Conversion Decays of Light Mesons

Susan Schadmand, IKP

talk at Baryons 2016
May 16-20, 2016, Florida State U
Reactions of hadrons with (virtual) photons

Why is it interesting?

- **explore intrinsic structure of hadrons**
  - form factors
  - to which extent does **vector meson dominance** hold?
- **background for physics beyond standard model**

- **rare pion decay** \( \pi^0 \rightarrow e^+ e^- \)

- **\( g - 2 \) of muon**
Dalitz (conversion) decays of mesons

\[ \frac{d\Gamma(A \rightarrow B \ell^+ \ell^-)}{dq^2} \cdot \frac{\alpha}{3\pi} \left[ 1 - \frac{4m_{\ell}^2}{q^2} \right]^{1/2} \left[ 1 + 2 \frac{m_{\ell}^2}{q^2} \right] \frac{1}{q^2} \times \left[ \left( 1 + \frac{q^2}{m_A^2 - m_B^2} \right)^2 - \frac{4m_A^2 q^2}{(m_A^2 - m_B^2)^2} \right]^{3/2} \left| \frac{F_{AB}(q^2)}{F_{AB}(0)} \right|^2 = |\text{QED}| \cdot \left| \frac{F_{AB}(q^2)}{F_{AB}(0)} \right|^2 \]

procedure: divide experimental \( q^2 \) distribution by QED

\[ F_{AB}(q^2) = 1 + q^2 \left[ \frac{dF_{AB}}{dq^2} \right]_{q^2=0} = 1 + q^2 b_{AB} = 1 + \frac{q^2}{6} r_{AB}^2 \]

slope parameter
b~ \( 1/m(\rho) \)
(1.7 GeV\(^{-2}\)) 'standard VMD'

1 - \( F=1 \) (QED)
2 - \( |F(q^2)| > 1 \) (VMD)
3 - \( |F(q^2)| < 1 \)

affects branching ratio

17 May 2016

Baryons 2016
(old) world data set: conversion decays

L.G. Landsberg, Electromagnetic decays of light mesons
IHEP in 1978—1980 on the “Lepton-G” spectrometer

for \( \omega \) meson, clearly additional mechanisms
apart from standard VMD
(black curves are fits to the data)

- confirmed by NA60 AA reactions, S. Damjanovic, PLB 677 (2009) 260

different experimental approach: elementary reactions, using di-electrons
new data sets: $\eta$ and $\eta'$

NA60 PLB (2016) in print

$\eta \rightarrow \gamma e e$

$|F_{\eta}|^2$

$\eta' \rightarrow \gamma e e$

$\operatorname{BR} (\eta' \rightarrow \omega e e) = (1.97 \pm 0.34 \text{(stat)} \pm 0.17 \text{(syst)}) \times 10^{-4}$
new data sets: $\omega$ and $\Phi$

**NA60 PLB (2016) in print**

- $\omega \rightarrow \pi ee$

**KLOE2 PLB (2015) 1**

- $\phi \rightarrow \eta ee$

**KLOE-2 PLB (2016) in print**

- $\phi \rightarrow \pi ee$

puzzle not solved yet
a tale of two experiments

<table>
<thead>
<tr>
<th>CLAS Jefferson Lab</th>
<th>experimental issue</th>
<th>WASA COSY-Jülich</th>
</tr>
</thead>
</table>
| γ + p (g12 experiment) | • cross section  
• multipion background | p + p (2010)               |
| LH₂ target         | external γ conversion               | pellet target + beam pipe |
| Cerenkov Counters  | dilepton identification             |                           |
| EM calorimeter     | photon detection                    | CsI EM Colrimeter         |

17 May 2016
Baryons 2016
meson production from the proton

\[ E_{cm} \text{ (GeV)} \]

\[ \sigma \text{ (mb)} \]

\[ \gamma + p \text{ total} \]

\[ E_{cm} - M_p \text{ (GeV)} \]

\[ E_{cm} - 2M_p \text{ (GeV)} \]

\[ \gamma p \text{ reactions:} \]
- in second resonance region, \( \sigma(\eta) > \sigma(\pi^0\pi^0) \)

\[ pp \text{ reactions:} \]
- either or both protons can be excited
- multi pion background

17 May 2016
Baryons 2016
η'→γee : cut-based analysis

- CLAS g12 experiment
- data analysis: g12 procedures
- q-factor signal extraction: 
  evaluate smooth background facet-by-event

- 359 event candidates
- 82 events (signal weight)

not competitive
more statistics with CLAS12 experiments
towards the $\omega-\pi$ transition form factor

kinematic fit for CLAS g12 dileptons

analysis strategy:
e+e- detection and missing particle

missing pion:
- missing mass is pion mass
- missing energy

missing photon:
- missing mass zero
- missing energy

missing nothing:
- missing mass and energy zero

$\omega \rightarrow \pi ee$

$\eta(\prime) \rightarrow \gamma ee$

$\rho/\omega \rightarrow ee$
Towards the $\omega - \pi$ transition form factor

- smooth background
- in-peak background: competing decays photon external conversion
- peaking background?

not background subtracted
not acceptance corrected

dilepton mass

clearly dominated by background
small masses: external conversion

next step: background study

17 May 2016
cut-based analysis: $\eta \rightarrow \gamma e^+e^-$

- Number of $\eta \rightarrow \gamma e^+e^-$: $43946.8 \pm 281.194$

WASA-at-COSY 2010 1.4 GeV pp run

- usual method: multipion phase space * polynomial fit to background (excluding peak)
- **background subtraction method good for dilepton analysis?**

Ankita Goswami
cut-based analysis: $\eta \rightarrow \gamma e e$

background study

- direct (not from $\eta$ decays)
- competing decays
- mostly phase space simulations (for now)
- for WASA, has to include charged pion pairs
- seen even better in invariant mass of decay particles
- needs improvement
- helps with sys errors

very promising and high statistics
reaching for the double Dalitz decay

- WASA-at-COSY standard analysis
- preliminary and not acceptance corrected.
- **consistency-check**: yield consistent with our preliminary single Dalitz decay analysis

**goal**: evaluate branching ratio

latest WASA result: nucl-ex/1509.06588

$$\text{BR} = (3.2 \pm 0.9_{\text{stat}} \pm 0.5_{\text{sys}}) \times 10^{-5}$$
Summary

chasing conversion decays of light mesons

• WASA-at-COSY:
  • $\eta$ meson decays

• CLAS g12 experiment
  • $\eta$ and $\omega$ decays

• CLAS12 campaigns:
  • $\eta'$ and $\Phi$ decays?

tough competition

physics landscape needs the results