Baryon spectroscopy: recent Kaon photoproduction results from CLAS

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EINN2009, Sep2009, Milos Island, Greece

- Motivation
  - Missing resonances
  - 1st complete measurement in pseudoscalar meson production
- Polarization observables at CLAS
  - Progress towards a complete measurement in K⁺ photoproduction on p
  - Measurements on the neutron
- Summary
• Clear indication of resonances in $\gamma p$ cross section for many channels

• Constituent quark models predict many resonances, but several missing
  • Mostly from $\pi N$ scattering and single $\pi$ photoproduction
  • Really missing or undetected since weak coupling to these channels
  • Try other channels. Eg. $K$ photoproduction

• Eg. Cross sections show some hints of new $D_{13}$.
  • Better to look at angular distributions and polarization observables.

After Cx, Cz from CLAS, revised as most likely P13.
Eur Phys J A34 (07) 243
Polarization observables in pseudoscalar meson production

4 Complex amplitudes: \textbf{16} real polarization observables.

Complete measurement from \textbf{8} carefully chosen observables.

$\pi N$ has high statistics but in $KY$ recoil is self-analysing 😊


Complete, and over-determined
Tagged photons at CLAS

- Tagged bremsstrahlung photons up to 6GeV.
- Timing resolution < 1 beam bucket.
- Circularly polarized
  - up to ~80% now standard
- Linearly polarized
  - coherent bremsstrahlung up to >90%.
Polarization observables at CLAS

\[ \gamma + N \rightarrow N + m \rightarrow Y + K \]

- Linear polarisation
- Circular polarisation
- Nucleon recoil polarimeter
- Hyperons are "self analysing"
- Longitudinally polarized nucleon targets
- Transverse polarized nucleon targets
Polarization observables - a simple example, $\Sigma$

$$\rho \int \frac{d\sigma}{d\Omega} = \frac{1}{2} \left( \frac{d\sigma}{d\Omega} \right)_{\text{unpol}} \left\{ 1 - P_{\text{lin}} \Sigma \cos 2\phi \right\}$$

Asymmetry = $N_\perp - N_\parallel / N_\perp + N_\parallel = \Sigma P \cos 2\phi$

- Systematics of detector acceptance cancel out.
- “Only” need to know $P_{\text{lin}}$, the degree of linear polarization.
1st pol. observables in K photoproduction on p at CLAS.

P, Cx and Cz (Using circularly polarized photons)


Will analogous result hold with the observables from linearly polarized?
From Brem. Calculation and piN results we expect 3% systematic error in P.
g8b preliminary results - $K^+\Lambda$ and $K^+\Sigma^0$

Craig Paterson, Glasgow

$\gamma p \rightarrow K^+\Lambda \rightarrow K^+p\pi^-$

$\gamma p \rightarrow K^+\Sigma^0 \rightarrow K^+\Lambda\gamma \rightarrow K^+p\pi^-\gamma$

Single polarization observables
- $\Sigma$ Photon asymmetry
- $P$ Recoil polarization (induced pol. along y)
- $T$ Target asymmetry

Double polarization observables
- $O_x$ Polarization transfer along x
- $O_z$ Polarization transfer along z

figure by R.Schumacher, CMU
g8b preliminary results - $K^+\Lambda$

- Results compared with previous results from GRAAL
  - 7, 50MeV Energy bins
  - 1175 -> 1475MeV
  - Good agreement with previous results
Results compared with previous results from LEPS

- 6, 100MeV Energy bins
- 1550 -> 2050MeV
- More bins for our data

Increase the angular coverage to backward angles

LEPS also recently have some consistent, new points at backward angles.
Hicks et al., PRC 76, 042201(R) (2007).
g8b preliminary results - $K^+\Lambda$

$O_x/O_z$ extracted from fit to 2d asymmetry

Target asymmetry from 2d asymmetry (not shown)

Recoil pol. from acceptance corrected proton dist.

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g8b preliminary results - $K^+\Lambda$

Double polarization observable $O_x$

- Results compared with Regge-Plus-Resonance model from Gent group

- Large Polarizations
- Some evidence for an important role for missing $D_{13}(1900)$ state
- Poor agreement at low energy
g8b preliminary results - $K^+\Lambda$

Full lambda polarization?

- Full polarization at forward angles
- Not repeated over full kinematic range
- More relations can be tested

$(P^2 + Q_x^2 + Q_z^2)^{1/2}$

$cos(\Theta_{c.m.})$
g9 FROST – FROzen Spin Target (butanol = $C_4H_9OH$)

Meson photoproduction with linearly and circularly polarized photons on polarized target

- **E02-112:** $\gamma p \rightarrow KY$ ($K^+\Lambda, K^+\Sigma^0, K^0\Sigma^+$)
- **E03-105/E04-102:** $\gamma p \rightarrow \pi^0 p, \pi^+ n$
- **E05-012:** $\gamma p \rightarrow \eta p$
- **E06-013:** $\gamma p \rightarrow \pi^+ \pi^- p$

**g9a running conditions**
- Longitudinally polarized target
- Circularly and linearly polarized photon beam 0.5-2.4 GeV
- Trigger: at least one charged particle in CLAS
- Target Pol > 80%, Relaxation time > 1600hrs – better than design goals

**g9b**
- March – July 2010
- Transversely polarized target
g9aFROST sample analysis of $\text{gp} \rightarrow \pi^+ n$

Eugene Pasyuk, ASU. Jo McAndrew, Edinburgh

- Select $\pi^+$ applying cut on $\beta$ vs. $p$
- Vertex cuts
- Select missing neutron

Asymmetry = $P_y \cos(2\varphi) + P_y P_z G \sin(2\varphi)$

$A = \frac{d_1 - \sigma_0 (1 - P_c P_T E)}{1 - \sigma_0}$

Based on ~2% of statistics

Preliminary, also in progress for K1.
K production on n. Deuterium target

- G10. Unpolarized photons on Deuterium
- 1st measurement of $\sigma$ for the $\gamma \, n \rightarrow K^+ \Sigma^-$  Sergio Anefalos Pereira, INFN.

- Detect $\pi^- n$, $K^+$
- $\Sigma$ from $\pi^- n$ inv. mass

- G13. Circularly and linearly polarized photons on Deuterium
- $\gamma \, n \rightarrow K^+ \Sigma^-$ analysis for polarization observables underway. Edwin Munevar, GWU
**K production on n. Deuterium target**

- How good a “free” neutron target is Deuterium?
- **G13.** Compare photon asymmetry of \( \gamma p (n) \rightarrow K^+\Lambda^0 (n) \) with \( \gamma p \rightarrow K^+\Lambda^0 \) (free and bound p)

\[ \gamma p (n) \rightarrow K^+\Lambda^0 (n) \] Russell Johnstone, Glasgow

Each plot is 200MeV photon energy bin

1100-2150MeV

- Free
- Quasi free

Free and quasi-free proton
Quasi free neutron good approx. to free, here.
K production on n. Deuterium target

$G13 \, \gamma n (p) \rightarrow K^0_s \Lambda^0 (p)$  \, $\gamma n (p) \rightarrow K^0_s \Sigma^0 (p)$

Neil Hassall, Glasgow
K production on n. Deuterium target

G13  1st measurement of Beam Asymmetry  $\gamma n (p) \rightarrow K^0_s \Lambda^0 (p)$

Neil Hassall, Glasgow

Single, and double polarization observables in progress
K production on n. Deuterium target

G13  1st measurement of Beam Asymmetry  $\gamma n (p) \rightarrow K^0_s \Sigma^0 (p)$

Neil Hassall, Glasgow

Single, and double polarization observables in progress
Summary

- **Kaon photoproduction at CLAS**

- **Missing resonances**
  - Recent measurements already having impact on resonance predictions

- **Polarization observables**
  - *Explosion* of possibilities at CLAS.
  - **Complete measurement** possible with K Y channels ... and **coming soon**

- **KY on proton**
  - \( \sigma, P, C_x, C_z \) measured *(g1c)*
  - \( \Sigma, T, O_x, O_z \) almost complete *(g8b)*
  - \( E, G, L_x, L_z \) data taken, being analysed *(g9a)*
  - \( F, H, T_x, T_z \) begins March 2010 *(g9b)*

- **KY on neutron**
  - 1st measurements of \( \sigma \) *(g10), P, C_x, C_z, \( \Sigma, T, O_x, O_z \) *(g13)* prelim results, and analysis underway

- **HDIce** A new kind polarized target with H and D scheduled for Autumn 2010 *(g14)*
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Recoil polarimetry possibilities?

\[ n(\theta, \phi) = n_0(\theta) \{ 1 + A(\theta)[P_y \cos(\phi) - P_x \sin(\phi)] \} \]

- How to do this for 4\( \pi \) detector

\( x \) and \( y \) (transverse) components of nucleon polarisation

Nucleon polarimeter for CB@MAMI, D. Watts, Edinburgh

g8b data. \( \gamma + p \rightarrow \pi^+ n \) with (n,p) scatter (detect \( \pi^+ p \))

K. Livingston
CLAS coherent bremsstrahlung facility

- Tagging spectrometer with high rate, good energy and timing resolution
- High precision goniometer (GWU)
- High quality, thin diamond (Glasgow)
- Tight photon beam collimation (ISU)
- Polarimetry

“A device called a goniometer tilts the diamond, much like a lady turning her hand to admire the sparkle of a new ring.” - JLAB On Target Magazine
Measurements with photon beam profile detector
D. Glazier, Glasgow

1st Measurement of 2D photon enhancement for coherent bremsstrahlung (MAMI, Mainz)
paper in preparation

- Good agreement with coherent bremstrahlung calculations
  - Improvements in incoherent component, collimation + multiple scattering.
- No evidence of high energy photons from quasi channeling.
- Investigation of 2D strip detector for polarimetry
**g8b preliminary results - $K^+\Lambda$**

- $K^+\Lambda$ Photon Asymmetry, $\Sigma$, extracted from $\cos(2\phi)$ fit to azimuthal kaon distribution
- Fits shown for 1 energy bin
- 340 (20E, 17$\theta$) kinematic bins
- Almost full angular coverage

\[
\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_{un}} \left( 1 - P^T \Sigma \cos 2\phi \right)
\]
g8b preliminary results - $K^+\Sigma^0$

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Increase the angular coverage to backward angles
Polarimetry: from pair \((e^+, e^-)\) production

H. Schmieden, Bonn

- Well described by QED, but experimentally difficult – small opening angle
- Pair production simulations by Kharkov group
- Polarimeter built and tested at Sping8, recently tested at Jlab

- Polarimeter to be based on Jlab design
- Microstrip detectors, or pixel detectors (Atlas group)
- Bonn student completed 10 months exchange in Glasgow now to be full time in Bonn.
Polarimetry: from hadronic reaction
R. Beck, Mainz -> Bonn

Use reaction with a known photon asymmetry

• Can be high statistics
• Very good relative monitor of polarization
• Combined beam, target polarization.
• Non-independent – depends on specific expt
• Need very good systematics or calibration
• Awaiting MAMI polarized target and polarised photon beam in 2nd half of 2007

Recent preliminary results from JLab (g8b)

• Proton target
• Back to back charge particles in Start Counter
• Atomic or hardonic?
• Asymmetry from ~20mins DAQ data
• Constant with E from 1.3GeV – 1.9GeV