Highlights of N* experiments at ELSA

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Highlights of N* experiments at ELSA

- ELSA facility
- Selected recent data
- Projects
NSTAR Mission

• Find laws of nature for hadron formation

• Identify relevant degrees of freedom (constituents and fields) in hadron-spectrum

• search and characterize resonances through excitation and decay

• study and analyze meson production quanta of hadronic interaction
Electromagnetic Approach

Electro-/photoproduction of mesons of various spin, flavour, ...

- measure (over-)complete sets of observables amplitudes feasible for pseudoscalar mesons maximize constraints, minimize redundancy

- well chosen cases to get extra clues e.g. omega-production, -modification, -mesic nucleons, ...
Meson photoproduction cross sections

\[ \gamma + p \rightarrow X \]

\[ \gamma + p \rightarrow p + \pi^- + \pi^+ \]

\[ \gamma + p \rightarrow p + \pi^0 \]

\[ \gamma + p \rightarrow p + \pi^0 + \pi^0 \]

\[ \gamma + p \rightarrow K^+ + \Lambda \]

\[ \gamma + p \rightarrow p + \eta \]
Experimental Toolbox

Successful efforts ➔ comprehensive toolbox for complete experiments

- pol’d e- and γ-beams in resonance region
- pol’d obstruction-less targets (longitudinal + transverse)
- High acceptance detectors w/ excellent sensitivity to ch’s of high impact for resonance search

Available @ Jlab, MAMI, LEPS, ELSA, …
Electron Stretcher Accelerator (ELSA, Univ. Bonn)

SAPHIR, Crystal Barrel, now BGO-OD

booster synchrotron 0.5 - 1.6 GeV

Electron Stretcher Accelerator (ELSA, Univ. Bonn)

W. Hillert, …
ELSA Beam Parameters

Energy Range: \(0.8 \text{ GeV} < E < 3.4 \text{ GeV}\)

Bunch Length: \(1 \text{ mm} < \sigma < 6 \text{ mm}\)

Horizontal Emittance: \(56 \text{ nm} \cdot \text{rad} < \varepsilon_h < 1 \text{ \mu m} \cdot \text{mrad}\)

Vertical Emittance: \(\varepsilon_v < 0.1 \cdot \varepsilon_h\)

Bunch Spacing: \(\Delta s = 2\text{ns}\)

External Current: \(1 \text{ fA} < I < 1 \text{ nA}\)

Duty Factor: \(70\% < DC < 90\%\)

Polarization: \(P > 65\% @ E < 2.4 \text{ GeV}\)
Photoproduction of $K^+ \Lambda(1520)$ @ SAPHIR

Prof. W.J. Schwille
Deceased in 2010

F.W. Wieland et al. EPJA (2011) 47

$\sigma$, t-distributions and decay angular distributions determined

all 4 decay channels agree in $\sigma$, but deviate from LAMP2 (1980) →

cf. Hosaka, NSTAR2009
Crystal Barrel / Taps set-up

- Polarized Target
- Forward Detector
- Gas-Cherenkov
- Crystal Barrel + Inner detector
- TAPS
- Photon intensity monitor
- Beam Dump
- Electron beam
- Goniometer
- Tagging system
Quasi-free photoproduction of $\eta$-mesons off the deuteron

no cut on spectator momentum

spectator momenta $p < 100$ MeV

I. Jaegle et al., subm. to EPJ A

position: $W \approx 1.67$ GeV
width: $\sigma \approx 25$ MeV (FWHM)

narrow structure in excitation fct. of $\gamma n \rightarrow n \eta$:
- GRAAL: $W \approx 1680$ MeV, $\Gamma < 30$ MeV
- Tohoku-LNS: $W \approx 1666$ MeV, $\Gamma < 40$ MeV
- ELSA: $W \approx 1685$ MeV, $\Gamma < 50$ MeV
- MAMI-C: $W \approx 1675$ MeV, $\Gamma < 40$ MeV
Quasi-free photoproduction of $\eta$-mesons off the deuteron

I. Jaegle et al., subm. To EPJ A
Observables in meson photo production

**single** pseudoscalar meson photo production

<table>
<thead>
<tr>
<th>photon</th>
<th>target</th>
<th>recoil</th>
<th>(target + recoil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>unpolarised</td>
<td>$\sigma_0$</td>
<td>0</td>
<td>T 0</td>
</tr>
<tr>
<td>linearly pol.</td>
<td>-$\Sigma$</td>
<td>H (-P)</td>
<td>-G</td>
</tr>
<tr>
<td>circularly pol.</td>
<td>0</td>
<td>F 0</td>
<td>-E</td>
</tr>
</tbody>
</table>

- $\gamma_{\text{lin}}$: Linearly polarised photons
- $\gamma_{\text{circ}}$: Circularly polarised photons
- $P_{T,z}$: Longitudinally polarised protons
- $P_{Y}^{\text{lin}}$, $P_{Y}^{\text{circ}}$: Polarised photons

**Example:** Longitudinally polarised protons: $P_{T,z}$
Circularly polarised photons: $P_{Y}^{\text{circ}}$

$$d\sigma = d\sigma_0 \left[ 1 - P_{Y}^{\text{lin}} \left( \Sigma \cos 2\Phi - G P_{T,z} \sin 2\Phi \right) - E P_{Y}^{\text{circ}} P_{T,z} \right]$$

Crystal Barrel / Taps set-up

- Polarized Target
- Crystal Barrel + Inner detector
- Forward Detector
- Gas-Cherenkov
- TAPS
- electron beam
- Gonimeter
- Tagging system
- Photon intensity monitor

Graph showing relative intensity and polarisation grade vs. photon energy.
Polarized Target w/ Crystal Barrel

Running time over 2500 hours in year 2008
over 2200 hours in year 2009

High. polarization

\[ P_+ = 83.4\% \]
\[ P_- = -80.9\% \]

fast build-up
(May/June)
05h04min

Pol.-time
06h10min

05h39min (August)
Polarised target

Longitudinally polarised

Solenoid with low mass layer

E, G, P data taken

Transversely polarised

Race track coil

T, P and H data taken

H. Dutz and S. Goertz
Double polarisation Observable $G$ in $\gamma + p \rightarrow p + \pi^0$

$E_\gamma = 733$ MeV

$E_\gamma = 767$ MeV

$E_\gamma = 800$ MeV

$E_\gamma = 833$ MeV

$E_\gamma = 867$ MeV

$E_\gamma = 900$ MeV

$E_\gamma = 933$ MeV

$E_\gamma = 967$ MeV

$E_\gamma = 1000$ MeV

$E_\gamma = 1033$ MeV

$E_\gamma = 1067$ MeV

$E_\gamma = 1100$ MeV

$\gamma p \rightarrow p \pi^0$

---

Maid  |  Said  |  BnGa  |  A. Thiel (Bonn)
Beam asymmetry $\Sigma$ in $\gamma + p \rightarrow p + \omega$
Crystal Barrel / Taps set-up

- Polarized Target
- Crystal Barrel + Inner detector
- Forward Detector
- Gas-Cherenkov
- TAPS
- electron beam
- Goniometer
- Tagging system
- Photon intensity monitor
- Beam Dump
- Graph with $\frac{P_\gamma}{P_e}$ on the y-axis and $\frac{E_\gamma}{E_e}$ on the x-axis.
Helicity dependent total cross section $\gamma + p \rightarrow p + \eta$

circularly polarised photon beam
longitudinally polarised proton target

Preliminary results (J. Müller)

\begin{align*}
\sigma_{1/2} & \quad \text{photonspin} \quad 1 \quad \text{nucleon-spin} \quad -1/2 \\
\sigma_{3/2} & \quad \text{photonspin} \quad 1 \quad \text{nucleon-spin} \quad +1/2
\end{align*}

$S_{11} (1535)$

$P_{11} (1710)$

$P_{13} (1720)$

$N_{1/2} - N_{3/2}$

$\sigma_{1/2} - \sigma_{3/2}$ [\mu b]

no acceptance correction

$E_\gamma$ [MeV]

$Maid$

$Said$

$BnGa$

$BnGaCur$

F. Klein – N* 2011
Polarization observables $I^s$ and $I^c$ → contr. Sokhoyan

\[
\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 \left\{ 1 + \delta_I [I^s \sin(2\phi) + I^c \cos(2\phi)] \right\}
\]

\[
I^c(\Phi^*) = I^c(2\pi - \Phi^*)
\]
\[
I^s(\Phi^*) = -I^s(2\pi - \Phi^*)
\]

\[\pi^0\] in the production plane

\[\Gamma^s\]

\[\Gamma^{(c)}(\Phi^*) = \Gamma^{(c)}(\Phi^* + \pi)\]

proton in the production plane

\[\Gamma^s\]

\[
\begin{align*}
I^c &= -0.078 \pm 0.053 \\
I^s &= 0.194 \pm 0.053 \\
I^c &= -0.093 \pm 0.054 \\
I^s &= -0.2065 \pm 0.054
\end{align*}
\]

36° < $\Phi^*$ < 54°

306° < $\Phi^*$ < 324°
Double polarisation observable $E$ in $\gamma + p \rightarrow p + \omega$

$\cos \theta^\omega$

$E$

1109 MeV < $E_\gamma$ < 1200 MeV

1200 MeV < $E_\gamma$ < 1300 MeV

1300 MeV < $E_\gamma$ < 1400 MeV

1400 MeV < $E_\gamma$ < 1500 MeV

1500 MeV < $E_\gamma$ < 1600 MeV

1600 MeV < $E_\gamma$ < 1700 MeV

1700 MeV < $E_\gamma$ < 1800 MeV

1800 MeV < $E_\gamma$ < 1900 MeV

1900 MeV < $E_\gamma$ < 2000 MeV


Photoproduction of $K^0\Sigma^+$ @ CBELSA/TAPS

6 particles identified (red)
7 particles identified (green)
All events

R Ewald, PhD thesis, Universität Bonn, 2010

→ contrib. T. Jude
Cross sections $\gamma p \rightarrow K^0 \Sigma^+$

Cross section measurements suggest strong t-channel dependency

Average $K^*\Sigma^+$ / $K^*\Lambda$ threshold

Black points: Ewald [1]
Red points: Casteljins [2]
Taken from [1]

Beam-target double polarisation observable $E$ in $K^0 \Sigma^+$

H. Schmieden: does $c$ contribute to $K^0 \Sigma^+$???

check $E$

Diagram:

- $\gamma$$
- K$\n- $K^*$
- $K$\n- $\Lambda / \Sigma$
- $\Lambda / \Sigma$

Counts vs $K^0$ invariant mass [MeV]

1.25 - 1.50 GeV

Parallel ($\sigma_{3/2}$)

Anti-Parallel ($\sigma_{1/2}$)

$\rightarrow$ contrib. T. Jude
**ω meson line shape near the production threshold**

\[ E_v = 900 \text{ – } 1300 \text{ MeV}; \quad E_{vN}^{\text{thr}} = 1109 \text{ MeV} \]


\[ \omega \text{ signal shows no significant deviation from the reference signals} \]

\[ \text{higher statistics needed} \]

\[ \rightarrow \text{BGO-OD} \]

comparison of the \( \omega \) line shape to the GiBUU calculations (J. Weil)

experimental data do not allow to distinguish between the various theoretical scenarios also near threshold!
New BGO - OD set-up

- ToF Walls
- Drift Chambers
- Dipole Magnet
- Scifi2 & MOMO
- Open Dipole – forward spectrometer
- Beam dump
- Photon tagging
- BGO – calorimeter
- MWPCs – inner tracking
- Si strips – fw tracking
- Target system
- Electron beam

F. Klein – N* 2011
BGO - OD experiment

Focus on vector meson production, recoil polarisation, strangeness photoproduction, excited hyperons, eg. $\Lambda(1405)$
BGO - OD experiment

member institutions:

Univ. of Bonn, Phys. Inst.
Univ. of Bonn, HISKP
Univ. of Messina, Italy
Univ. of Edinburgh, UK
Univ. of Moscow, Russia
INFN-LNF Frascati, Inst. Sup. di Sanità & INFN Roma1, Italy
Univ. of Pavia, INFN Pavia, Univ. of Torino & INFN Torino, Italy
Univ. of Roma “Tor Vergata” and INFN Roma2, Italy
Nat. Sc. Center Kharkov Inst. of Phys. & Techn., Ukraine
Petersburg Nucl. Phys. Inst. (PNPI), Gatchina, Russia
Univ. of Basel, Switzerland
Contributions to NSTAR2011 from ELSA

Tue
• **T. Jude** - Double polarization asymmetry in neutral kaon production w/ CBELSA/TAPS

Wed
• **J. Hartmann** - Double polarization observables in meson photoproduction w/ CBELSA/TAPS
• **N. Sparks** - $\pi^0$ photoproduction off the proton at forward angles using CBELSA/TAPS

Thu
• **V. Sokhoyan** - Polarization observables $I_s$ and $I_c$ in $\gamma p \rightarrow p\pi^0\pi^0$ with CBELSA/TAPS
• **H. Eberhard** - Measurement of polarization observables in $\omega$-photoproduction
• **A. Wilson** - Photoproduction of $\pi 0\omega$ meson pairs off the proton at CBELSA/TAPS
• **I. Jaegle** - Meson photoproduction off light nuclei
Summary

• tools for double polarization exp‘s w/ high acceptance for photons

• single & double meson production done w/ CBELSA/TAPS
d_\sigma, \Sigma, E, G, P, H, T for \pi and \eta on proton

• neutron under attack

• second complementary spectrometer BGO-OD commissioning better control and inclusion of charged final states focus on recoil polarimetry, strangeness, \omega, medium effects, …
Summary

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  dσ, Σ, E, G, P, H, T for π and η on proton

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  better control and inclusion of charged final states
  focus on recoil polarimetry, strangeness, ω, medium effects, …

Personal wishes and hopes on N*-activities:
  avoid costly stamp collection …
  theorists, help orthogonalize exp’s !!

  breakthrough, please come soon!