yy - Physics at BES-III

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MesonNet Meeting 2013, Prague
Introduction

- Electromagnetic transition form factors
  - interaction of pseudoscalar mesons and two (virtual) photons
  - information on meson structure
  - input to calculations for $a_\mu = \frac{1}{2}(g_\mu - 2)$
    - completely limited by hadronic contributions!

- Hadronic Light-by-Light Scattering:
  - Perturbative methods not applicable
  - Transition Form Factors needed as input
    ➔ High precision measurements necessary
The BES-III Detector at BEPC-II

**BEPC-2**
- e+e- collider
- $2.0 \leq \sqrt{s} \leq 4.6$

**Collected Data**
- $1.2 \times 10^9 \ J/\Psi$
- $0.5 \times 10^9 \ \Psi'$
- $2.9 \text{ fb}^{-1} \ \Psi''$
- $5 \text{ pb}^{-1} \ \tau$-scan
- $0.5 \text{ fb}^{-1} @ 4.01 \text{ GeV}$
- $2.8 \text{ fb}^{-1} @ 4.23 / 4.26 / 4.36 \text{ GeV} + \text{scan}$

**Detector Features**
- 1T Magnetic Field
- MDC
  - $\sigma(p)/p = 0.58\%$
  - $\sigma(E)/E = 6.0\%$
- TOF
  - $\sigma(t) = 100\text{ps}$
- EMC
  - $\sigma(E)/E = 2.5\%$
- Muon Chambers
  - $p > 400 \text{ MeV/c}$

**BES-III Detector Overview**
- Magnet yoke
- SC magnet
- TOF
- Be beam pipe
- MDC
- CsI calorimeter
Measurement Strategy

Meson Production in Two-Photon Collisions

- Space-like Transition Form Factors
- \( F(Q_1^2, Q_2^2), \ Q_i^2 \equiv -q_i^2 \)

Single Tag Technique

Measure only

- One scattered lepton
- Decay products of meson

Reconstruct second lepton from 4-momentum conservation

- Require small scattering angle
  
  Small \( Q^2 \)

\[
|F(Q_1^2, Q_2^2)|^2 \rightarrow |F(Q_1^2, 0)|^2 \rightarrow |F(Q^2)|^2
\]
Feasibility Studies

- **Ekhara 2.1**
  - Double-Octet model
  - $\sqrt{s} = 3.773$ GeV
  - $L_{\text{int}} = 10$ fb$^{-1}$
  - Only detector geometry

**Result:**
- TFF measurable up to $Q^2 = 10$ GeV$^2$
- Unprecedented accuracy below 4 GeV$^2$
- Above 4 GeV$^2$ accuracy comparable to CLEO

BSc Theses: A. Hahn, B. Kloss
Data Analysis

- Currently Available Data
  - 2.9 fb$^{-1}$ @ $\Psi(3770)$
  - 1 fb$^{-1}$ @ 4.23 GeV
  - 0.8 fb$^{-1}$ @ 4.26 GeV
  - 0.5 fb$^{-1}$ @ 4.36 GeV

- Analysis Example: $e^+e^- \rightarrow e^+e^- \pi^0$
  - $\geq$ 2 good photons
  - $\chi^2$ test to find best $\pi^0$
  - 1 charged track
  - PCA with $R_{xy} \leq 1$ cm, $R_z \leq 10$ cm
  - PID with $E_{cal}/P_{MDC}$ ratio $> 0.8$
Background Channels

- Radiative Bhabha Scattering
- Other QED Background
- Hadronic Final States
- External Photon Conversion
- Two-Photon Events with ISR
- Two-Photon Production of other mesons

\[ \{ \text{Babayaga@NLO} \} \]

\[ \{ \text{BesTwogam} \} \]
Background Rejection

- Reconstruct untagged lepton
- 4-Momentum conservation
- Reject events with $|\cos(\theta_e)| > 0.99$

- Helicity angle of $\pi^0$
- $\angle(\gamma_{\pi^0}, \pi^0_{Lab})$
- Reject events with $\cos(\theta_H) > 0.8$
Background Rejection

- Reject events with $R_\gamma < -0.1$ and $R_\gamma > 0.2$
- Polar angle difference of photons
  - Reject events with $|\Delta \theta_{\gamma\gamma}| < 3^\circ$
Background Rejection

- Polar angle of $\pi^0$ in CMS
- Reject events with $\cos(\theta_\pi) > 0.8$
Current Status of $\pi^0$ TFF measurement

- 20% background contamination
- Bin-wise background subtraction
- Agreement of data and MC

To Do List:
- Cut optimization
- Detailed background Studies
- Efficiency and Systematics
Summary

- Significant contribution from BES-III to TFF measurements
  - From 0.3 GeV$^2$ up to 10 GeV$^2$
  - Unprecedented accuracy up to 4 GeV$^2$
  - Cross check with CELLO, CLEO, BaBar and BELLE

- Analyses of $\pi^0$, $\eta$, $\eta'$ are being performed in Mainz
  - Good agreement of data, MC, and prev. measurements for $\pi^0$ achieved
  - Detailed background studies needed
  - First results to be expected soon

- Long term plan:
  - Measurement of scalar and tensor meson production
  - Measurement of polarization observables
  - Double tagged measurements
Backup
Previous Measurements

- Measurements for $\pi^0$, $\eta$, $\eta'$ by CELLO, CLEO, BaBar, and Belle
- Disagreement between BaBar and Belle measurement for $\pi^0$
- Data scarce at low $Q^2$

Monte Carlo Generator

Ekhara 2.1

- Exclusive generator for two-photon production of $\pi^0$, $\eta$, $\eta'$, $\pi^+\pi^-$
- Provides several TFF descriptions
- Double Octet model in good agreement with measurements