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G. von Holtey: EXPERIMENTAL ACTIVITIES AT BONN, HIGH ENERGY EXPERIMENTS BELOW 1 GeV. -

"Frascati Meeting on Electronsynchrotron"
Frascati, November 5-7, 1970

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Invited talk, given at the
"Frascati Meeting on Electronsynchrotron"
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G. von Holtey[(x)]: EXPERIMENTAL ACTIVITIES AT BONN, HIGH ENERGY EXPERIMENTS BELOW 1 GeV.-

1. - INTRODUCTION. -

At the Bonn Physical Institute there are two electron synchrotrons with end-point energies of 500 MeV and 2,5 GeV. The main aims of research at these machines are photo-and electroproduction of pseudoscalar mesons, photoproduction of higher mass mesons as the η, K and ϕ-meson. Further polarisation measurements of the recoil nucleons from the π^o- and π^+-photoproduction reaction, elastic and inelastic electron-proton scattering and to an ever increasing extend nuclear structure experiments.

In a fourty minutes talk it would be quite impossible to give a to a certain extent complete picture of all these different topics. So I am glad, having been asked to restrict myself to the activities covering the energy region up to about 1 GeV. This rules out the higher mass meson production experiments as well as the measurements done so far on the electron beam.

Nevertheless, to give an overallpicture of the experimental activities in high energy physics at Bonn, before going into the details,

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I would like to start with two slides, giving a general view of the two electron synchrotrons and the performed experiments.

2.- GENERAL VIEW OF THE SYNCHROTRONS AND THE PERFORMED EXPERIMENTS.-

2.1.- The 500 MeV Synchrotron[1].-

In Fig. 1 an outline of the 500 MeV synchrotron is given. The main parameters of this machine are collected in Table I.

The 9 magnets perform a maximal magnetic field of 10 kg. The electrons are focused with the alternating gradient principle ($Q_r = 2.42$; $Q_r = 2.66$). With a repetition frequency of 50 Hz the duty cycle is 5%. The maximum circulating beam intensity is 5×10^{11} eps.

TABLE I

Parameter list of the two Bonn Electron-Synchrotrons.

	500 MeV	2.5 GeV
Focusing typ	alternating gradient	
Number of basic periods	9	12
Basic lattice	0/2 F/2 D F/2 0/2	0/2 F D 0/2
Field at k_o	10 kG	11 kG
Mean radius	2,5 m	11,1 m
Injection	Van de Graaff 3 MeV	linac 25 MeV
Repetition frequency	50 Hz	
Duty cycle	5%	
Intensity (eps)	5×10^{11}	5×10^{12}
Beams	$2 \times \gamma$	$5 \times \gamma$, $1 \times e^-$

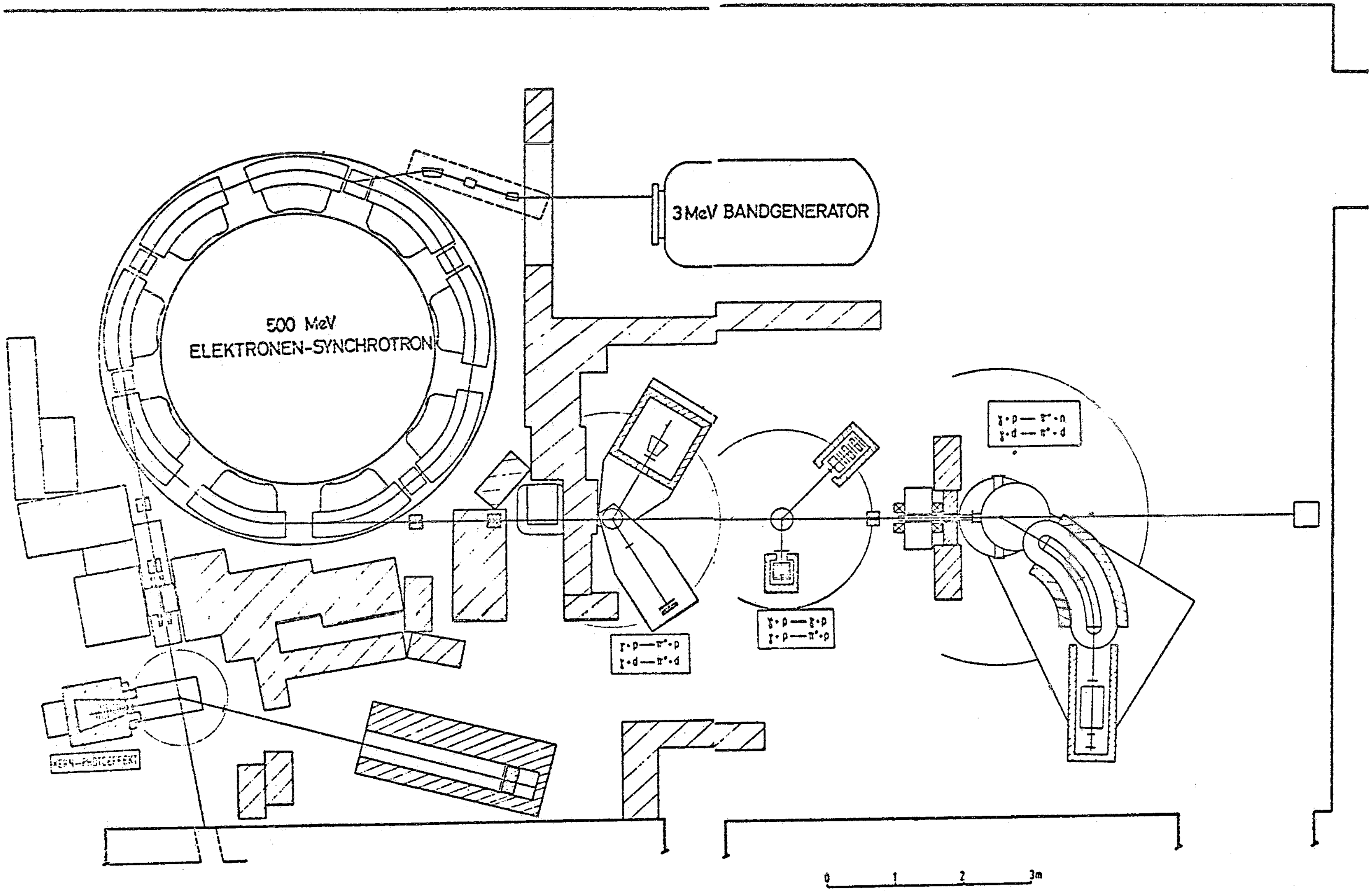

FIG. 1 - Lay-out of the 500 MeV electron synchrotron and the performed experiments.

At this time there are two gamma-ray beams running (see Fig. 1 and Table II). On the first there is built up an experiment measuring the nuclear photoeffect on oxygen O^{16}. Along the second photon beam there are three targets being part of several different experiments. The first is measuring π^o-photoproduction differential cross sections in hydrogen at small angles and also coherent π^o-production on deuterium, using a second arm to detect the deuteron.

On the second target there are two different experimental set-ups. One is measuring differential cross sections of π^o-photoproduction on protons in the region of low proton momentum, using a H_2-gas target. The second experiment, the apparatus of which is shown in Fig. 1, is a proton compton scattering measurement in the region of the first pion-nucleon resonance.

The third target in this gamma-ray beam belongs to a magnetic spectrometer, which can be rotated between angles of 0^o and 180^o degree. This set-up has been used for a systematic study of the

TABLE II

Experiments at the 500 MeV Electron Synchrotron

1.) $\gamma + O^{16} \rightarrow N^{14} + p + n$	$\frac{d\sigma}{d\Omega}$, p and n detected	data taking
2.) $\gamma + p \rightarrow \pi^o + p$	$\frac{d\sigma}{d\Omega}$ (small θ_{CM}) 2γ-decay	completed
3.) $\gamma + p \rightarrow \pi^o + p$	$\frac{d\sigma}{d\Omega}$ (low k_γ), gas target	taking data
4.) $\gamma + p \rightarrow \gamma' + p'$	$\frac{d\sigma}{d\Omega}$, γ' and p' detected	taking data
5.) $\gamma + p \rightarrow \pi^o + p$	systematic study of $\frac{d\sigma}{d\Omega}$	completed
6.) $\gamma + p \rightarrow \pi^+ + n$	systematic study of $\frac{d\sigma}{d\Omega}$	completed
7.) $\gamma + d \rightarrow \pi^o + d$	$\frac{d\sigma}{d\Omega}$, deuteron form factor	taking data
8.) $\gamma + d \rightarrow \pi^+ + 2n$ $\pi^- + 2p$	ratio: $\frac{\pi^-(d)}{\pi^+(d)}$ and $\frac{\pi^+(d)}{\pi^-(p)}$	taking data

neutral - and positive pion photoproduction differential cross section on protons in a wide kinematical range. At this stage the spectrometer is used to analyse the recoil deuterons from the coherent π^o-photoproduction process and also for a systematic measurement of the π^- / π^+-ratio from deuterium.

Normally two groups are measuring simultaneously. The synchrotron itself is now running for more than 12 years with a high total usefull beam time, which is at this time larger than 6000 hours per year. This machine was the first alternating gradient synchrotron in Europe.

2.2.- The 2.5 GeV-Synchrotron(2).-

Fig. 2 shows a view of the 2,5 GeV-electron synchrotron together with the experiments grouped around. The main parameter of this machine are given in Table I.

The electrons produced by a 25 MeV linear accelerator are injected into the ring by multiturn injection. The ring consists of 12 magnets with the basic structure 0/2 F D 0/2 ($Q_r = Q_v = 3.4$). The repetition frequency is 50 Hz, as it is at the small machine, giving a microscopic duty cycle of 5%. The present intensity of the circulating beam is 5×10^{12} eps, corresponding to a current of about 50 mA.

At this time there are 5 gamma-ray beams and one external electron beam. The latter is produced by means of a resonant extraction system, which up to now works with an efficiency of about 60% and at beam energies up to 2 GeV.

Walking along the direction of the circulating beam the following reactions are analysed (see Table III).

Beam γ1:

1. - Photoproduction of $K^+ \Lambda^o$ and $K^+ \Sigma^o$ using a three section strong focusing magnetic spectrometer to analyse the K-mesons. Differential cross sections for both reactions have been measured up to 1.5 GeV(3). In a second step the polarisation of the Λ^o-hyperon will be simultaneously measured.

2. - Photoproduction of π^o-mesons on hydrogen between 0.5 and 2.1 GeV, detecting the recoil protons by the magnetic spectrometer of experiment 1.

3. - With the same spectrometer a photoproduction measurement of positive pions on a polarized proton target is foreseen.

4. - Photoproduction of η^o-mesons. The two decay photons are detected

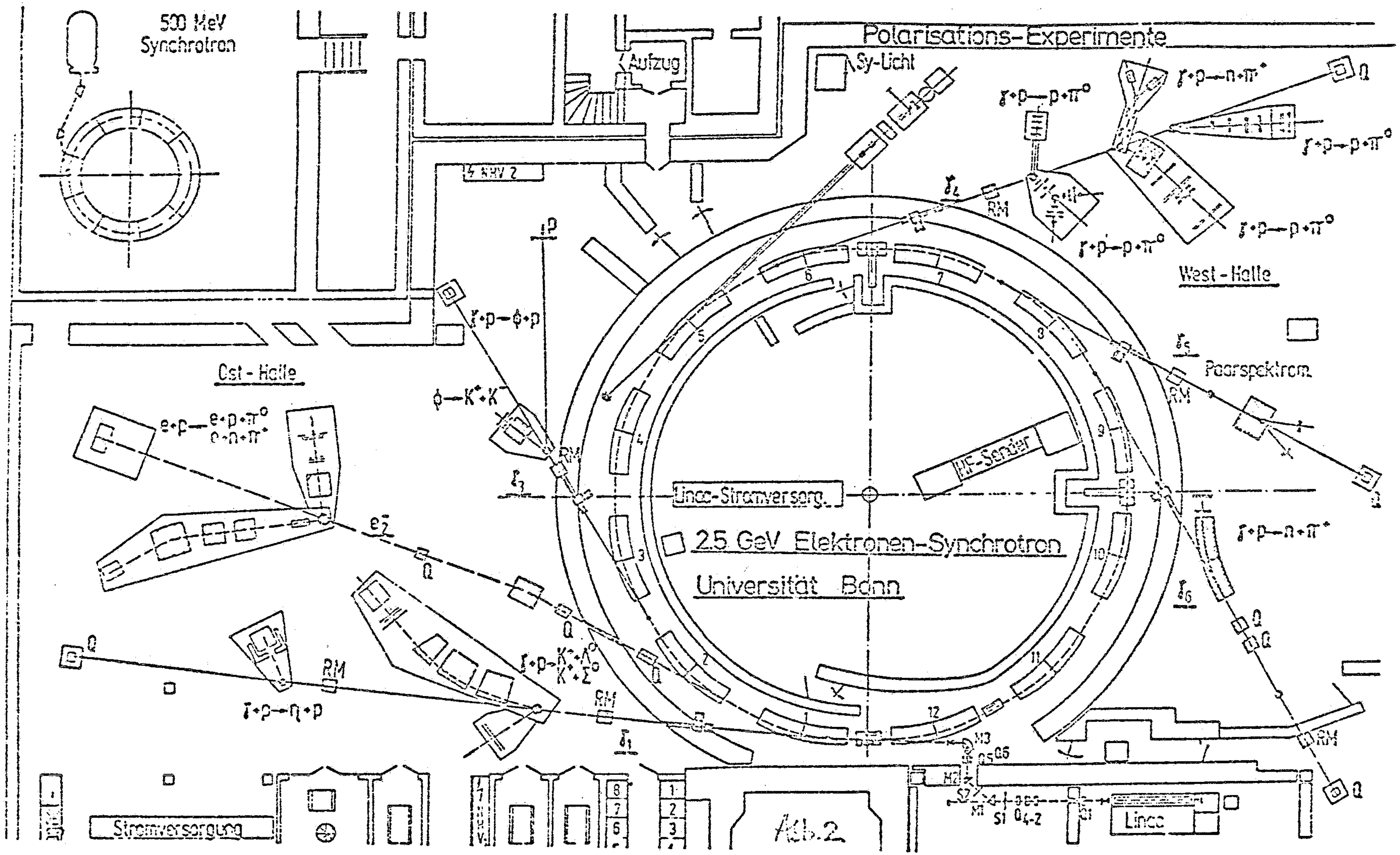

FIG. 2 - Lay-out of the 2.5 GeV electron synchrotron and the performed experiments.

by total absorption Cerenkov counters. The differential cross section will be measured between 1.8 and 2.3 GeV photon energy for c.m. angles $<60^{o}$.

TABLE III

Experiments at the 2.5 GeV Electron-Synchrotrons

1.) $\gamma + p \rightarrow K^{+} + \Lambda^{o}$ $K^{+} + \Sigma^{o}$	$\frac{d\sigma}{d\Omega}$, Λ^{o}-polarisation	data taking
2.) $\gamma + p \rightarrow \pi^{o} + p$	$\frac{d\sigma}{d\Omega}$, magnetic spectrometer	setting up
3.) $\gamma + p \rightarrow \pi^{+} + n$	asymmetrie, with polarized target	in preparation
4.) $\gamma + p \rightarrow \eta^{o} + p$	$\frac{d\sigma}{d\Omega}$, 2γ-decay	data taking
5.) $e^{-} + p \rightarrow e^{-} + p$	proton form factors	completed
6.) $e^{-} + p \rightarrow e^{-} + p + \pi^{o}$ $n + \pi^{+}$	$\frac{d\sigma}{d\Omega}$, pion form factor	in preparation
7.) $\gamma + p \rightarrow \phi + p$	$\frac{d\sigma}{d\Omega}$ (near threshold), 2k-decay	setting up
8.) $\gamma + p \rightarrow \pi^{o} + p$ $\pi^{+} + n$	polarisation of recoil nucleon	data taking
9.) $\gamma + p \;\; \pi^{+} + n$	$\frac{d\sigma}{d\Omega}(\theta_{CM} = 180^{o})$	data taking

Beam e_2^-:

At the external electron beam there is placed a large spectrometer consisting of three quadrupoles and one bending magnet. It is especially designed for a good resolution of the c.m. energy of the pion nucleon system.

5. - Using this device the form factors of the proton for momentum transfers from 15 f^{-2} to 50 f^{-2} have been measured with elastic elec-

tron-proton scattering for large scattering angles[4]. Measurements of inelastic electron-proton scattering in the region of the first resonance are in progress.

6.- Using a second arm (magnet + wire spark chambers) electroproduction of pions will be measured.

Beam γ3:

7.- Photoproduction of ϕ-mesons. The differential cross section will be measured in the threshold region up to 2.5 GeV and for c.m. angles less than 90^o. The ϕ-meson is detected by its decay into two K-mesons. In addition the proton will be detected by time of flight measurements.

Beam γ4:

8.- The group of experiments at this beam are different polarisation measurements, analising the polarisation of the recoil proton or neutron in the π^o-respectively π^+-photoproduction process. These experiments will be described in more detail in what follows.

Beam γ5:

At this photon beam there is placed a pair spectrometer to measure the gamma-ray spectrum.

Beam γ6:

9.- Finally there is an experiment measuring the π^+-photoproduction differential cross section at backward angles for photon energies between 600 MeV and 1.5 GeV.

This 2.5 GeV machine came into operation in 1967 and is now running with nearly 6000 usefull beam hours per year.

In the following I want to give a more detailed description of some of these experiments. Thereby, I shall not go to much into the details of the experimental set-ups, but rather concentrate on the obtained data and comparisons with other measurements.

3.- PHOTOPRODUCTION OF SINGLE PIONS ON NUCLEONS.-

3.1.- Differential cross section without polarisation.-

Pion photoproduction from nucleons has, for nearly two decades, been the subject of a great deal of attraction, both experimental and theoretical. Up to 1965 more than 50 experiments have been reported measuring photoproduction reactions in the region of the first resonance[5].

However, in spite of the numerous experimental information, the data were not sufficient to allow for a detailed calculation of the smaller multipoles. Comparing the different measurements, available at that time, one finds a broad band of deviations typically of the order of 20 - 30%.

One of the main difficulties of photoproduction experiments in the first resonance region are the numerous error sources contributing in the same order of magnitude and, moreover, in the most cases show up a strong dependence on kinematical variables. In this situation a reliable estimate of the systematic errors becomes rather difficult.

In order to overcome this obstacle and to reduce the total systematic error down to $\pm 5\%$, at Bonn, two simultaneous experiments on π^0-photoproduction using two independent experimental techniques were performed[6]. The next figure (Fig. 3) shows the two experimental set-up's. The recoil protons were detected by a range telescope and in the second case by a magnetic spectrometer, both arrangements using the same gamma-ray beam of the 500 MeV synchrotron.

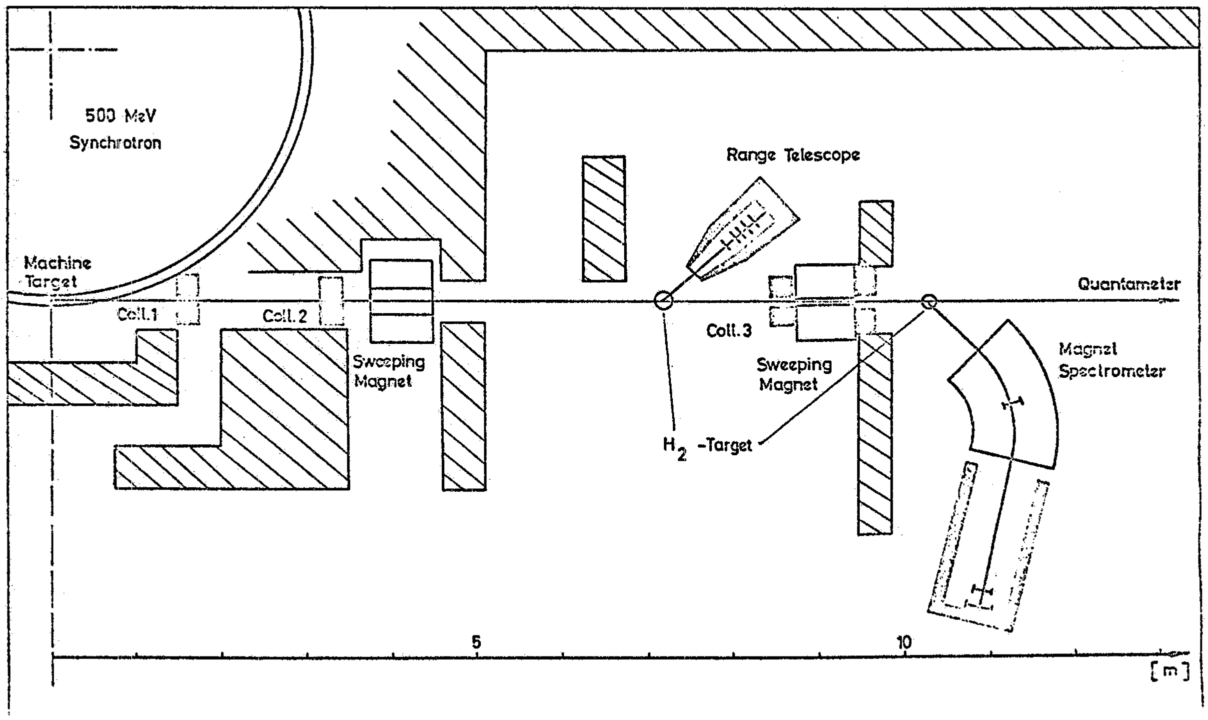

FIG. 3 - Experimental set-up of the two simultaneous π^0-photoproduction measurements at the 500 MeV synchrotron.

Differential cross sections were investigated for laboratory photon energies between 200 and 440 MeV and for c.m. angles larger than 50^{o}, permitting a direct comparison of the data in a wide kinematical range. In this manner the influence of systematic errors sources inherent in the different experimental arrangements could be studied very carefully.

For the comparison polynomial fits to the magnet data were used as references in order to suppress the influence of counting statistics. The resulting systematic deviations between the two experiments are shown in Fig. 4.

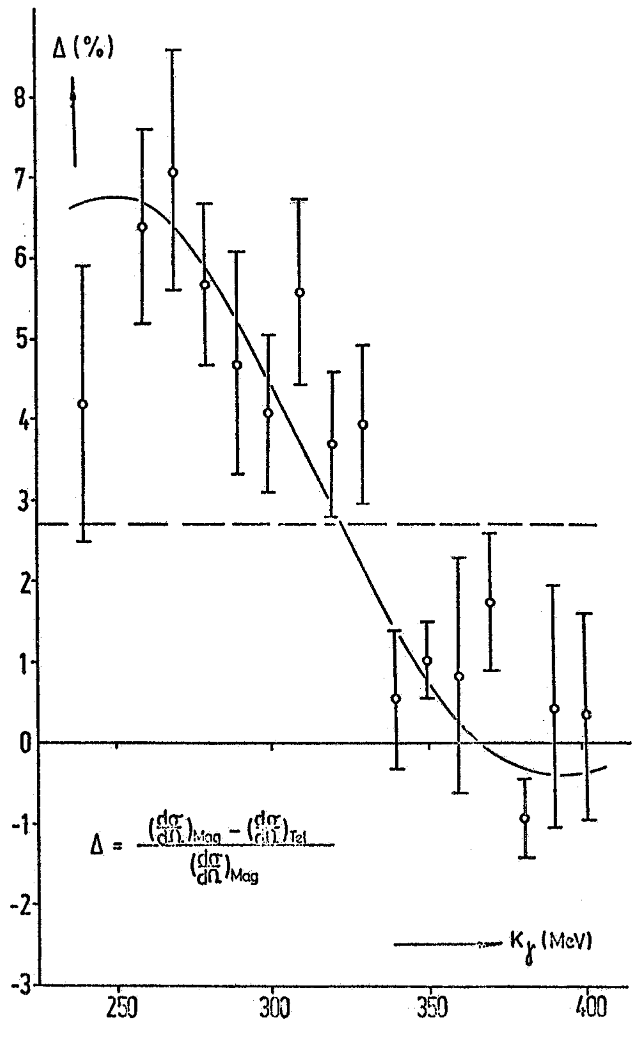

FIG. 4 - Deviations between the π^{o}-photoproduction magnet and telescope cross section. The deviations are averagded over the angular distributions.

They vary between 0% and 7%, demonstrating a clear dependence on photon energy. This can be understood by assuming a 0.6% shift in the photon energy calibration and a 2.6% scale factor difference between the two experiments. It should be stressed, however, that these deviations are smaller than the total systematic errors, which have been estimated to be less than ± 5% for both experiments.

The two measurements therefore were combined to one data set by correcting the scale factors and energy calibration of both experiments in equal parts. As an example Figure 5 shows some of the 23 obtained angular distributions of this combined data set. The curves in this figure are second order polynomial fits in $\cos \theta_{CM}$.

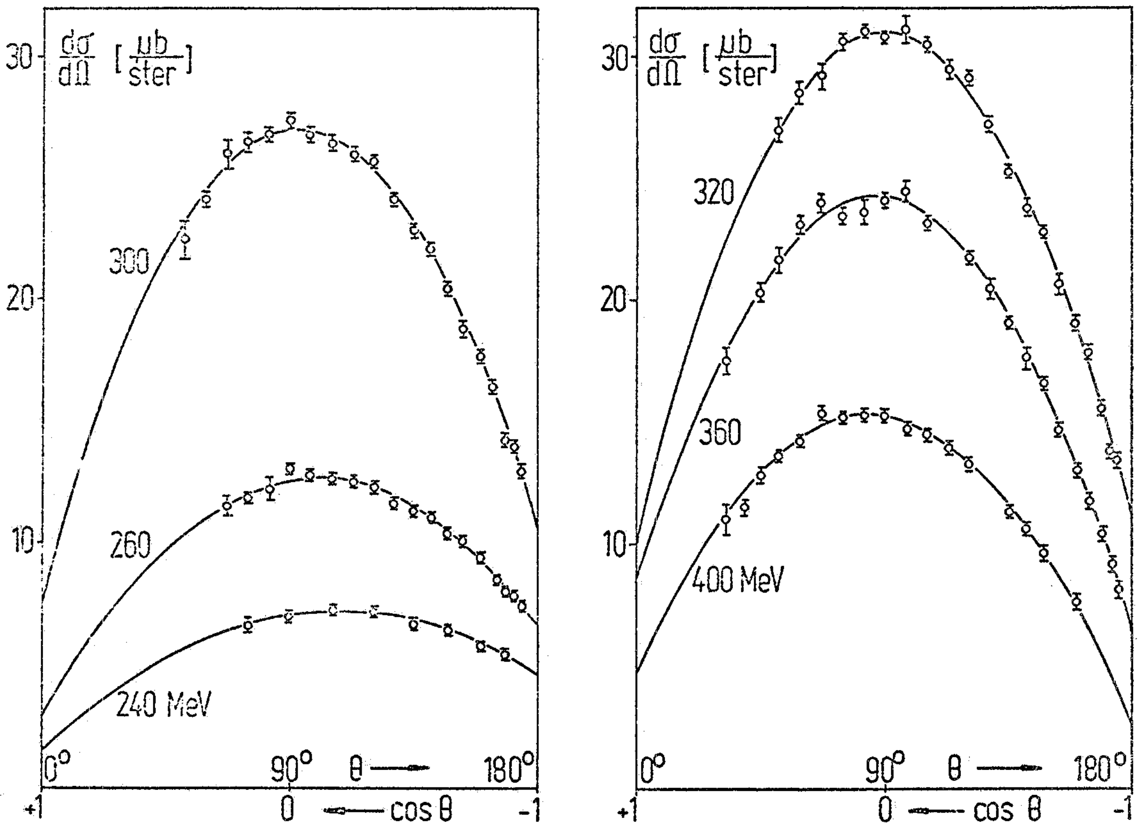

FIG. 5 - Angular distributions for various energies of the combined π^0-photoproduction data. The full line is a polynomial fit to the data.

For a comparison of this combined π^0-photoproduction data--set with previous measurements the 90 degree excitation curve, where most experiments have been done, is drawn in Fig. 6. On inspection one finds clear evidence for the fact, that the Bonn data are systematically 10 - 15% higher than nearly all previous measurements. At least a part of this discrepancy may be explained by the resolution correction, which is missing in most of the previous experiments.

The comparison with the recent π^0-photoproduction measurements done at Orsay(30) gives a resonable good agreement. The deviations, which vary between 0% and - 10% with respect to our data can be understood by a 5 - 6% scale factor difference, which is compatible with the estimated systematic errors.

With this new Orsay and Bonn measurements the experimental situation for the photoproduction cross section of neutral pions is quite satisfactory in the energy region around the resonance and for center-of-mass angles larger than 60^o.

In order to extend these measurements to smaller angles an experiment has been performed very recently at our laboratory, detecting the two gamma-rays from the π^o-decay with total absorption Cerenkov counters(7). In this experiment angular distributions between 10^o and 70^o were taken for photon energies between 340 and 420 MeV.

The results at two photon energies are shown in Fig. 7 together with the Bonn and Orsay data. The solid line represents the fit of a recent multipole analysis by Nölle, Pfeil and Schwela(8). The comparison indicates, that the new experiment gives typically 10% higher values than the combined magnet-telescope measurement. However, in spite of this, the two measurements are compatible with respect to the total systematic errors.

At present a further experiment is in progress at Bonn, with the aim to measure the π^o-photoproduction cross section at small angles and low energies, detecting the recoil protons coming from a gas target(9). In this experiment the protons are analysed by a time-of-flight measurement.

At energies above 440 MeV π^o-photoproduction data are still scarce and not very accurate. However these energies are very important for the determination of the energy dependence of the multipoles between 400 and 500 MeV. In the recent multipole analysis(8) for example, both isospin parts of the M_{1-} multipole turned out to be completely undertermined in this energy region.

This gap will be filled somewhat by a further experiment planed at the 2.5 GeV synchrotron(10). This group proposes to measure an exitation curve between 0.5 GeV and 2.1 GeV photon energy at 150^o c.m. angle and also angular distributions between 130^o and 170^o c.m. for two energies between 1 GeV and 1.5 GeV. In this measurement the recoil proton will be analysed by a magnetic spectrometer and detected by Cerenkov counters.

Let me now turn to the photoproduction of positive pions on protons. This reaction has been measured at the Bonn 500 MeV synchrotron very recently(11), using the same magnetic spectrometer that was used for the π^o-experiment(6). More than 400 differential cross sections were obtained in a wide kinematical region for c.m. angles between 15^o and 180^o and for photon energies between 220 MeV and 425 MeV. Some typical angular distributions are shown in Fig. 8. The indicated statistical errors (one standard deviation) are in the order

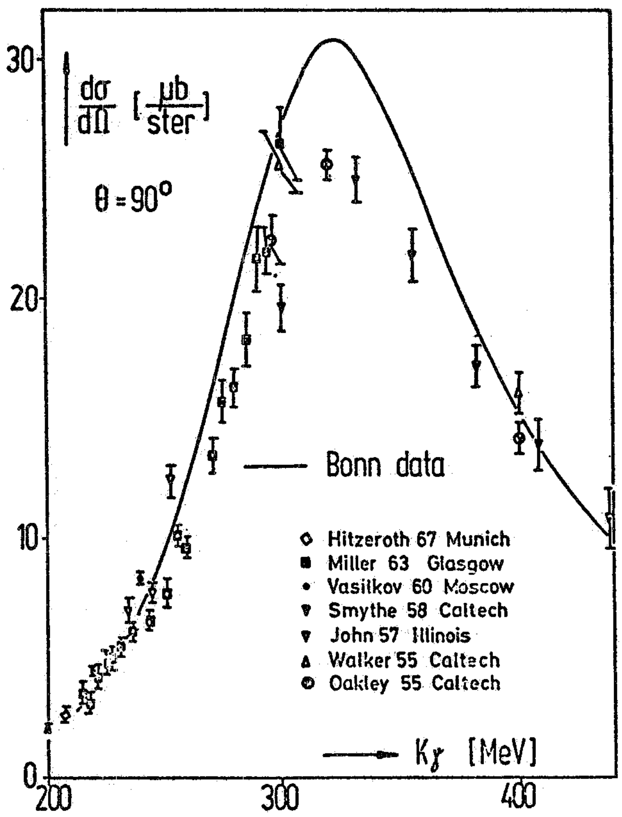

FIG. 6 - Comparison of the Bonn data (full line) with other measurements at $\theta_{CM} = 90^o$.

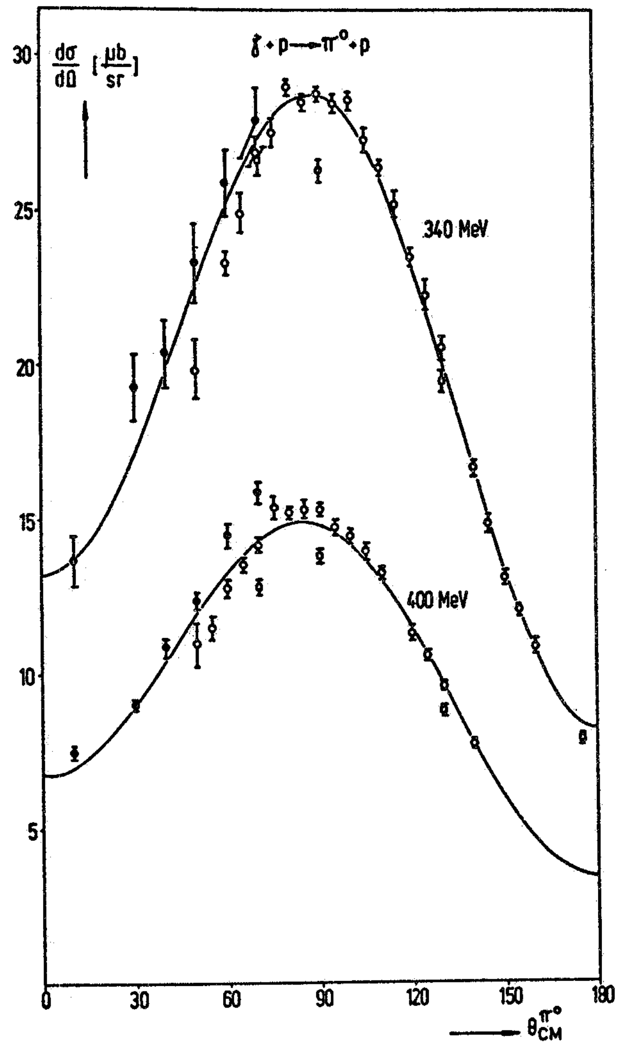

FIG. 7 - Comparison of the differential cross section at two energies on π^o-photoproduction of different recent experiments. Bonn, ref. (7), Bonn combined data, ref. (6), Orsay, ref. (30), full line: multipole analysis by Noelle et al. ref. (8).

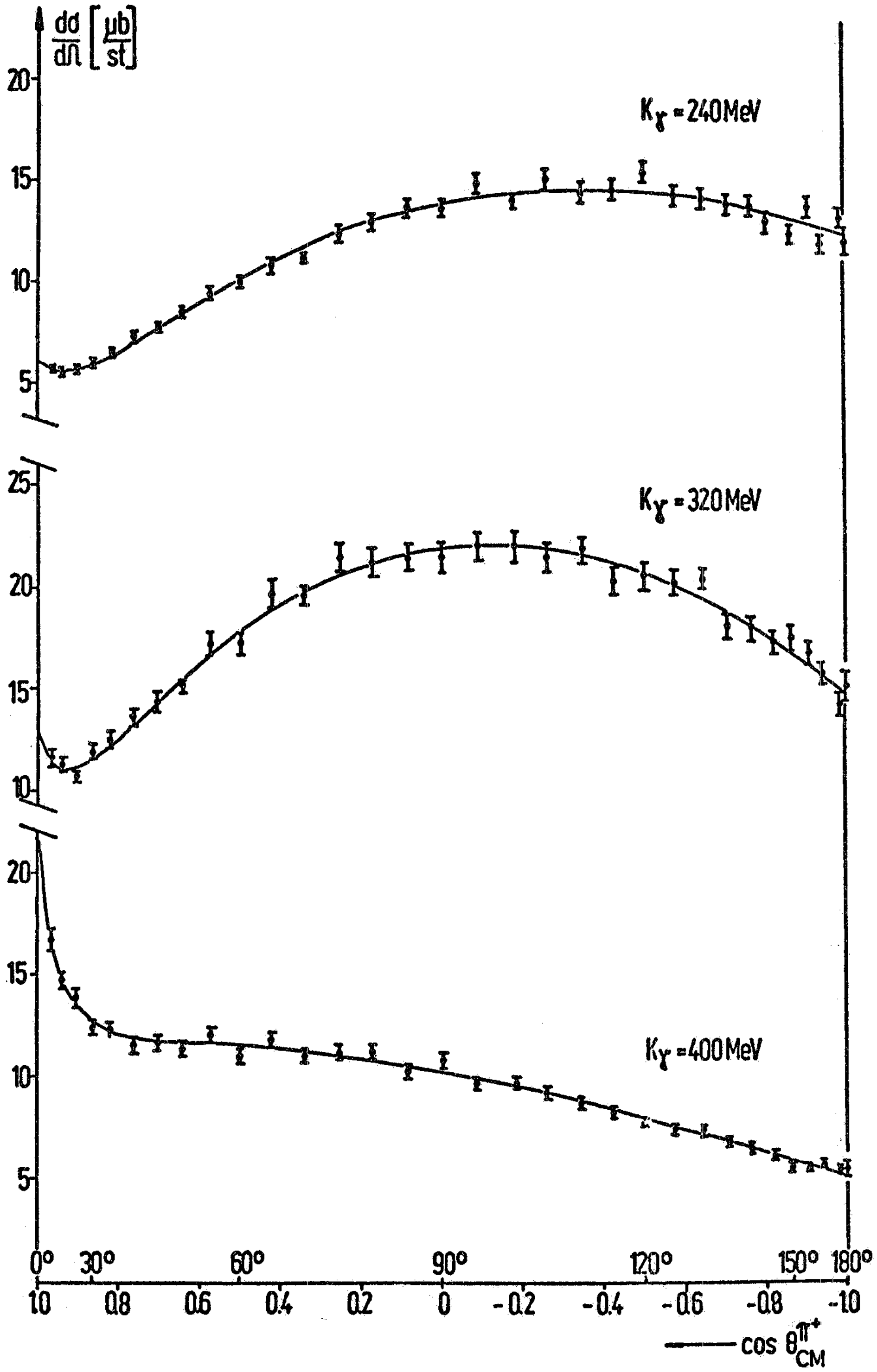

FIG. 8 - Angular distributions of the π^+-photoproduction differential cross section at various energies. The points are the measurements of ref. (11). The full line is a least square fit to the data.

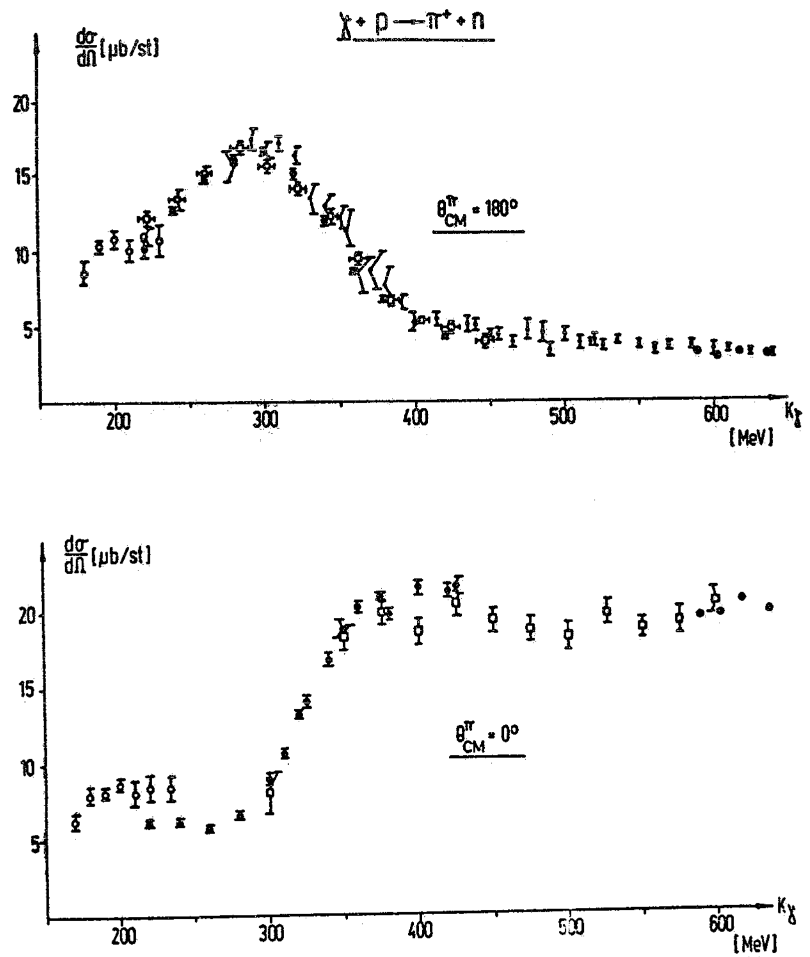

FIG. 9 - Comparison of recent π^+-photoproduction data at $\theta^{\pi}_{CM}=0^o$ and $\theta_{CM}=180^o$. Moscau, ref. (13), (fit extrapolations): Bonn, ref. (11), (fit values): Orsay, ref. (12), Tokyo, ref. (14):

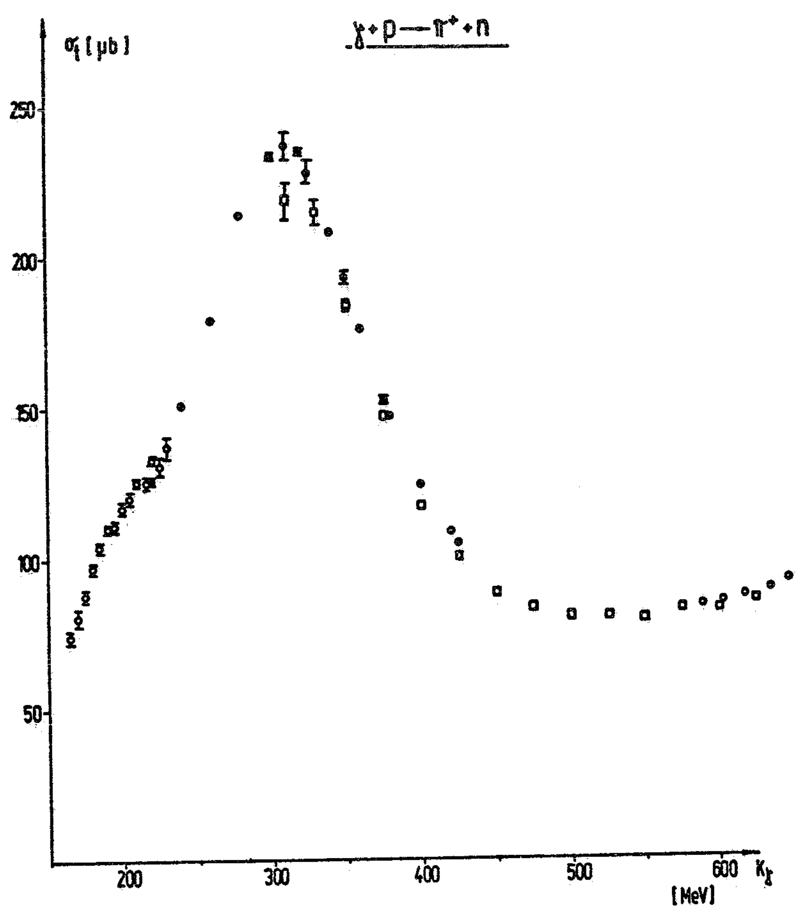

FIG. 10 - π^+-photoproduction total cross section. For the point labels see caption of Fig. 9.

of $\pm$ 3%, the estimated systematic errors are less than $\pm$ 6%. The solid line is a least square fit to the data.

I will not go into a detailed comparison with other recent experiments on π^+-photoproduction. There are first of all the measurements from Orsay[12], giving differential cross sections in a wide kinematical region and the measurements near threshold from the Moscow Institut[13]. The overall agreement between these measurements and the new Bonn data is resonably good as can be seen in Fig. 9. Here angular distributions for the extreme angles 0° and 180° are drawn. At 180° there are also indicated the very new points from the Tokio Institute[14]. In Fig. 10 the total cross section is shown as obtained from these experiments.

There are two main differences of these new π^+-data, to the older data. The first is a somewhat higher maximum in the total cross section at the first resonance. The second is a more pronounced rise of the differential cross section at foreward angles above the resonance.

At higher energies there is an experiment at Bonn, measuring the π^+-photoproduction cross section on protons at backward angles[15]. The experimental set-up is shown in Fig. 11. The pions produced at the hydrogen target were momentum analysed by a magnetic spectrometer and detected by a scintillation counter hodoscope. The spectrometer is built up by an alternating focusing synchrotron magnet, the spare-magnet of the 2.5 GeV synchrotron, and two quadrupoles. The momentum resolution per hodoscope channel is about 0.5% which corresponds to a photon energy resolution of 35 MeV at 2 GeV photon energy.

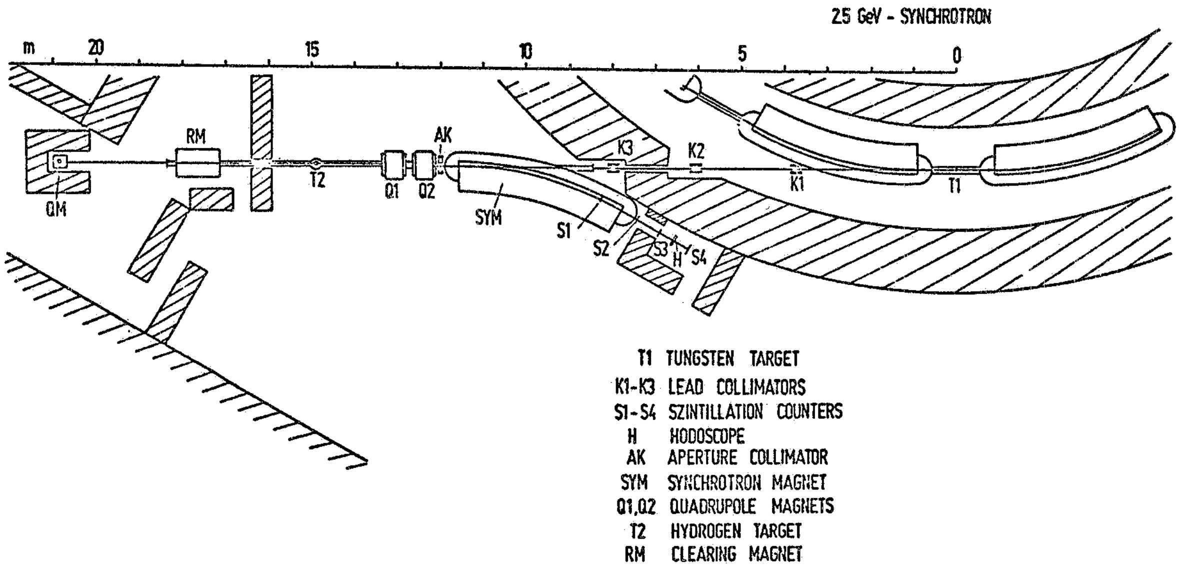

FIG. 11 - Experimental lay-out of the π^+-photoproduction measurement at backward angles, ref. (15).

Up to now differential cross sections have been taken for photon energies between 600 MeV and 1.3 GeV. These are shown in Fig. 12 together with theoretical calculations. The data are in good agreement with the predictions of the phenomenological analysis of Walker (full line) [16]. The general behaviour of the measured cross section, that is a shoulder at 700 MeV and a flat bump around 900 MeV, is also produced by the isobar model predictions of Kim and Pfeil (dashed line)[17].

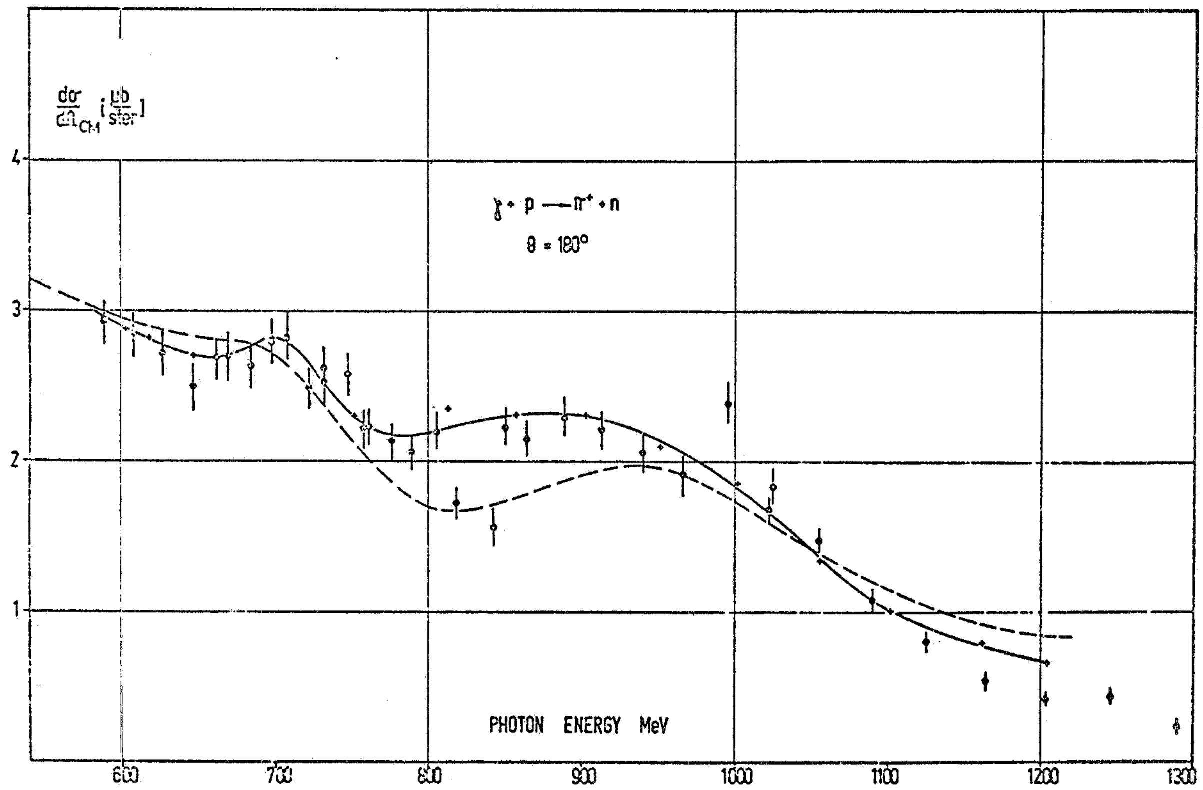

FIG. 12 - π^+-photoproduction differential cross section at $\theta^{\pi}_{CM} = 180^o$. Experimental points: ref. (15), theoretical curves: - Walker-fit, ref. (16), ---Kim-fit, ref. (17).

Backward π^+-photoproduction has been measured in the same kinematical region by three other groups very recently. There is a Cornell measurement [18], one of an Orsay/Daresbury Collaboration[19] and also a Tokio experiment[14]. Below 1 GeV the agreement of all these measurements is in the order of 10%, except in the region around 900 MeV, where this flat bump is much more pronounced with the Orsay and Tokio measurements. Above 1 GeV the Bonn and Orsay data agree very well, but the data from Cornell and even more those from Tokio are higher by a factor of 2 and more.

The Bonn measurements will be extended to lower energies and also to higher energies up to 2 GeV.

3.2.- Asymmetry with polarised target.-

Next, I want to say a few words to the experimental program at Bonn, concerning polarised target measurements.

A Cern-type butanol polarized proton target has been built at our laboratory, and is now running with a 40% polarisation[20]. First tests in a photon beam will be carried out at the end of this year.

The experimental program plans to measure first asymmetry in the π^+-photoproduction cross section. With this reaction the background problems are not as severe as they are in the neutral pion production case. In detail it is planed to measure the asymmetry in the produced pions for c.m. angles between 30^o and 60^o in an energy intervall between 500 MeV and 1200 MeV.

Isobar model predictions yield asymmetry values ranging from + 50% to -50% in this energy region. The estimated beam time per asymmetry point is about 2 days.

3.3.- Polarisation of the recoil nucleons.-

The next topic on my list are the polarisation measurements. There are four groups at Bonn doing this kind of experiments. Three of them measure the polarisation of the recoil proton in the reaction $\gamma + p \rightarrow \pi^o + p$[21] and one group is looking at the polarisation of the recoil neutron from the π^+-photoproduction reaction $\gamma + p \rightarrow \pi^+ + n$[22].

On the upper right corner of figure 2 a view of the experimental arrangements can be seen. The reason why there are three different experiments measuring the proton polarisation is the wide range of recoil proton energies, covered in the experimental program. Depending on the proton energy different types of analysing targets and therefore different experimental set-ups have to be used (see Table IV).

TABLE IV

set-up	analyser	proton energy
A	H_2	200 - 500 MeV
B	C_{12}	90 - 250 MeV
C	He	10 - 50 MeV

The first set-up (A), using hydrogen analyser has been designed for high proton energies. The protons were detected by a set of sonic spark chambers and a homogeneous magnetic field. The second (B) works for medium energies with a carbon analyser, and uses a range telescope and acustic spark chambers for detecting the recoil proton. The third arrangement has an He target to analyse the polarisation of low energy protons. Here the proton momentum is measured with the time-of-flight method and the scattering angle again with the aid of sonic spark chambers.

Some of the obtained data are shown in the next two figures. The first (Fig. 13) gives the polarisation at low energies, together with a few points from Stanford[23] and Tokio[24], which fit nicely into the Bonn data. The solid line is a fit obtained by the recent multipole analysis of Nölle et al.[8]. In Fig. 14 the reduced polarisation is drawn

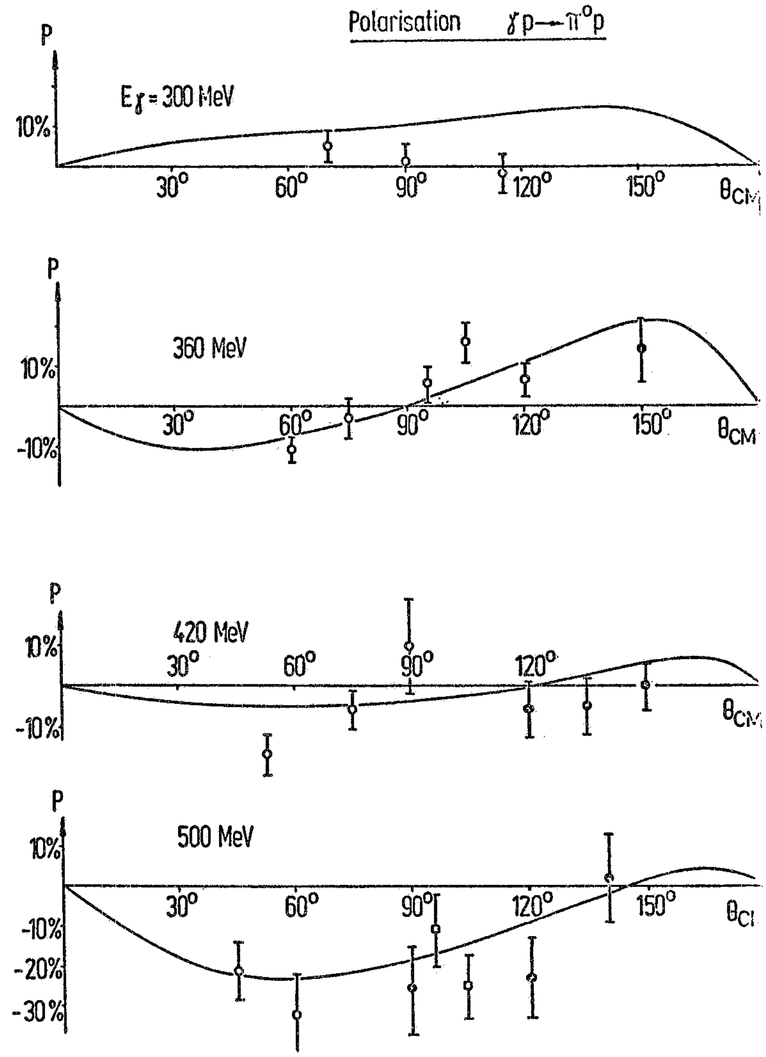

FIG. 13 - Polarisation of the recoil proton in the reaction $\gamma p \rightarrow \pi^0 p$. Open and full circles are Bonn measurements with He respective C_{12} analyser (see ref. (21)). Open squares are points from Stanford, ref. (22).

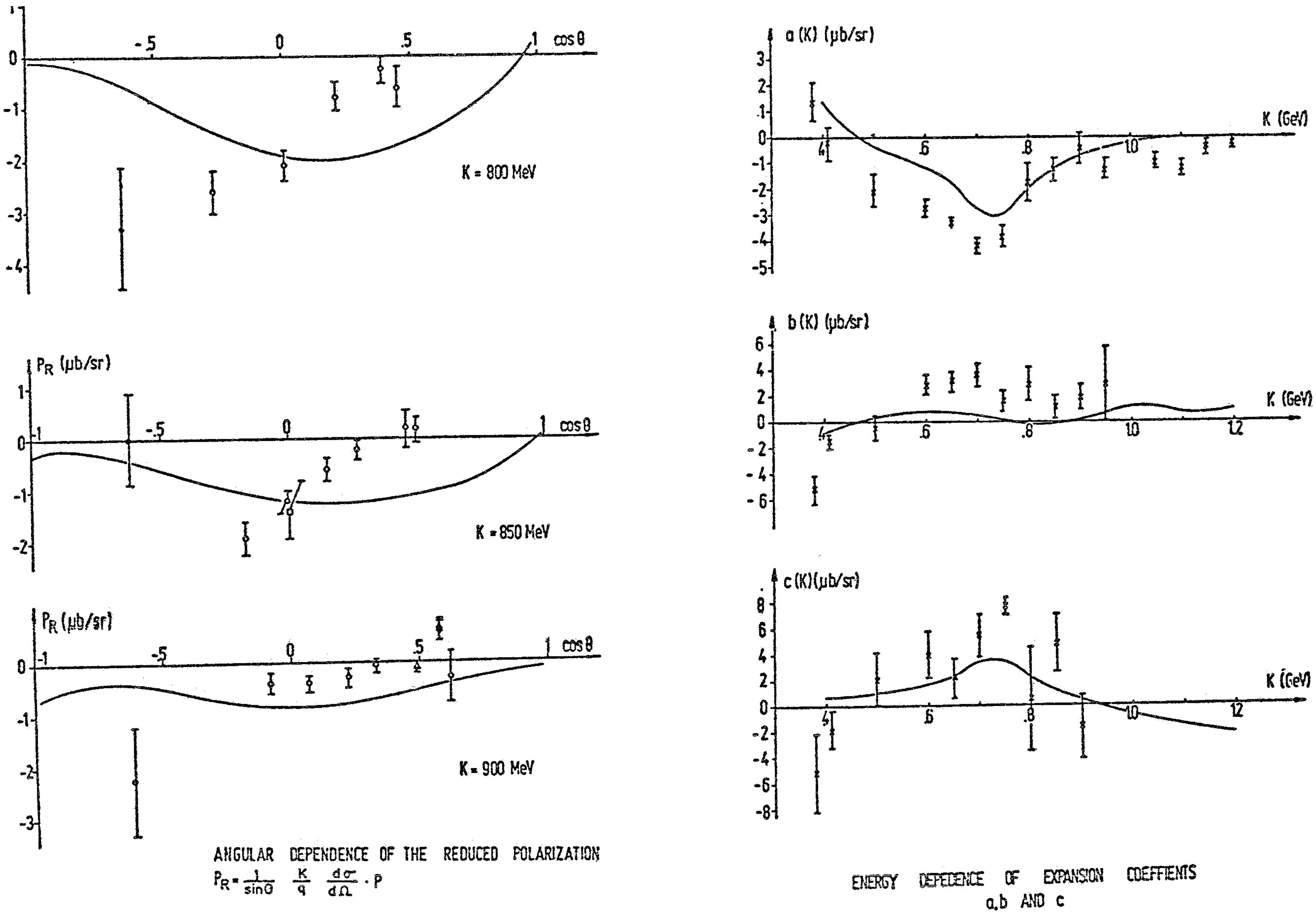

FIG. 14 - Angular dependence of the reduced polarisation (left side). Energy dependen_ce of the expansion coefficients a, b and c. Solid line: Fit by W. Pfeil, ref. (17).

at higher photon energies. This quantity is defined as

$$P_r = \frac{1}{\sin\theta} \frac{k}{q} \frac{d\sigma}{d\Omega} P = a(k) + b(k)\cos\theta + c(k)\cos^2\theta + \ldots..$$

and can be expanded as a polynominal in $\cos\theta_{CM}$, the pion production angle. On the right side of this figure the expansion coefficients are given as a function of the photon energy. In order to fit the available data it is obviously necessary to take the $\cos^2\theta$-term into account, but the data do not yet allow to determine possible contributions from higher terms.

These measurements will be extended to fill up the existing angular distributions and to get better information on the expansion parameters.

The neutron polarisation experiment[22] uses the arrangements of experiment (A) to analyse angle and momentum of the produced positive pion. The neutrons are scattered on liquid hydrogen and are thereafter detected in two large scintillator blocks. The analysing power of hydrogen for neutrons in the hereby covered energy range (30 - 120 MeV) is well known.

The data analysed up to now are shown in the next figure (Figure 15), which is an excitation curve at 60°. These points first confir

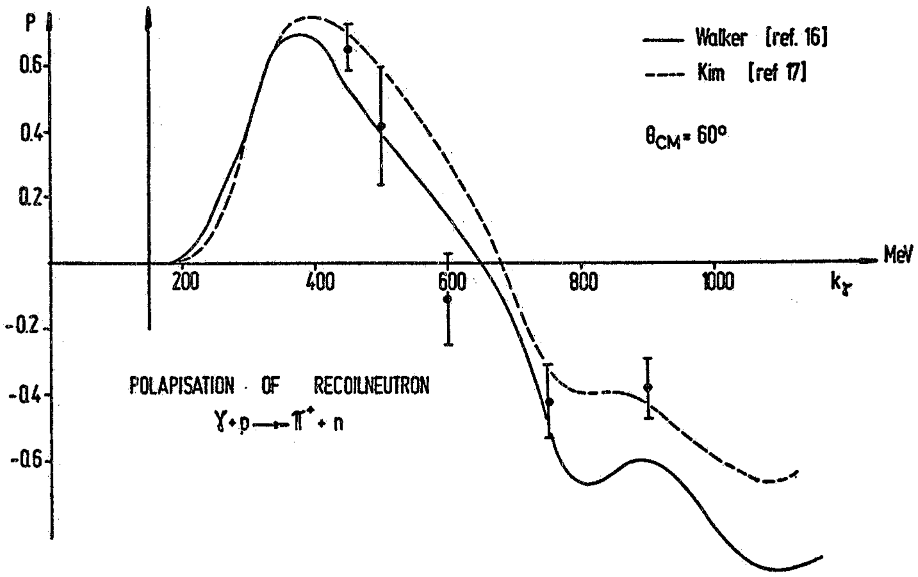

FIG. 15 - Polarisation of the recoil neutron from the reaction $\gamma p \rightarrow \pi^+ n$ (ref. (22)), in comparison with theoretical predictions, ref. (16), (17).

med the rather high neutron polarisation, which was predicted by several theoretical models in the region of the first resonance. Next a 90^{o} excitation curve will be measured up to 1.6 GeV.

4. - PHOTOPRODUCTION OF SINGLE PIONS ON DEUTERIUM. -

Under this topic I want to describe two experiments running at present at the small synchrotron. The first is a measurement of the coherent production of neutral pions on deuterons, the second a systematic study of the π^-/π^+-ratio from deuterium.

4.1. - Coherent production of π^{o}-mesons. -

The process of coherent photoproduction of neutral pions from deuterium, $\gamma + d \rightarrow \pi^{o} + d$, is regarded as a potential source of information on

(i) the structure of the deuteron, and
(ii) the photoproduction of neutral pions on the neutron.

The usefulness of measurements of this reaction, however, depends on the existence of a valid theoretical description, which allows the two different informations to be separated.

The standard method for analysing this reaction is the impulse approximation, however, severe problems arise from the final state interactions. Multipole pion scattering, for example, may result in a decrease of the impulse approximation cross section by more than 30%. The lack of knowledge of the size of these corrections also makes a derivation of the deuteron form factor from the coherent π^{o}-production data rather difficult.

On the other hand there is still a great lack of data in this reaction and the large fluctuation of the available data makes a comparison with theoretical calculations rather uncertain. Under this aspect we started a program to measure the coherent production process with high precision in a wide kinematical region(25). Thereby the deuteron is detected by a magnetic spectrometer.

First results have been obtained in the upper energy region for angles between 70^{o} and 110^{o} and for momentum transfers ranging from -0,13 to -0,28 GeV^2. Our results at 80^{o} and 90^{o} are shown in Fig. 16 together with data from two other groups. The quantity that is compared here, is the measured differential cross section divided by the form factor, thus eliminating the rather steep decrease of the cross section with increasing momentum transfer.

There is a remarkable disagreement with the Stanford data(26),

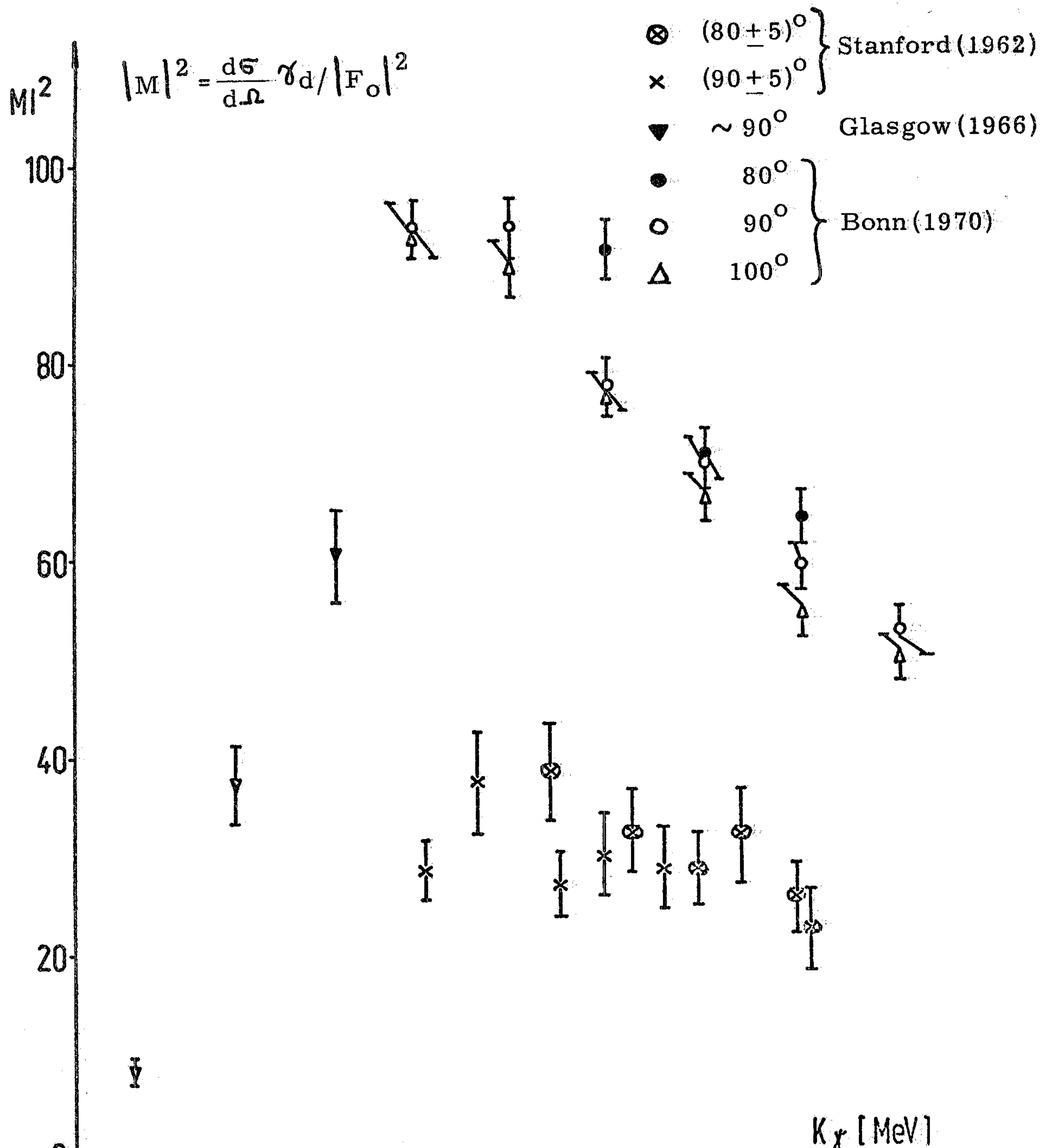

FIG. 16 - Differential cross section of the coherent π^o-photoproduction devided by the deuteron s-wave form factor of ref. (28). The experimental points are: ⊗ and × ref. (26), ▼ ref. (27), ●, ○ and △ ref. (25).

but together with the data from Glasglow[27], the shape of the first resonance is produced. This is expected to occur, since due to the impulse approximation the quantity $|M|^2$ should be proportional to the cross section of neutral pion production on protons.

Fig. 17 shows the deuteron form factor as obtained from our data. This effective form factor was extracted from our deuteron data and the cross section of π^0-photoproduction on protons[6], assuming a pure magnetic dipole contribution and following impulse approximation. The agreement with the theoretical form factor calculated by Hadjioannon[28] is much better than one should expect under these assumptions. This theoretical form factor is a pure s-wave form factor, using a repulsive core wavefunction of the deuteron.

In the further program of this experiment the cross section will be measured also in the low energy region.

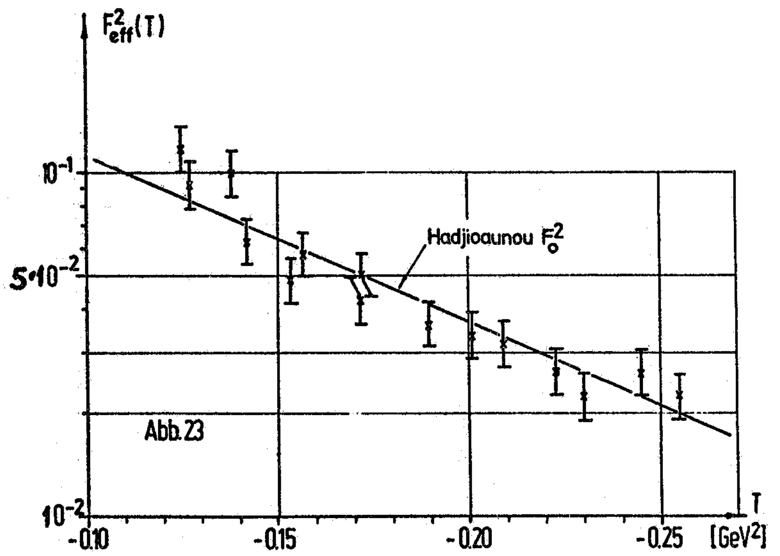

FIG. 17 - Comparison of deuteron form factor. Experimental points: ref. (25), solid line: ref. (28).

4.2.- π^-/π^+-ratio measurement.-

The aim of this experiment is a systematic study of the absolute yield of negative and positive pions from deuterium in a wide kinematical region around the first resonance[29]. Thereby only the charged mesons are detected by a magnetic spectrometer. The obtained data together with the π^+-measurements on protons[11] will result in a consistent and complete list of information (i) for the π^-/π^+-ratio on deuteron and (ii) for the ratio of positive pion-production on bound protons to that on free protons.

5. - PROTON COMPTON EFFECT. -

The next experiment, I would like to mention, is measuring the proton Compton effect in the region of the first pion-nucleon resonance. The proton Compton effect has been the subject of growing interest during the last years; because of the fact, that with the now available high precision photoproduction data, together with the help of dispersion relations, better predictions of the Compton differential cross section can be made. A Bonn group therefore performed an experiment to measure angular distributions of the Compton cross section in the region of the first resonance(31).

The difficulty of this experiment is not the low cross section, which is of the order of a tenth of a μ-barn, but the contribution of π^o-photoproduction which is larger by a factor 50 - 100. To diminish the contribution of this competing process, besides the proton also the photon is detected, using a total absorption sandwich-counter. With the additional help of a suitably fixed end-point energy of the synchrotron the photon contribution of the π^o-decay could be reduced to only 10 - 30%.

At this time two angular distributions have been measured at mean photon energies of 420 MeV and 380 MeV. These results are given in Fig. 18. The future program of this group foresees angular distributions at three more energies at and below the first resonance.

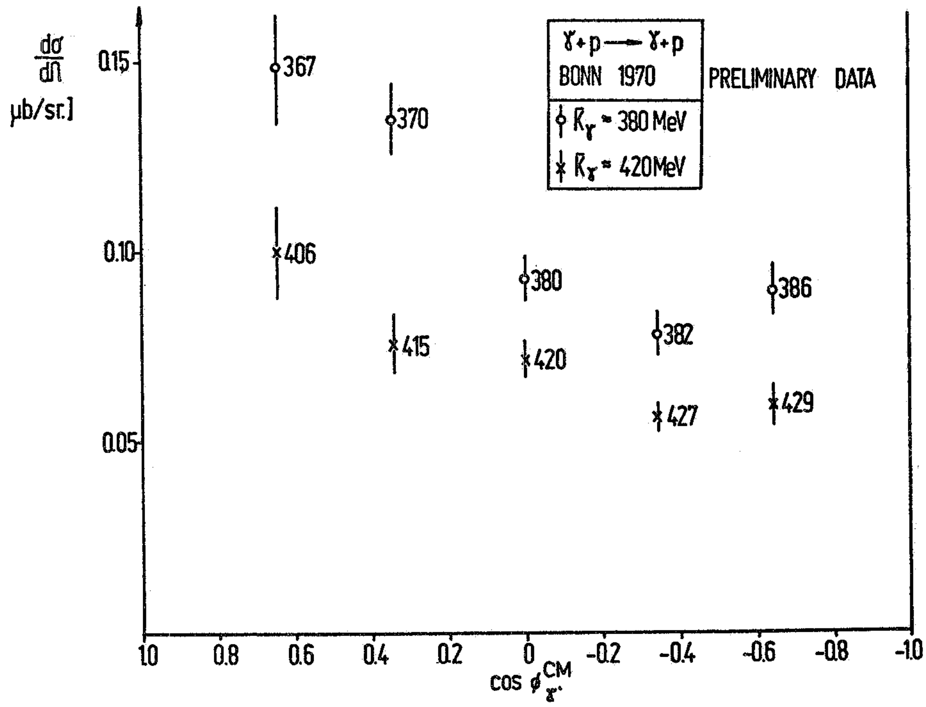

FIG. 18 - Angular distributions of the proton Compton effect at mean photon energies of 380 MeV and 420 MeV. Points are from ref. (31).

6. - NUCLEAR PHOTOEFFECT. -

Next I briefly want to discuss an experiment of the reaction

$$\gamma + O^{16} \rightarrow N^{14} + p + n .$$

The aim is to measure the differential cross section of this "quasi--deuteron"-process, detecting both outcoming nucleons, and to get better information about the proton-neutron correlation which is in this connection often called the "quasideuteron model".

In the frame of this model the cross section of the process can be factorized in two parts.

$$\sigma\,(\gamma O^{16} \rightarrow N^{14} pn) \sim F(|\vec{P}_{pn}|) \times \sigma\,(\gamma + [pn] \rightarrow pn)$$

The first part beeing only a function of the relative momentum of the proton-neutron system and the second beeing the cross section of the deuteron photodisintegration reaction. The first function can be calculated with the help of the nuclear shell model. So, this reaction provides one with a good test of the "quasideuteron model" by comparing the obtained cross section with that of deuteron photodisintegration.

To eliminate uncertainties in the measuring process the photodisintegration of the deuteron will be measured with the same apparatus by alternating use of a water target for the first process and a heavywater target for the process to be compared.

By the experimental set-up both outcoming nucleons are detected and angle and momentum analysed, the proton by a range telescope the neutron by measuring time-of-flight between target and neutron-counter.

Up to now no complete analysed data are available(32).

7. - POLARIZED ELECTRON SOURCE. -

Finally, I would like to mention an investigation of a source of polarized electrons, performed at Bonn during the last years, which is intended for use in the 2.5 GeV synchrotron(33). An intense lithium atomic beam is polarized to a degree of 0,8 by a magnetic six-pole field. The valence electrons then are set free by ultraviolett light of a Xenon flash tube. The polarisation of the photoelectrons is measured by Mott scattering. The up to now obtained polarisation is $P = 0.55 \pm 0.05$. The intensity of the source is 2×10^8 epp with a pulse length of 20 μsec.(34). The maximum possible repetition rate is 50 Hz and will result in 10^{10} eps.

With this intensity perhaps a lower limit is reached for a device like this to be used as an electron source in a synchrotron. But there are still rather severe problems to be solved, mainly concerned with the usefull beam time and the stability of this complex arrangement.

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