Impact of the “untagged” invariant on the single-tag $e^+e^- \to e^+e^-\mathcal{P}$ cross-section (arXiv:1202.1171 + . . .)

Sergiy IVASHYN[1] Henryk CZYŻ[2]

1 Akhiezer Institute for Theoretical Physics
NSC “KIPT”, Kharkiv, Ukraine
2 Chełkowski Institute of Physics
University of Silesia, Katowice, Poland

April 17, 2012

Structure of this talk

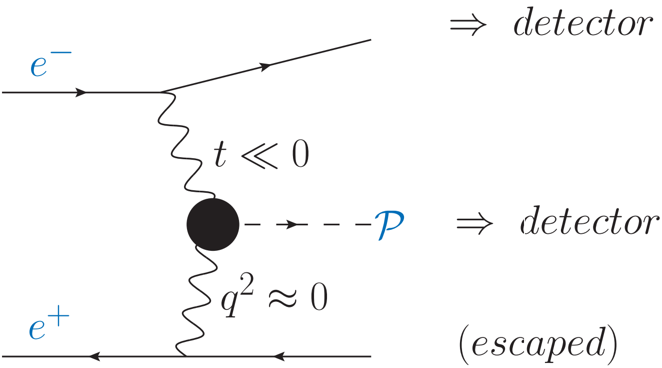
1. A few words about “single-tag” experiments
2. Is it in fact the $F(Q^2, 0)$ that is measured?
3. Can one measure $F(Q^2, q^2)$?

1. A few words about “single-tag” experiments

2. Is it in fact the $F(Q^2, 0)$ that is measured?

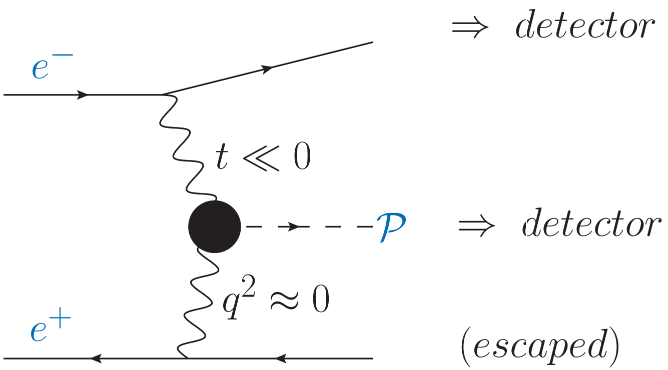
3. Can one measure $F(Q^2, q^2)$?

Single-tag $e^+e^- \to e^+e^-\mathcal{P}$



The first invariant, $Q^2 = -t$, is associated with the detected lepton

Single-tag $e^+e^- \to e^+e^-\mathcal{P}$



The second invariant, q^2, is associated with the missing lepton and can be constrained by the event selection

The BaBar's π^0 case

B. AUBERT *et al.* PHYSICAL REVIEW D **80**, 052002 (2009)

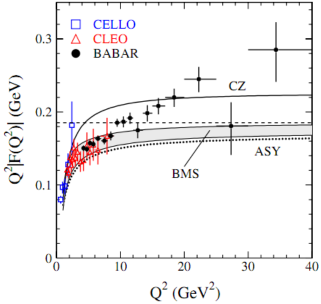


FIG. 23 (color online). The $\gamma\gamma^* \to \pi^0$ transition form factor multiplied by Q^2. The dashed line indicates the asymptotic limit for the form factor. The solid and dotted lines show the predictions for the form factor [8] for the CZ [26] and asymptotic (ASY) [27] models for the pion distribution amplitude, respectively. The shaded band represents the prediction for the BMS [28] pion DA model.

✓ Data/theory discrepancy

⇒ Tons of debates…

1 A few words about “single-tag” experiments

2 Is it in fact the $F(Q^2, 0)$ that is measured?

3 Can one measure $F(Q^2, q^2)$?

Discussion within Vector meson dominance

Peter Lichard PHYSICAL REVIEW D **83**, 037503 (2011)

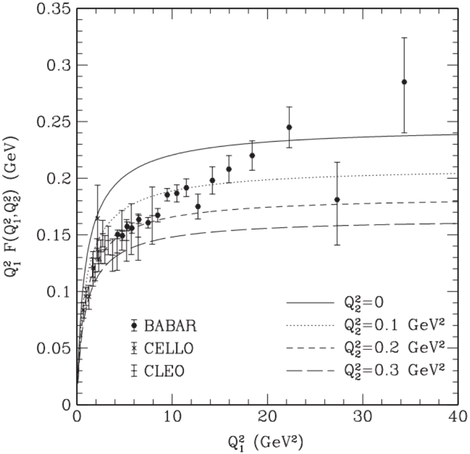


FIG. 3. Dependence of $Q_1^2 F(Q_1^2, Q_2^2)$ on Q_1^2 for four fixed values of Q_2^2 calculated in the full version of our model. The CELLO [10], CLEO [9], and *BABAR* [1] data are also shown.

Is it in fact $F(Q^2, 0)$ that is measured?

Discussion within Light-cone sum rules

N. G. Stefanis,[1,†] A. P. Bakulev,[2,‡] S. V. Mikhailov,[2,§]
and A. V. Pimikov[2,3,¶]

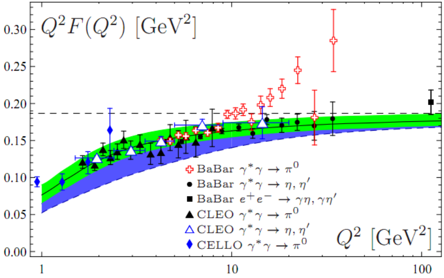


Figure 2: (color online). Theoretical predictions for the scaled $\gamma^*\gamma\pi^0$ transition form factor in comparison with data taken from various experiments, as indicated, using the theoretical framework described in the text. The upper (green) strip shows the results obtained in [5] using the method described in the text. The lower (blue) strip represents the influence of the small virtuality of the quasi-real photon induced by the untagged electron.

Is it in fact $F(Q^2, 0)$ that is measured?

The form factor and the cross section

$$d\,\sigma_{avg}(e^+e^- \to e^+e^-\pi^0) \;=\; \frac{1}{4}\frac{1}{2s} d\,Lips_3 \sum |\mathcal{M}|^2$$

$$\mathcal{M} \;=\; -\frac{4\,i\alpha^2}{f_\pi} F(t_1, t_2)\,\epsilon_{\mu\nu\alpha\beta}\,\frac{1}{t_1\;t_2}\,(q_1-p_1)^\alpha\,(q_2-p_2)^\beta \times (\bar{v}(p_1)\,\gamma^\mu\,v(q_1))\;(\bar{u}(q_2)\,\gamma^\nu\,u(p_2))$$

- The factor $1/t_2$ strongly suppresses the impact of the t_2-dependence of $F(t_1, t_2)$ on the cross section

Measured quantity

$d\,\sigma_{avg}$ integrated within (quite complicated) cuts

The BaBar's comment on the uncertainty

B. AUBERT *et al.* PHYSICAL REVIEW D **80,** 052002 (2009)

$$F^2(Q^2) = \frac{(d\sigma/dQ^2)_{\rm data}}{(d\sigma/dQ^2)_{\rm MC}} F^2_{\rm MC}. \qquad (8)$$

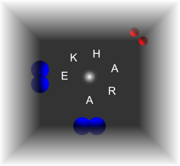
The calculated cross section $(d\sigma/dQ^2)_{\rm MC}$ has a model-dependent uncertainty due to the unknown dependence on the momentum transfer to the untagged electron. We use a q_2^2-independent form factor, which corresponds to the QCD-inspired model $F(q_1^2, q_2^2) \propto 1/(q_1^2 + q_2^2) \approx 1/q_1^2$ [23]. Using the vector dominance model with the form factor $F(q_2^2) \propto 1/(1 - q_2^2/m_\rho^2)$, where m_ρ is ρ meson mass, leads to a decrease of the cross section by 3.5%. This difference is considered to be an estimate of model uncertainty due to the unknown q_2^2 dependence. However, it should be noted that this estimate depends strongly on the limit on q_2^2. The value of 3.5% is obtained with $|q_2^2| < 0.18\ \mathrm{GeV}^2$. For a less stringent q_2^2 constraint, for example $|q_2^2| < 0.6\ \mathrm{GeV}^2$, the difference between the calculated cross sections reaches 7.5%.

- $\Rightarrow$ Yes, it *is indeed* the $F(Q^2, 0)$
- ✓ The related uncertainty *was* estimated
- $\Rightarrow$ Thus, the fuss about nothing?

- We performed a simulation of model-dependent and q^2-dependent effects in the cross section

  (for details see `arXiv:1202.1171`)

EKHARA 2.1



H. Czyż, S. Ivashyn,
Comp.Phys.Comm., 182, 1338 (2011)

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

$e^+e^- \to e^+e^- \eta$

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

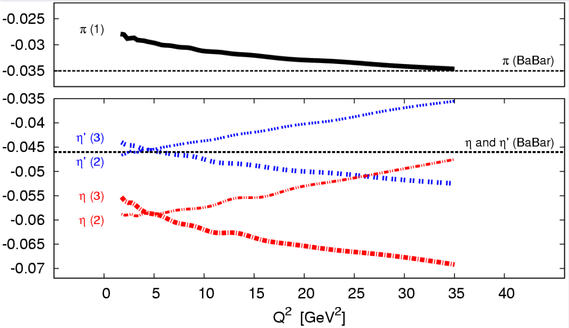
NEW “realistic” form factors

H. Czyż, S. Ivashyn,
A. Korchin, O. Shekhovtsova
arXiv:1202.1171, to appear in Phys.Rev.D

http://prac.us.edu.pl/%7Eekhara

The relative difference of the cross sections

$(d\sigma[full] - d\sigma[approx])/d\sigma[full]$

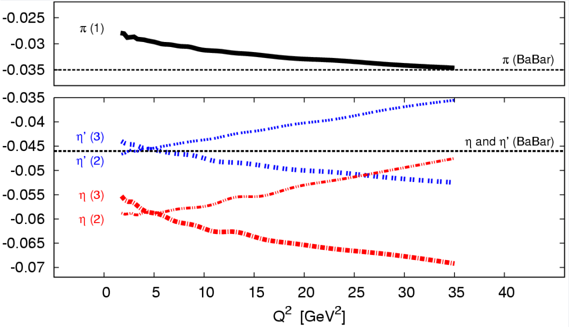


$\Leftarrow$ how good is the approximation $F(Q^2, q^2) \approx F(Q^2, 0)$

- $d\sigma[approx]$: $F(Q^2, q^2) \approx F(Q^2, 0)$
- $d\sigma[full]$ accounts for full $F(Q^2, q^2)$

The relative difference of the cross sections

$(d\sigma[full] - d\sigma[approx])/d\sigma[full]$



$\Leftarrow$ how good is the approximation $F(Q^2, q^2) \approx F(Q^2, 0)$

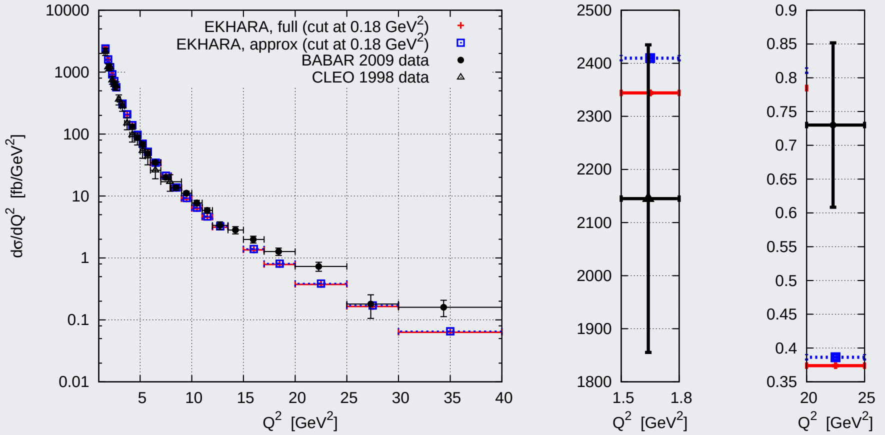
Cuts :

(1) $|q_2^2| < 0.18$ GeV^2

(2) $|\cos\theta^*_{e\mathcal{P}}| > 0.99$ and $|q_2^2| < 0.6$ GeV^2

(3) $|q_2^2| < 0.38$ GeV^2

$\frac{d\sigma}{dQ^2}$: full, approximate and data



Cuts: $|q_2^2| < 0.18 \text{ GeV}^2$

Our remarks (summary)

- The impact of the approximation $F(Q^2, q^2) \approx F(Q^2, 0)$ on the cross section was estimated and accounted for by BaBar
- our simulation of π^0 cross section leads to a similar estimate of uncertainty

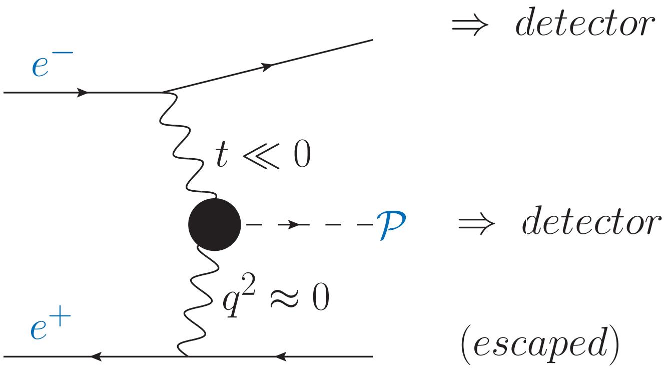
[for details see `arXiv:1202.1171`]

- The statistical error at BaBar was bigger than the above uncertainty

The issue of $F(Q^2, q^2) \approx F(Q^2, 0)$ is **not a reason** for the data/theory discrepancy

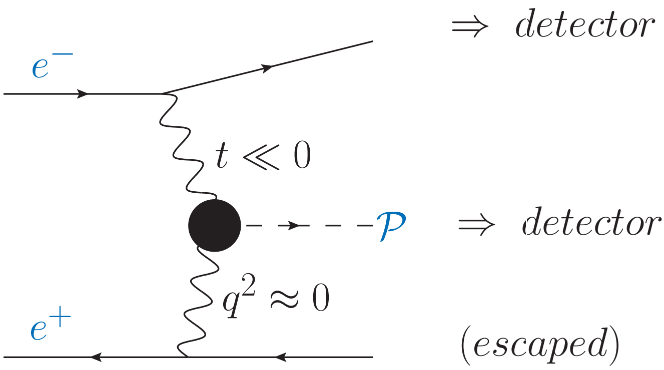
1. A few words about “single-tag” experiments
2. Is it in fact the $F(Q^2, 0)$ that is measured?
3. Can one measure $F(Q^2, q^2)$?

Single-tag $e^+e^- \to e^+e^-\mathcal{P}$



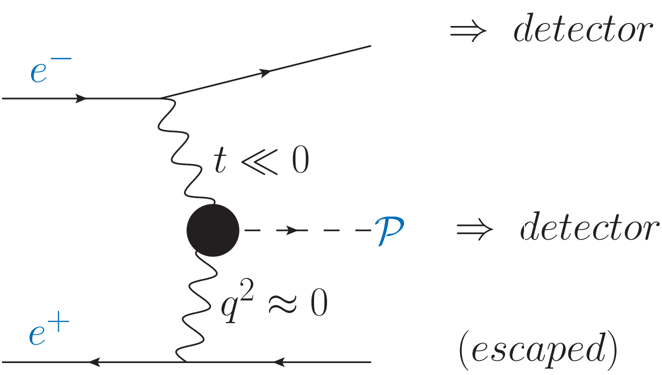
The second invariant, q^2, is associated with the missing lepton and can be constrained by the event selection

Single-tag $e^+e^- \to e^+e^-\mathcal{P}$



Let's vary the q^2 cut $\Rightarrow$ a couple of bins in q^2

Single-tag $e^+e^- \to e^+e^-\mathcal{P}$



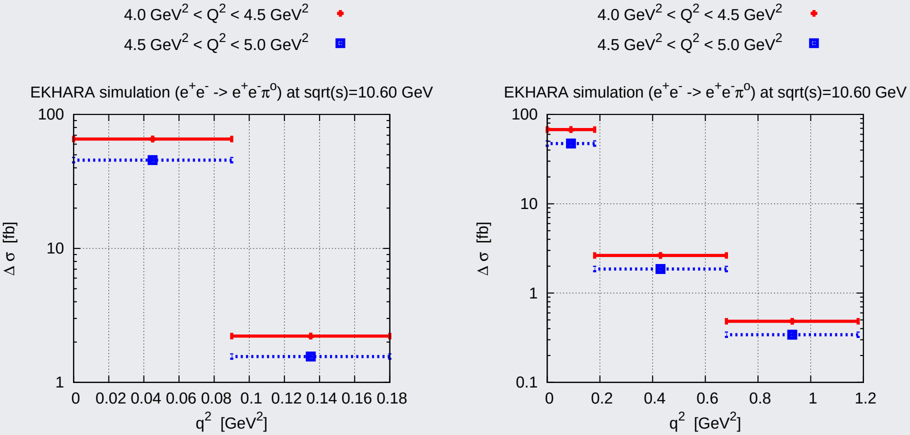
Let's vary the q^2 cut $\Rightarrow$ a couple of bins in q^2

- **How many events one could expect?**

- $d\sigma$ drops down rapidly with both Q^2 and q^2
- Q^2 is “scanned” by the detected lepton
  - the bulk of the events are in the first bins
  - $\Rightarrow$ gives the Q^2 range
- q^2 is cut by the the event selection (“missing lepton angle, etc.”)
  BaBar: $|q^2| < 0.18$ GeV^2 BES-III: [1] $|q^2| < 0.07$ GeV^2
  - let's have a couple of bins in q^2 around this cut
    $\Rightarrow$ “split” the existing cut
    $\Rightarrow$ “expand” the existing cut

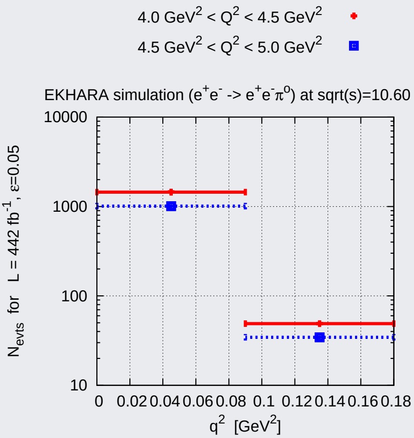
[1] Our guesstimate

BaBar energy. Integrated cross section

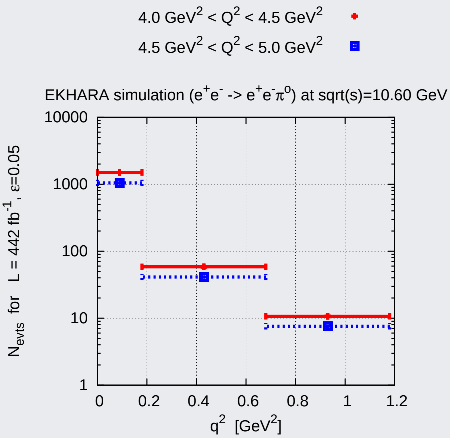


“split” “expand”

BaBar energy. Number of events

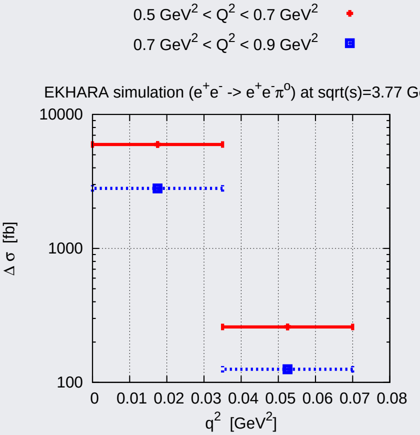


"split"

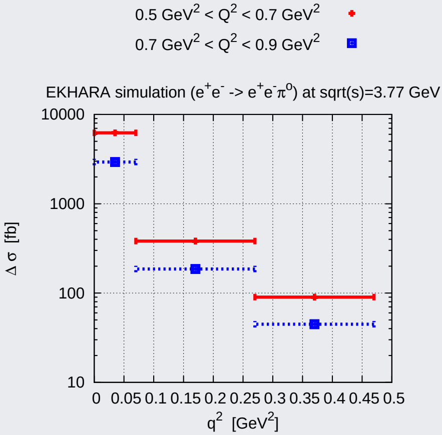


"expand"

BES-III energy. Integrated cross section

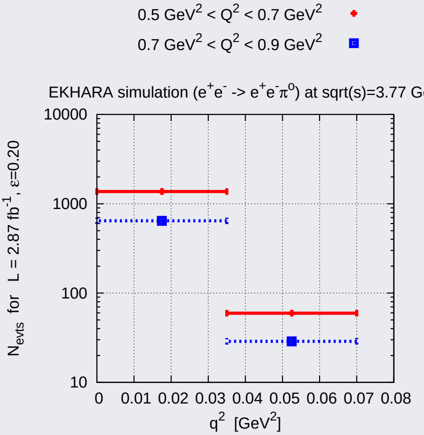


"split"

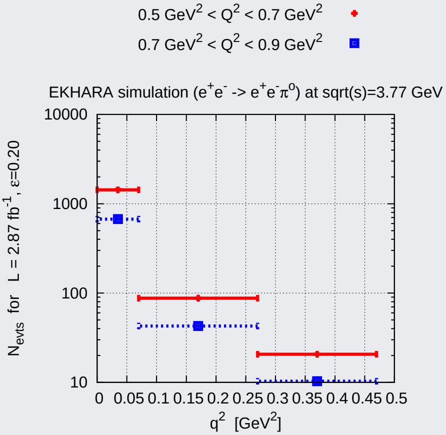


"expand"

BES-III energy. Number of events



"split"



"expand"

Can one measure $F(Q^2, q^2)$?

- Our simulation is simplified . . .

Can one measure $F(Q^2, q^2)$?

- Our simulation is simplified ...
- ...but it indicates a reasonable statistics with the already existing integrated luminosity at BaBar and BES-III...

Can one measure $F(Q^2, q^2)$?

- Our simulation is simplified ...
- ... but it indicates a reasonable statistics with the already existing integrated luminosity at BaBar and BES-III...
- ... for a first couple of bins in Q^2 and q^2

Can one measure $F(Q^2, q^2)$?

- Our simulation is simplified ...
- ... but it indicates a reasonable statistics with the already existing integrated luminosity at BaBar and BES-III...
- ... for a first couple of bins in Q^2 and q^2
- But this would already be a great achievement!

We suggest the experimentalists to study
how the existing q^2 cuts could be “split” or “expanded”

Spare slides

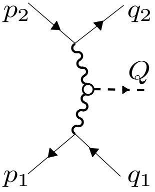
The form factor and the cross section

$$d\,\sigma_{avg}(e^+e^- \to e^+e^-\pi^0) \;=\; \frac{1}{4}\frac{1}{2s} d\,Lips_3\,\sum|\mathcal{M}|^2$$

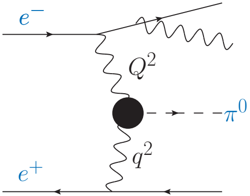
$d\;Lips_3$ is the differential 3−body Lorentz-invariant phase space

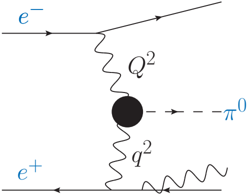
$$\mathcal{M} \;=\; -\frac{4\,i\alpha^2}{f_\pi}\,F(t_1,t_2)\,\epsilon_{\mu\nu\alpha\beta}\,\frac{1}{t_1\;t_2}\,(q_1-p_1)^\alpha\,(q_2-p_2)^\beta \\ \times\;(\bar{v}(p_1)\,\gamma^\mu\,v(q_1))\;(\bar{u}(q_2)\,\gamma^\nu\,u(p_2))$$

The normalization is $F(0,0)=1$



- Experimental cuts on the the missing lepton are based on the assumption of 3-body final state in the signal process (please correct me, if I am wrong)
- A part of the radiative corrections — hard photon emission $\Rightarrow$ 4-body final state





- How much does this radiative corrections “shift” the Q^2, q^2 and other distributions?

At present time we are working on the implementation of the radiative corrections in EKHARA