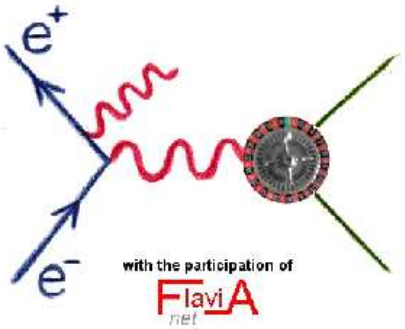
$\gamma^* - \gamma^*$ physics with EKHARA generator

H. CZYŻ, IF, UŚ, Katowice

MonteCarLow WG Meeting, Liverpool 2010



Based on:

H. Czyż, Sergiy Ivashyn,
"EKHARA Monte Carlo generator for annihilation:
$e^+e^- \to e^+e^-\pi^0$ and $e^+e^- \to e^+e^-\pi^+\pi^-$"
arXive 1009.1881 - submitted to CPC
H. Czyż, E. Nowak-Kubat
"The reaction $e^+e^- \to e^+e^-\pi^+\pi^-$ and
the pion form factor measurements via the radiative return method"
Phys. Lett. B634 (2006) 493.

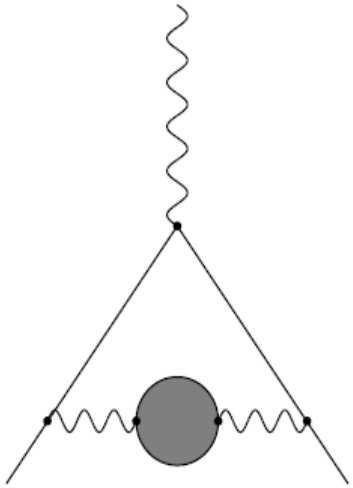
The challenge

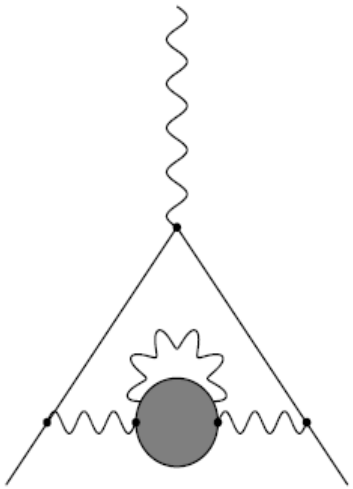
- including BaBar 2π results in the e+e− combination + estimate of hadronic LBL contribution (Prades-de Rafael-Vainhstein, 2009) yields

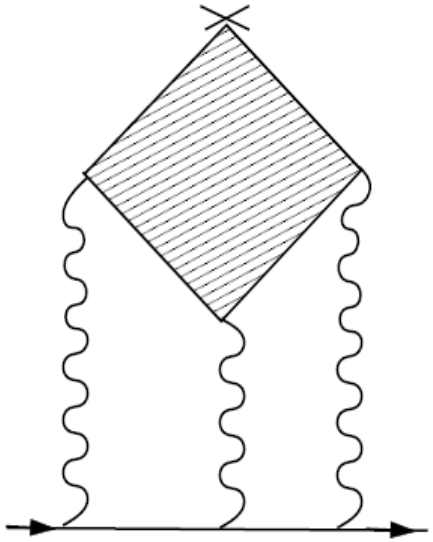
$$a_\mu^{SM}[e+e-] = (11\,659\,183.4 \pm 4.1 \pm 2.6 \pm 0.2)\ 10^{-10}$$

HVP LBL EW (± 4.9)

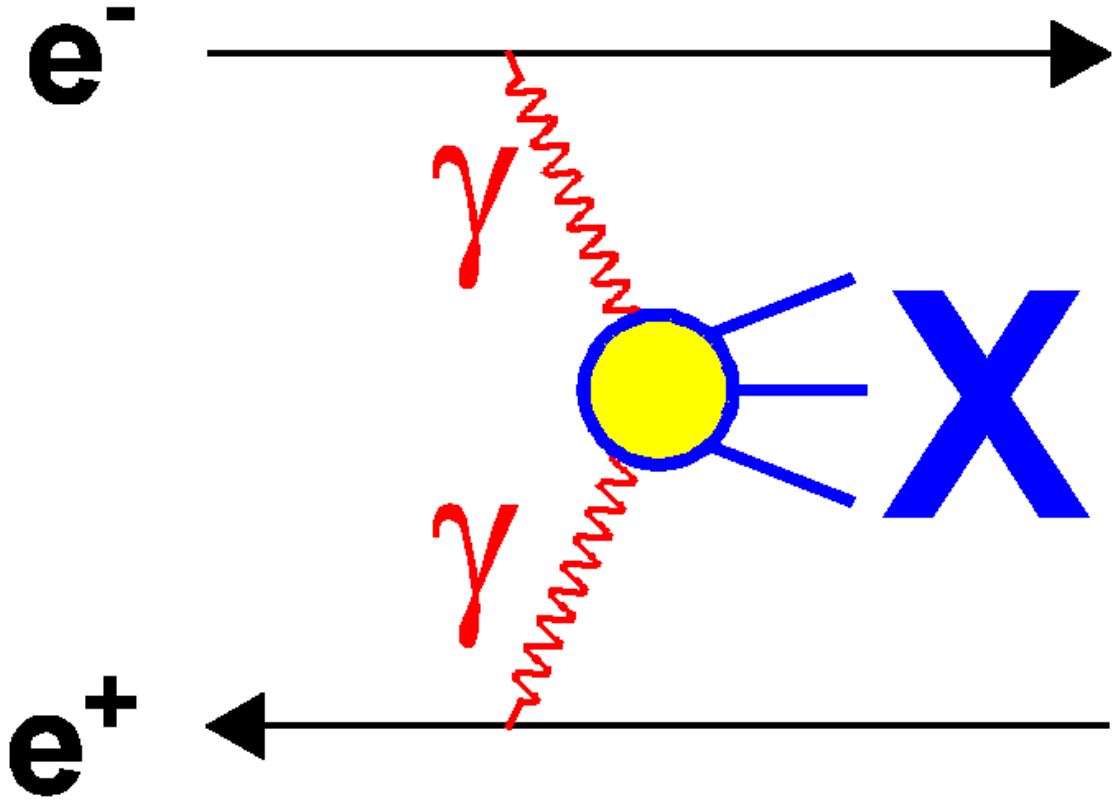
- E-821 updated result $11\,659\,208.9 \pm 6.3$



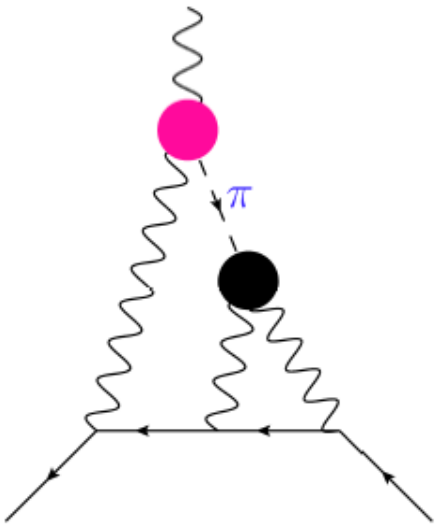




Photon-photon interactions



Pion exchange in hadronic LbL



$F_{\pi^*\gamma^*\gamma^*}$ form factors are key objects

- external vertex : $F_{\pi\gamma\gamma}(t_\pi, t_\pi, 0^2)$
  - ✓ far off-shell pion
  - ✓ zero-energy photon
- internal vertex : $F_{\pi\gamma\gamma}(t_\pi, t_1, t_2)$
  - ✓ totally off-shell object

These form factors were never measured

LO amplitude

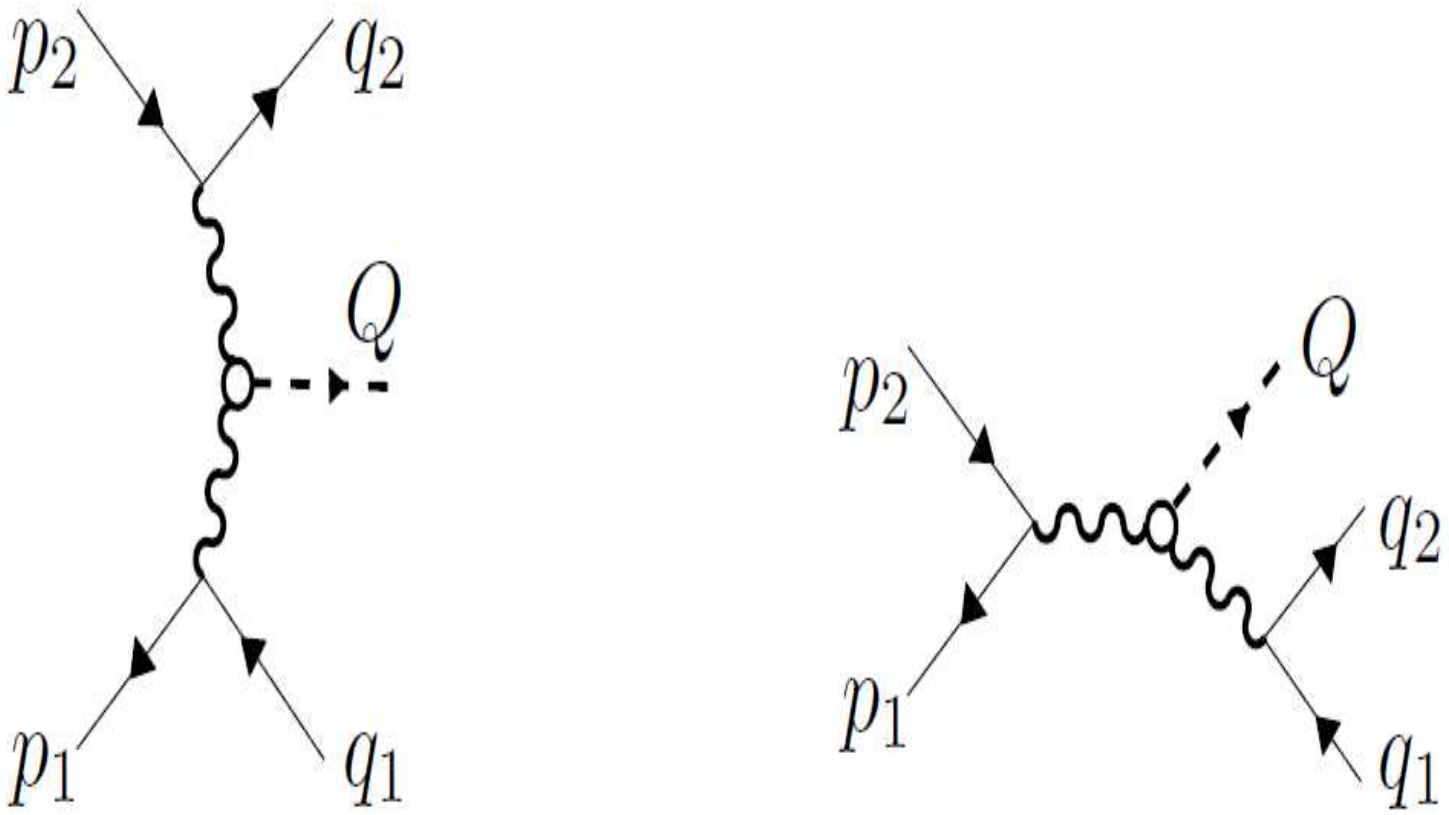


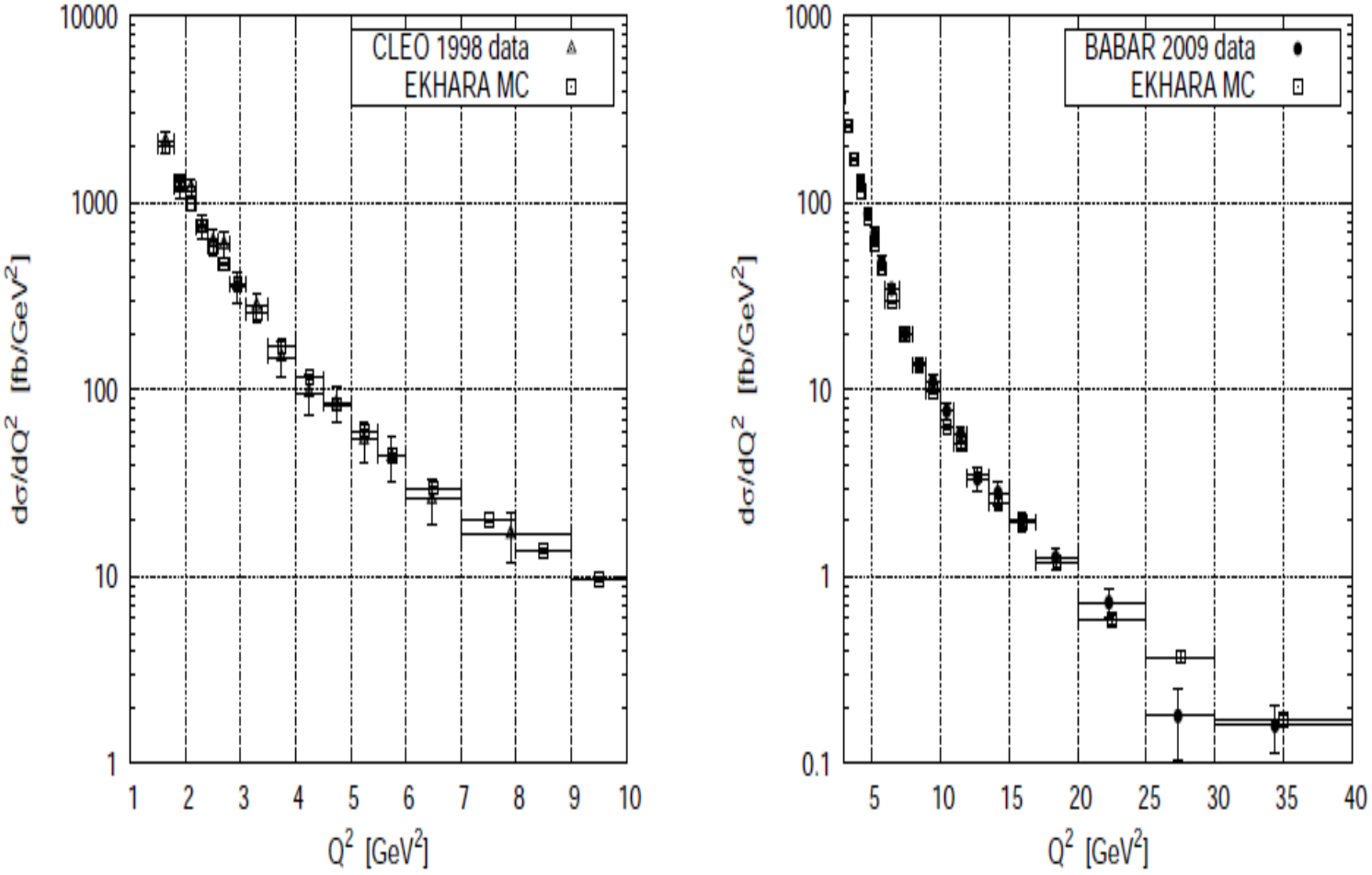
Figure 1: The t-channel *(left)* and the s-channel *(right)* diagrams for $e^+e^- \to e^+e^-P$

LO amplitude

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

$$\mathcal{M}_s = \frac{4i\alpha^2}{f_\pi} F\left(s,(q_1+q_2)^2\right)\,\epsilon_{\mu\nu\alpha\beta}\,\frac{1}{s\,(q_1+q_2)^2}\,(p_1+p_2)^\alpha\,(q_1+q_2)^\beta$$
$$\left(\bar{v}(p_1)\,\gamma^\mu\,u(p_2)\right)\,\left(\bar{u}(q_2)\,\gamma^\nu\,v(q_1)\right).$$

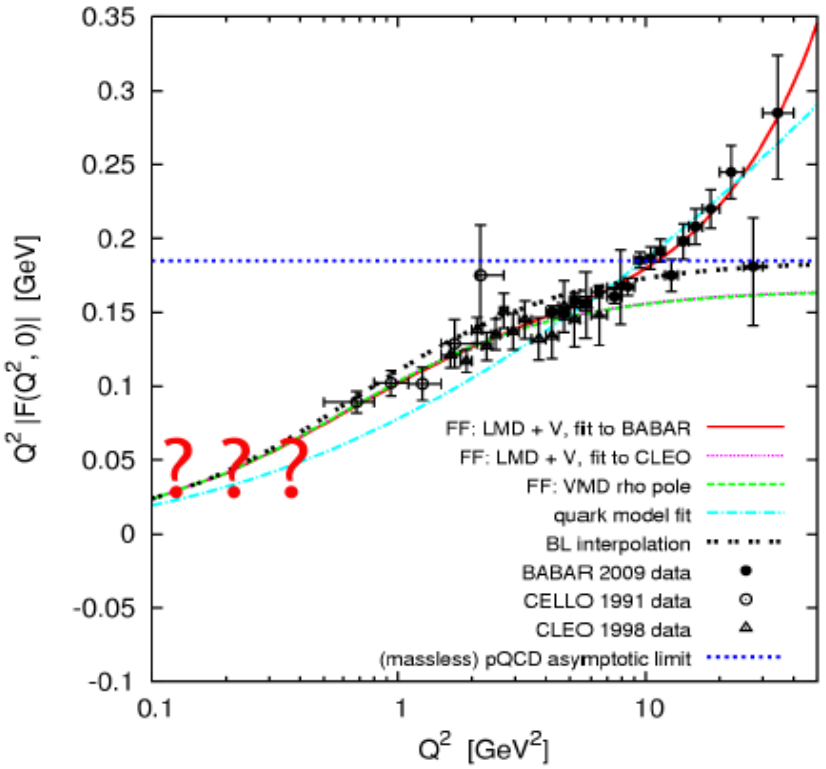
EKHARA vs. data



Form factor by A. Nyffeler (2009)

Form factor

$$Q^2 F_{\pi^0\gamma^*\gamma}(m_\pi^2, Q^2, 0)$$



Theory:

[A. Nyffeler, 0912.1441]

[M. Knecht and A. Nyffeler,

Phys. Rev. D**65**, 073034 (2002)]

[ibid.]

[A. E. Dorokhov, 0905.4577]

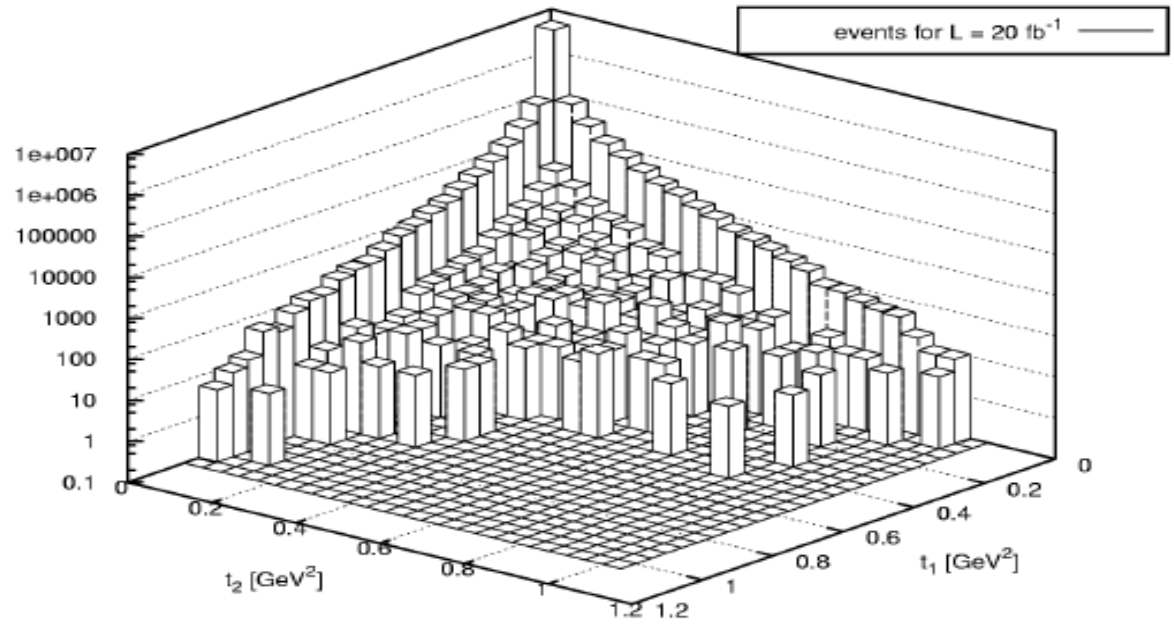
[G. P. Lepage and S. J. Brodsky,

Phys. Rev. D **22**, 2157 (1980)]

No data at $0.02\ \text{GeV}^2 < Q^2 < 0.4\ \text{GeV}^2$

KLOE2

no cuts

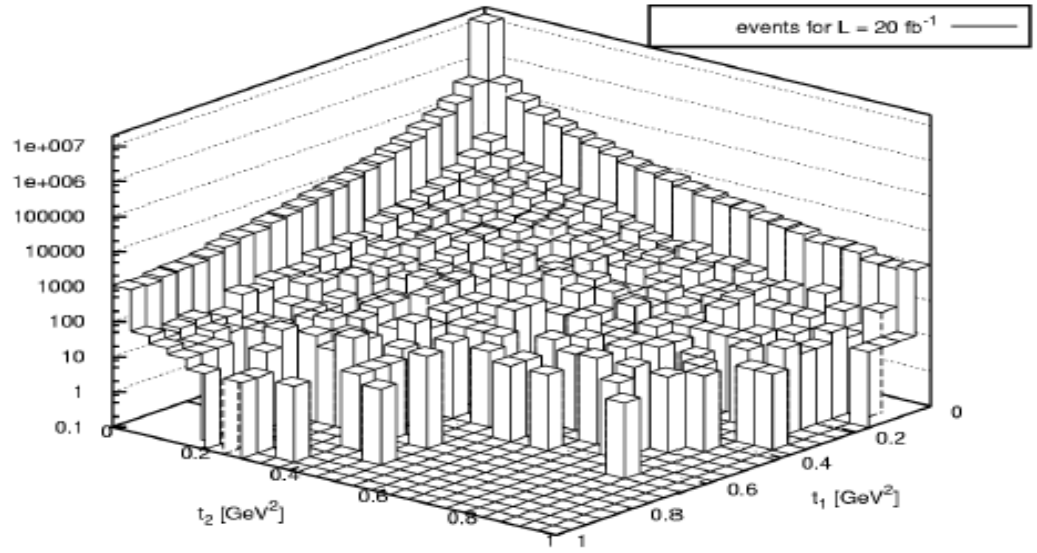


- both invariants are well populated

BES-III

BES-III at small Q^2

example: no cuts

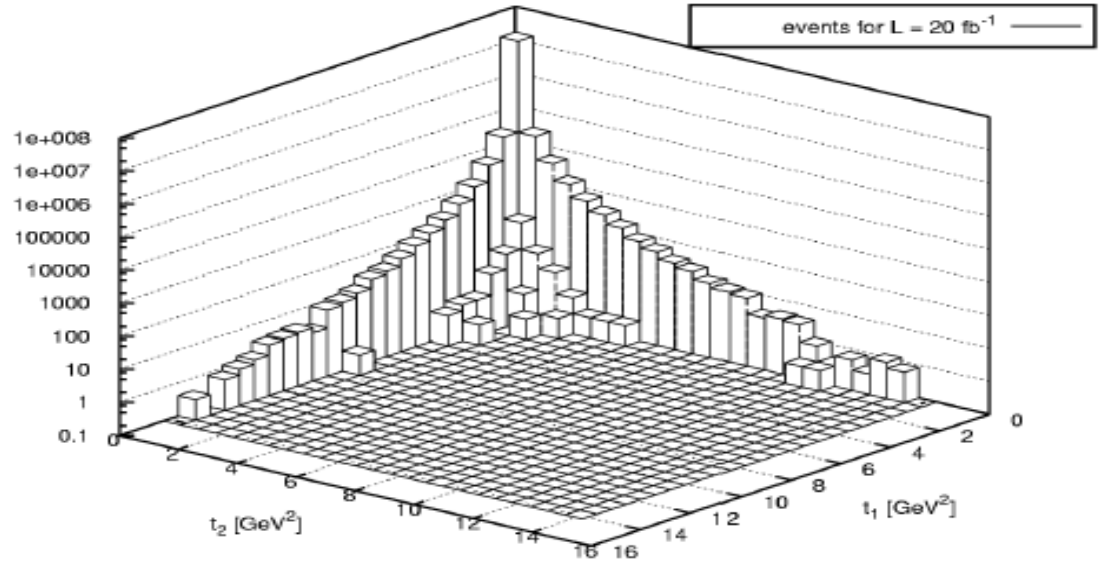


- $\sqrt{s} = 3$ GeV, $\int \mathscr{L} dt = 20$ fb^{-1}
  (~ 9 months at $\mathscr{L} = 10^{33}$ cm^{-2} s^{-1})

BES-III

BES-III at high Q^2

example: no cuts

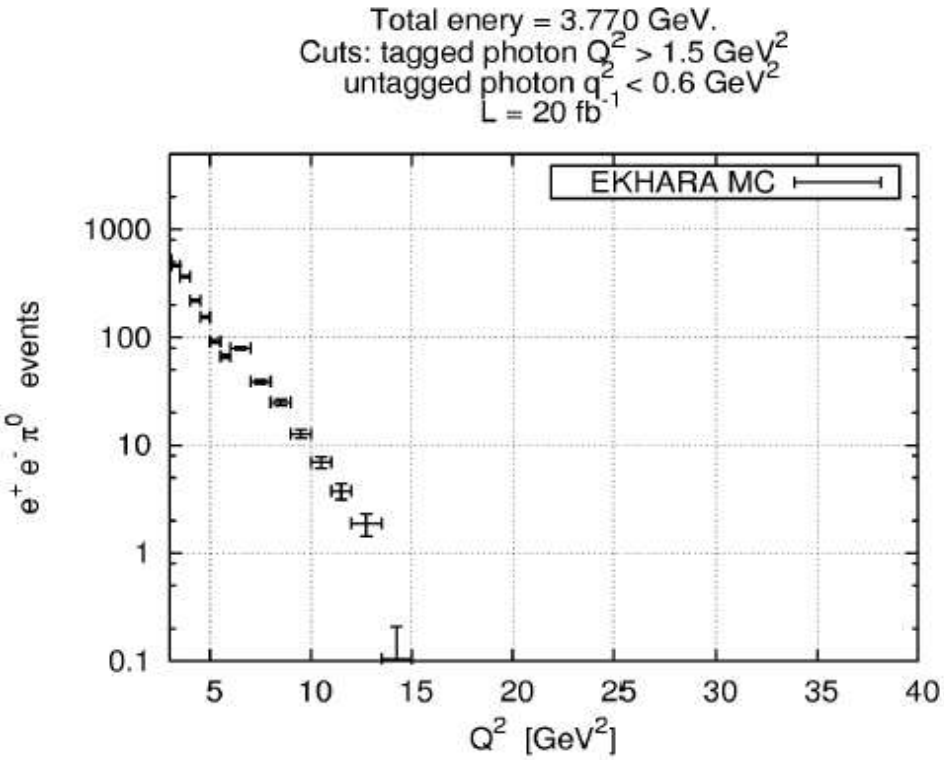


- $\sqrt{s} = 3.770$ GeV, $\int \mathscr{L} dt = 20$ fb^{-1}
  (~ 9 months at $\mathscr{L} = 10^{33}$ cm^{-2} s^{-1})

BES-III

Single-tag measurement at BES-III

e.g. for extraction of the form-factor $F(m_\pi^2, Q^2, 0)$



Planned upgrades

- radiative corrections to be added
- η and η'
- further work on $\pi^+\pi^-$