



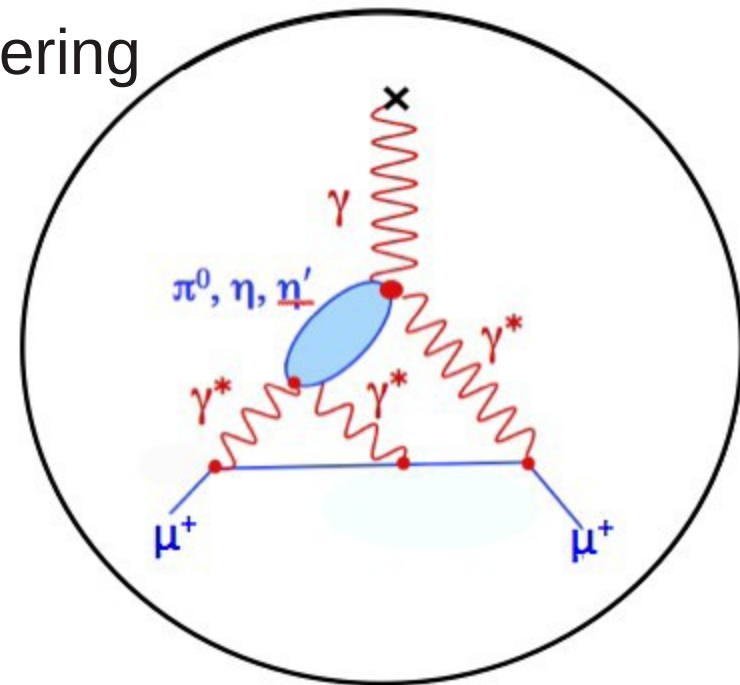
$\gamma\gamma$ - Physics at BES-3

11. April 2013 | Christoph Florian Redmer

13th Meeting of the Working Group on Radiative Corrections and Generators
for Low Energy Hadronic Cross Section and Luminosity

Motivation

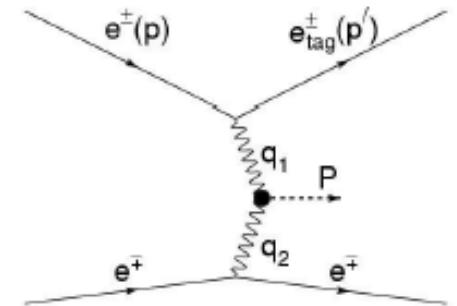
- Electromagnetic Meson Transition Form Factors (TFF)
 - Meson structure
- Anomalous magnetic moment $a_\mu = \frac{1}{2}(g_\mu - 2)$
 - 3.6 σ discrepancy between experiment and theory
 - largest uncertainty from hadronic contribution
 - Input for Light-by-Light scattering



How to Measure TFF's

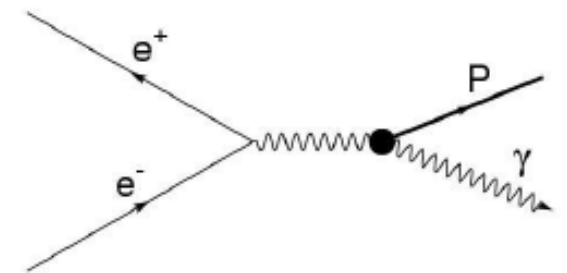
➤ Two-photon production of the meson

- $-S+M^2 < q_1^2 < 0, q_2^2 \approx 0, Q^2 \equiv -q_1^2$
- $d\sigma/dQ^2$ falls as $1/Q^6$



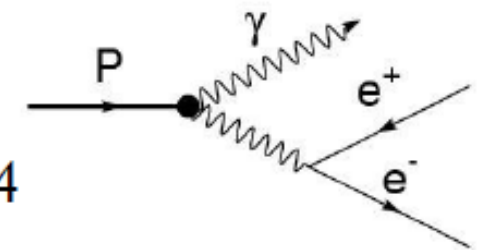
➤ Annihilation process $e^+e^- \rightarrow P\gamma$

- $Q^2 = S > M^2$
- $\sigma \propto 1/S^2$



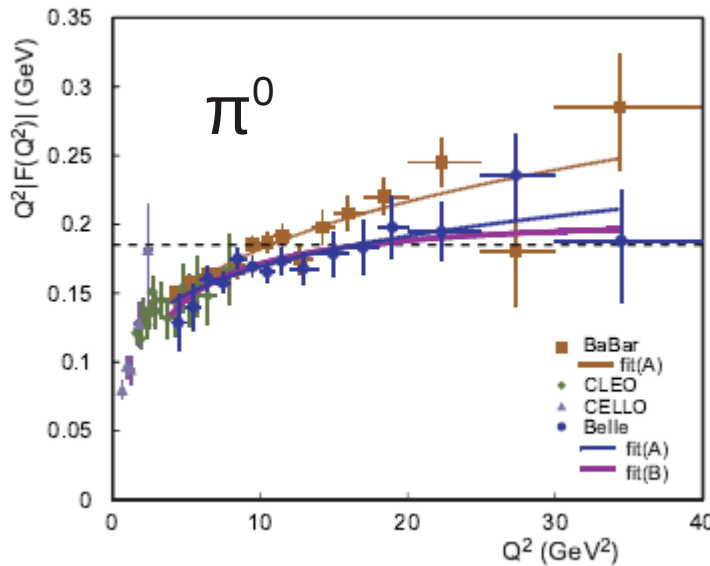
➤ Dalitz decay $P \rightarrow \gamma e^+e^-$

- $0 < Q^2 < M^2$
- $M^2 d\Gamma/dQ^2 \approx (2\alpha/\pi)\Gamma(P \rightarrow \gamma\gamma)$ at $Q^2/M^2 \approx 1/4$

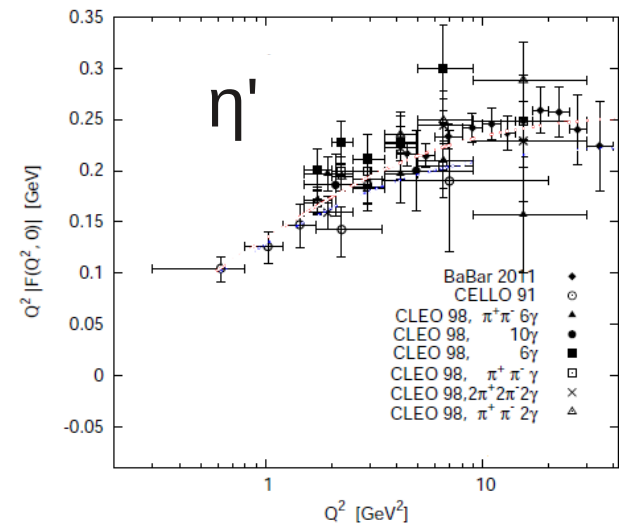
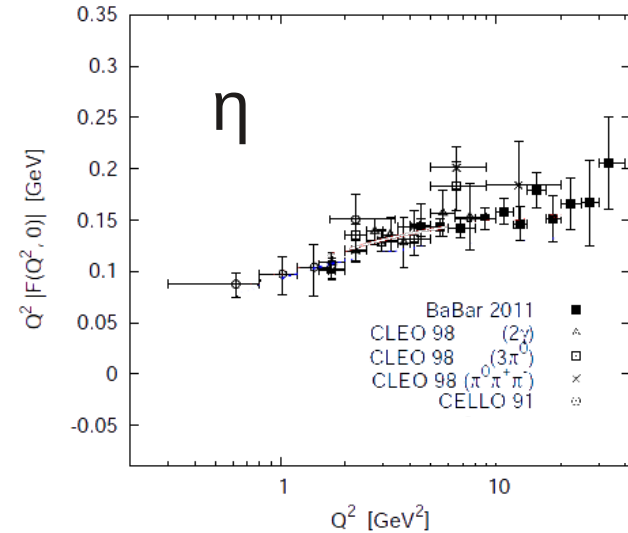


Previous Measurements

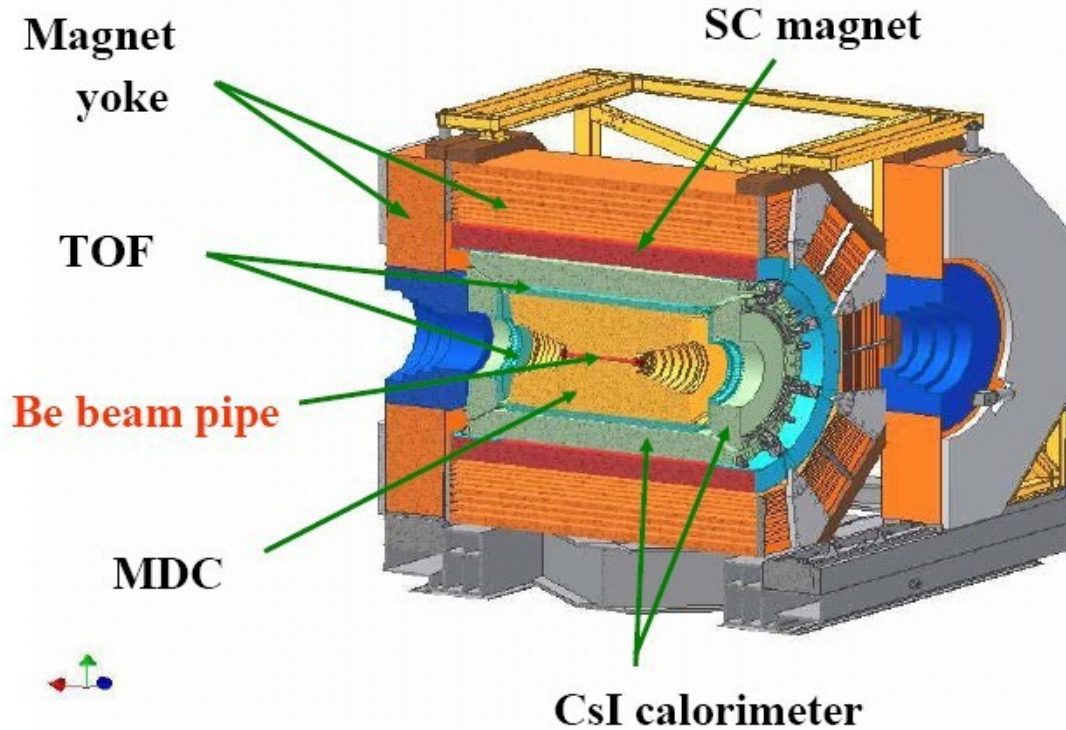
- Measurements for π^0 , η , η' by CELLO, CLEO, BaBar, and Belle
- Disagreement between BaBar and Belle measurement for π^0
- Data scarce at low Q^2



BaBar: Phys.Rev.D80 (2009) 052002
 Belle: Phys.Rev.D86 (2012) 092007



The BES-3 Detector at BEPC-2



- 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
 - $p > 400 \text{ MeV}/c$

BEPC-2

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

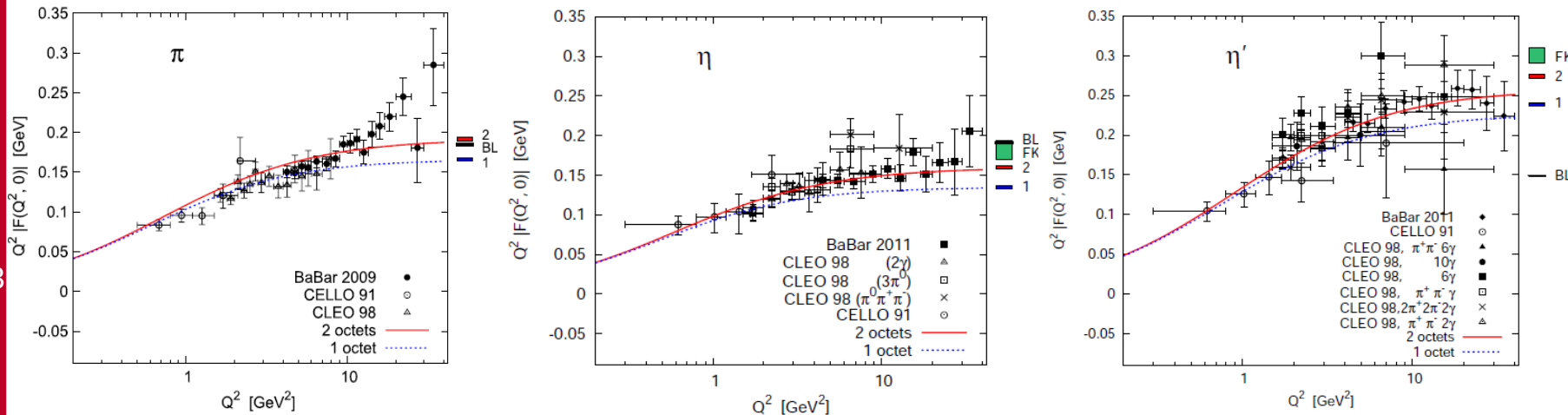
Collected Data

- $1.2 \cdot 10^9 \text{ J}/\Psi$
- $0.5 \cdot 10^9 \Psi'$
- $2.9 \text{ fb}^{-1} \Psi''$
- $5 \text{ pb}^{-1} \tau\text{-scan}$
- $0.5 \text{ fb}^{-1} @ 4.01 \text{ GeV}$
- $515 \text{ pb}^{-1} @ 4.26 \text{ GeV}$

Ekhara 2.1

- Double octet model
- Good agreement with previous measurements
- Cross sections calculated

- To be implemented in BES analysis framework



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Physics at BES-3

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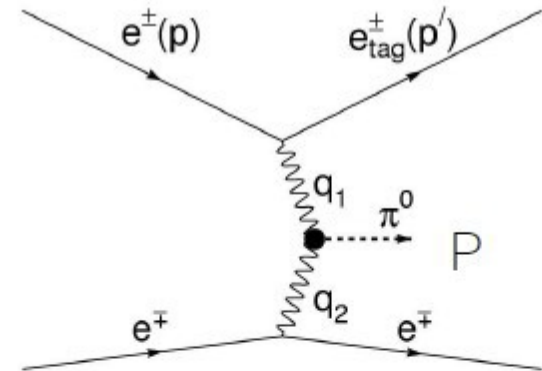
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Analysis Strategy

Single Tag Technique

Measure only

- One scattered lepton
- Decay products of meson

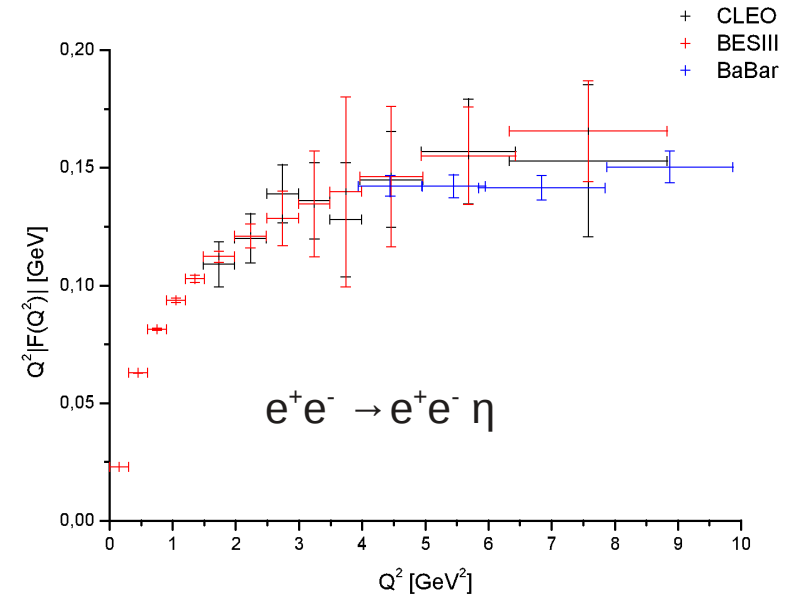
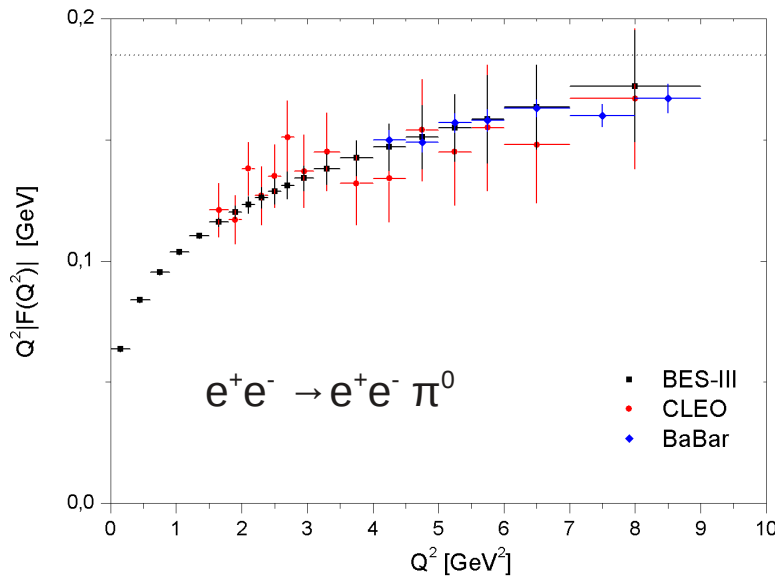


Reconstruct second lepton from 4-momentum conservation

- Require small scattering angle
 —————> Small Q^2

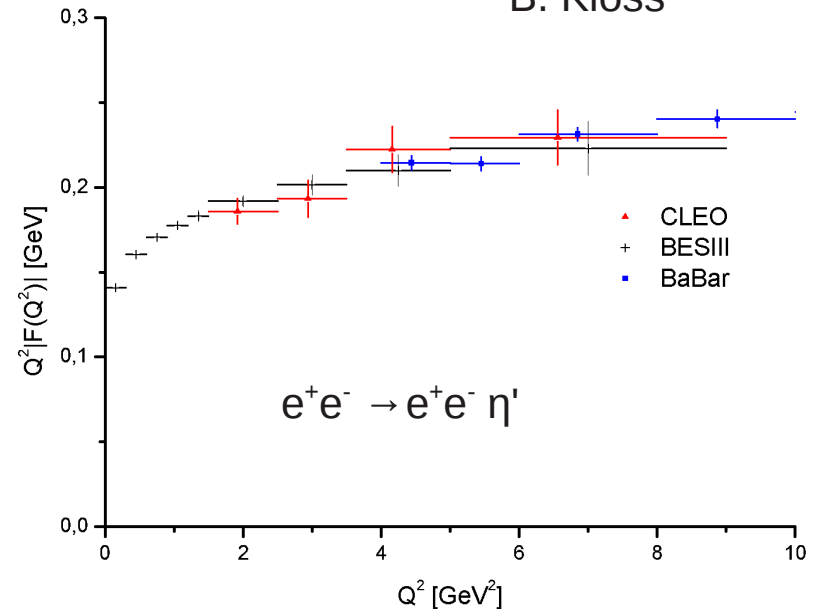
$$|F(Q_1^2, Q_2^2)|^2 \longrightarrow |F(Q_1^2, 0)|^2 \longrightarrow |F(Q^2)|^2$$

Feasibility Studies



- $\sqrt{s} = 3.773 \text{ GeV}$
- $L_{\text{int}} = 10 \text{ fb}^{-1}$ (long term goal)
- Only detector geometry

BSc Theses: A. Hahn,
B. Kloss



- TFF up to $Q^2 = 10 \text{ GeV}^2$
- statistical precision comparable to CLEO
- First measurement below 1.5 GeV^2

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γγ Physics at BES-3

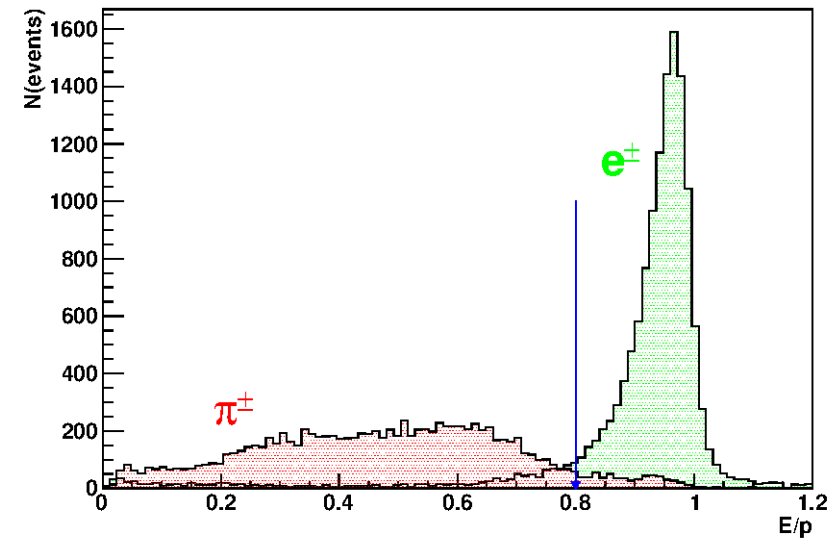
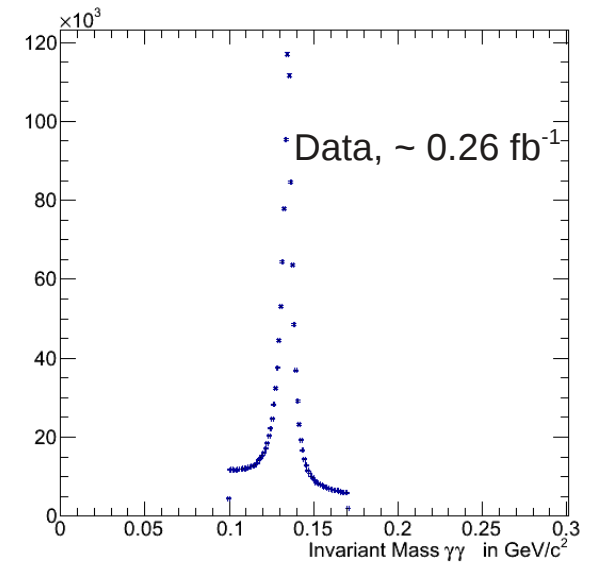
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Analysis Example: π^0

Basic event selection

- ≥ 2 good photons
- χ^2 test to find best π^0 , $\chi^2 < 50$
- ≥ 1 positively charged track
- PCA with $R_{xy} \leq 1$ cm, $R_z \leq 10$ cm
- PID with E_{cal} / P_{MDC} ratio > 0.8



Currently:

- Only events with exactly one positron candidate

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

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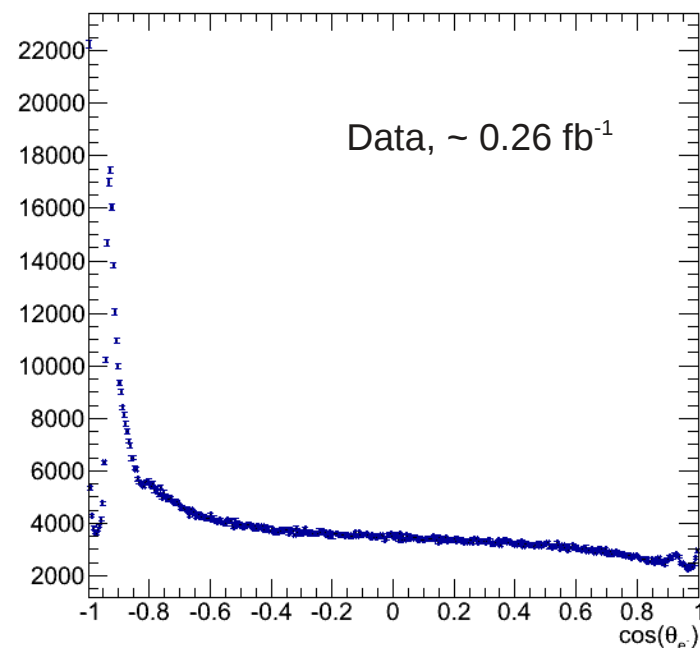
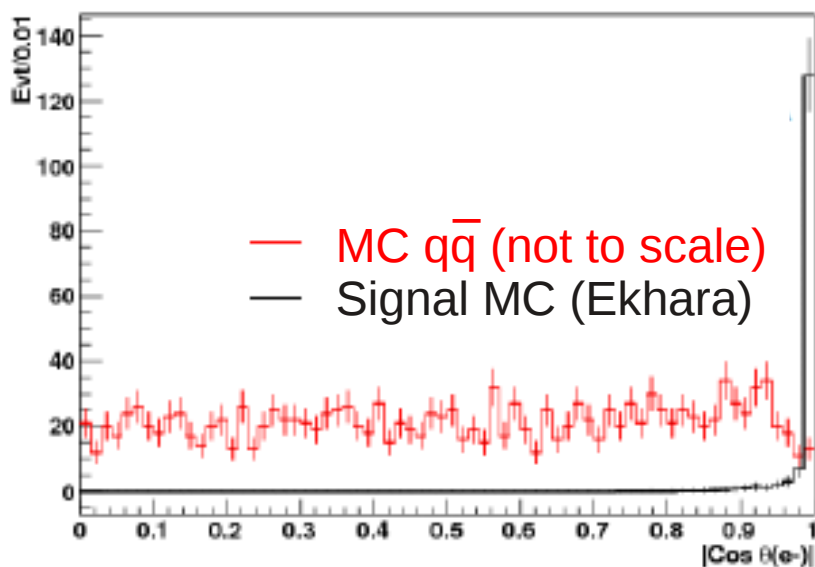
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Single Tag Condition

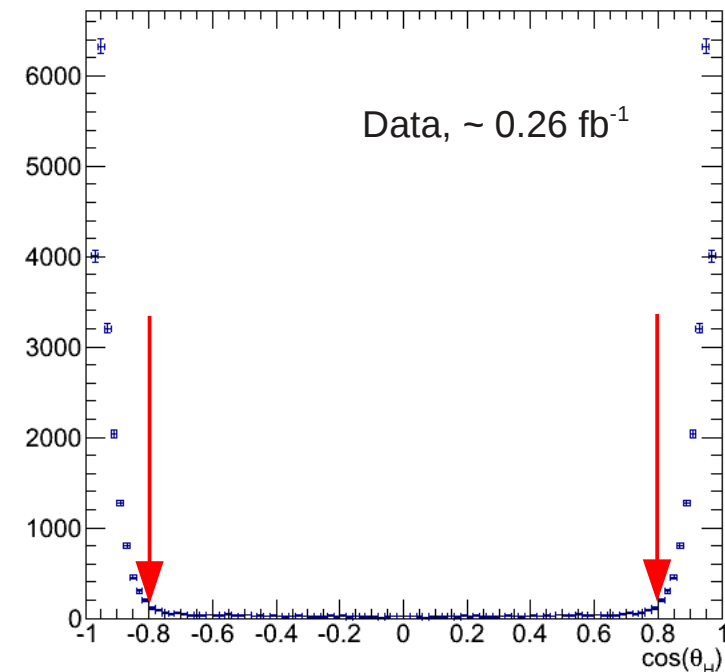
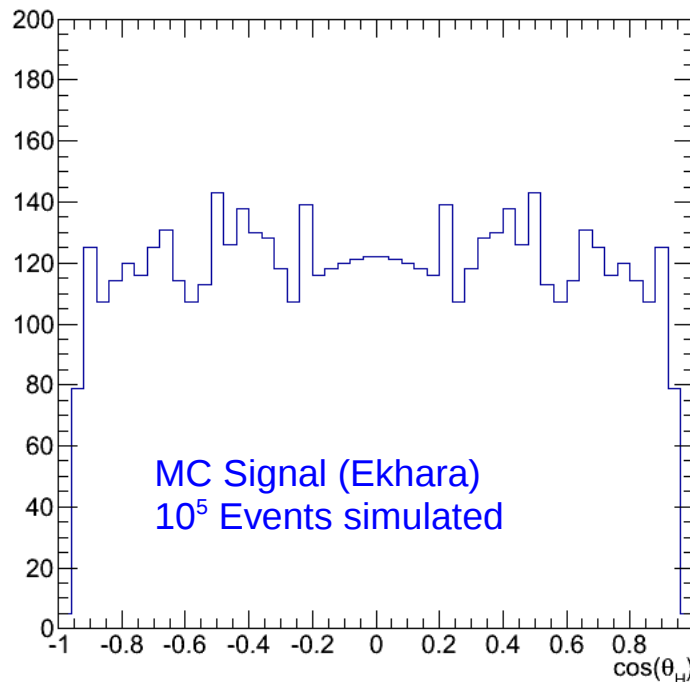
- Reconstruct untagged lepton
 - 4-Momentum conservation
- Reject events with $\cos(\theta) > -0.99$



- Major part of background removed

Helicity Angle π^0

- Angle θ_H between γ in the π^0 rest frame and the π^0 in the lab. frame
- Flat distribution for signal events expected from MC
- Background peaked at large absolute values of $\cos(\theta_H)$

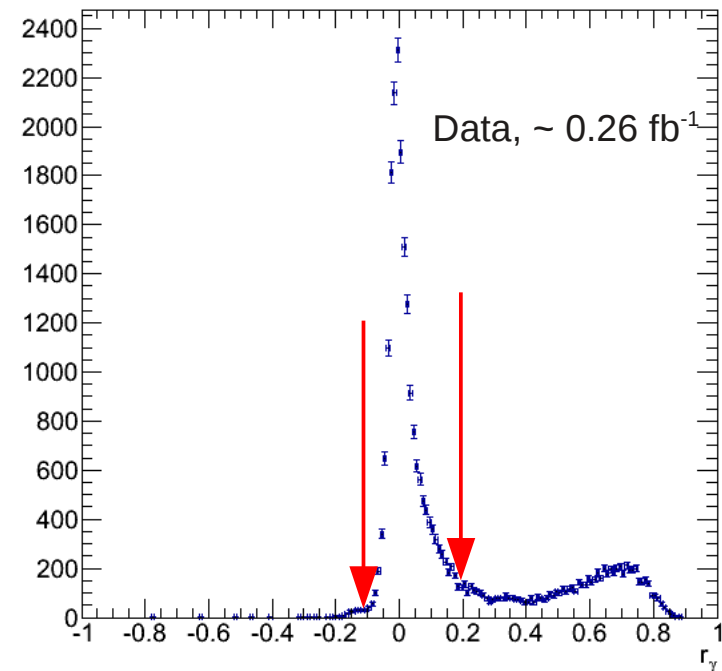
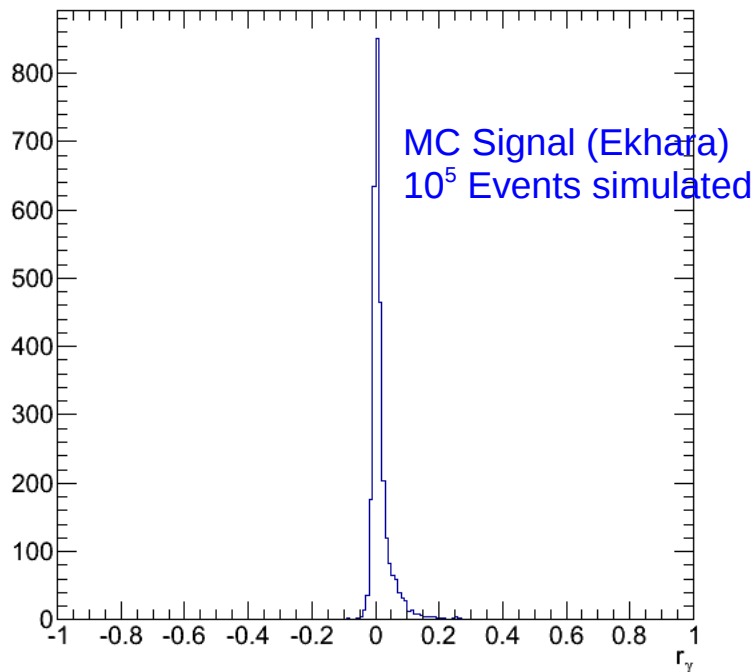
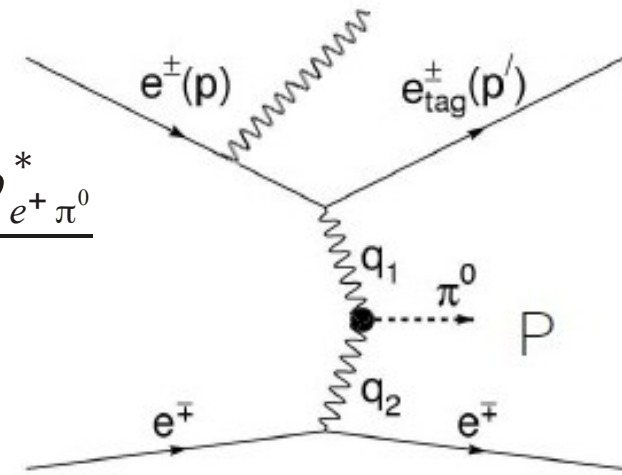


ISR Events

- ISR results in wrong Q^2

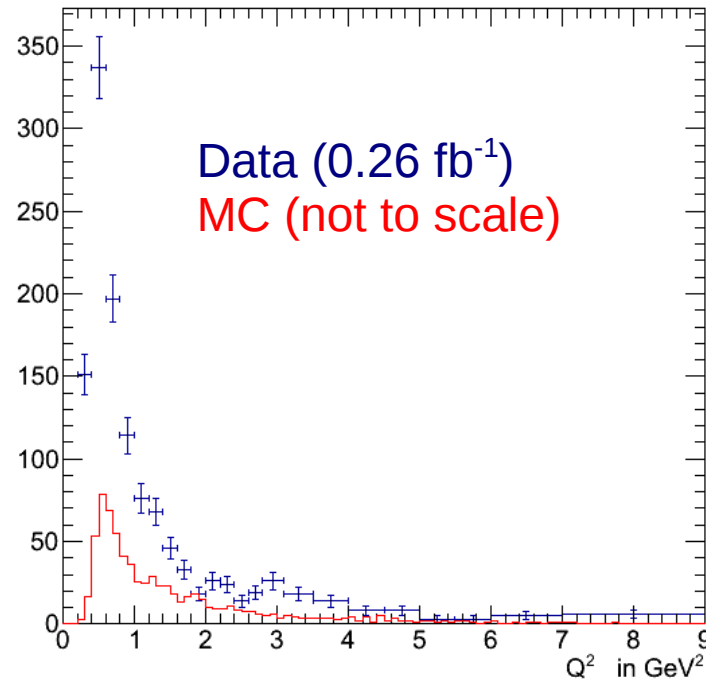
- Useful observable:
$$r = \frac{\sqrt{s} - E_{e^+\pi^0}^* - p_{e^+\pi^0}^*}{\sqrt{s}}$$

- If ISR,
$$r = r_\gamma = \frac{2 E_\gamma}{\sqrt{s}}$$



Status Summary

- Analysis chain developed



- Cuts need optimization
- More detailed background studies needed
- TFF to be extracted

Status of TFF measurements at BES-3

- $e^+e^- \rightarrow e^+e^- \pi^0$

- Detailed studies of data and Monte Carlo

E. Prencipe*,
CFR

- $e^+e^- \rightarrow e^+e^- \eta$

- Detailed Monte Carlo studies
- First tests on data

E. Prencipe*,
R. Bormuth*

- $e^+e^- \rightarrow e^+e^- \eta'$

- First Monte Carlo studies

M. Diefenbach

C.F. Redmer

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Summary

- Significant contribution from BES-3 to TFF measurements
 - Up to 10 GeV^2
 - First measurements below 1.5 GeV^2
 - Cross check with CLEO and BaBar results
- Analyses of π^0 , η , η' are being performed in Mainz
- First results to be expected soon
- Long term plan:
 - Measurement of two PS meson production