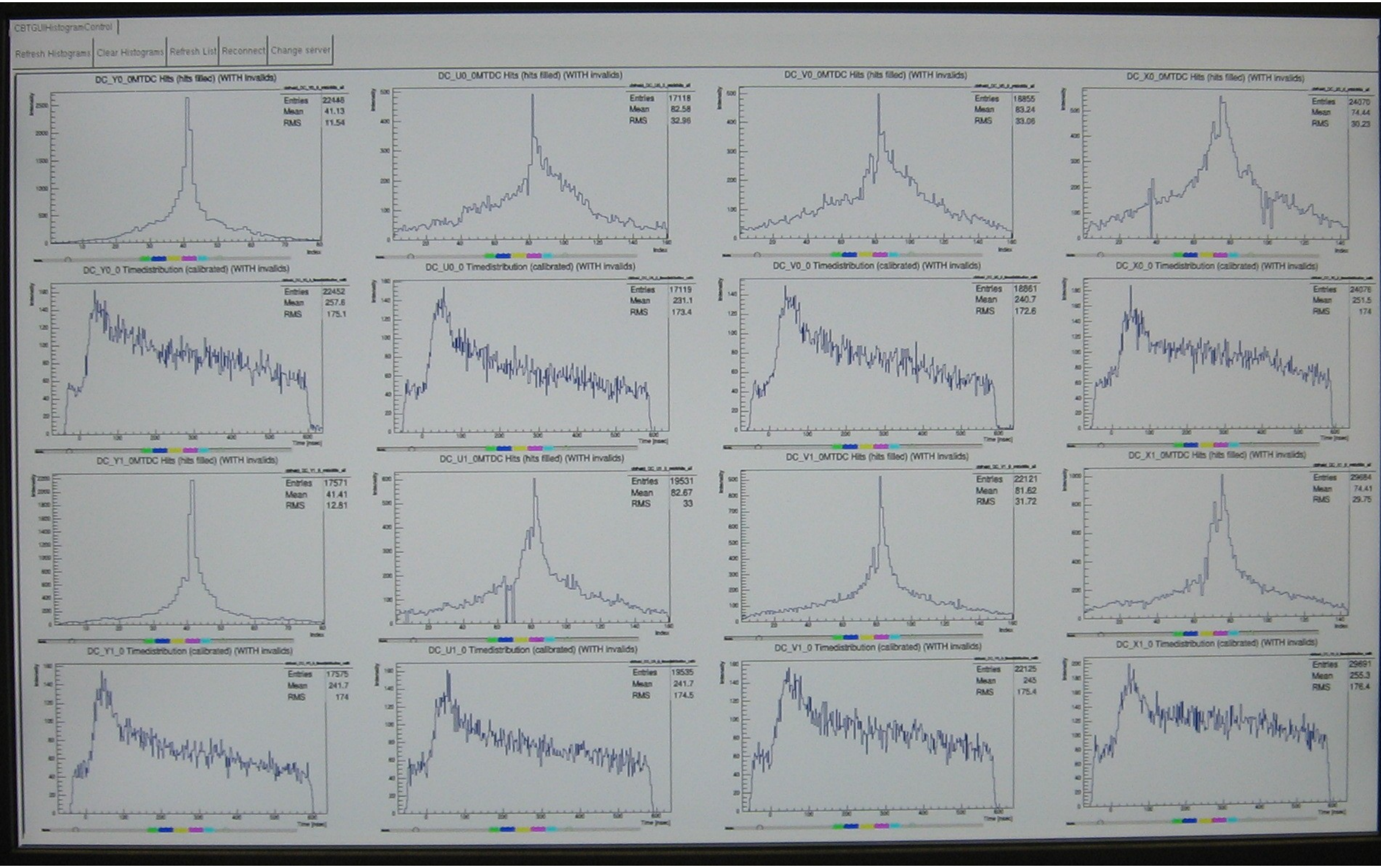


Spurrekonstruktion

Bisher:
Position der Drähte als Hit-Position

Verbesserte Rekonstruktion:
Nutze Driftzeit zur Verbesserung der räumlichen Auflösung

ЛМФ 2015 (гамма-нуклон)



Планы на 2016 г.

Бонн, CB-ELSA:
Завершение модернизации установки, выход на набор статистики.

Бонн, BGO-OD:
Обеспечение надёжной работы детекторов.
Участие в циклах измерений.