

FEVA/ PHOKHARA 6.0

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Phokhara 6.0 ($\pi^+ \pi^-$)

- ISR (NLO, exact)
- FSR (1photon)
- Interference (LO)

- models for $f_0\gamma$
 - Achasov (simplified)
 - Non structure
 - Bini model (KLOE?)
- vacuum polarization

FEVA($\pi^+ \pi^-$)

- (ISR+FSR) (LO)
- ISR RC: SF method
- Interference (LO)

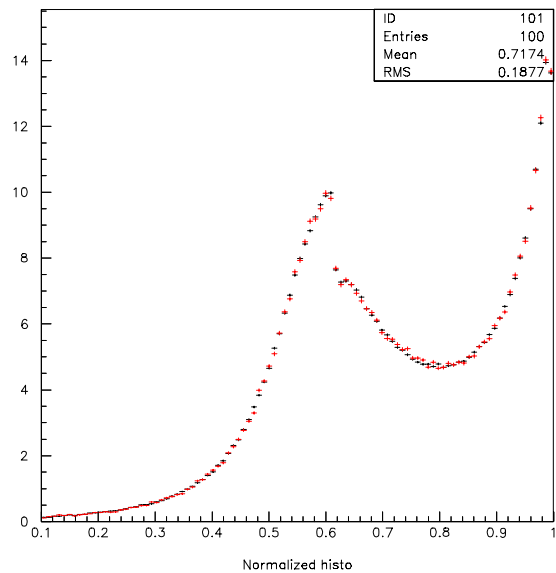
- models for $f_0\gamma$
 - 4q Achasov ($f_0 + \sigma$)
 - 4q Achasov (f_0)
 - ChPT (Oset et al.)

- double vector contribution
($\phi \rightarrow \rho \pi \rightarrow \pi^+ \pi^- \gamma$)

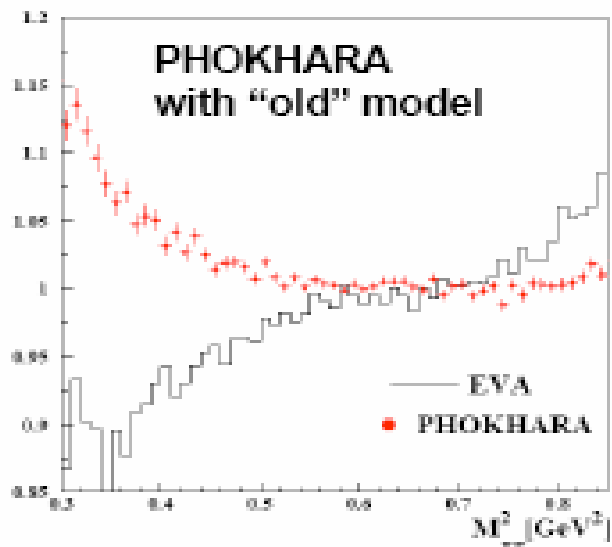
LO comparison

2008/04/10 14.26

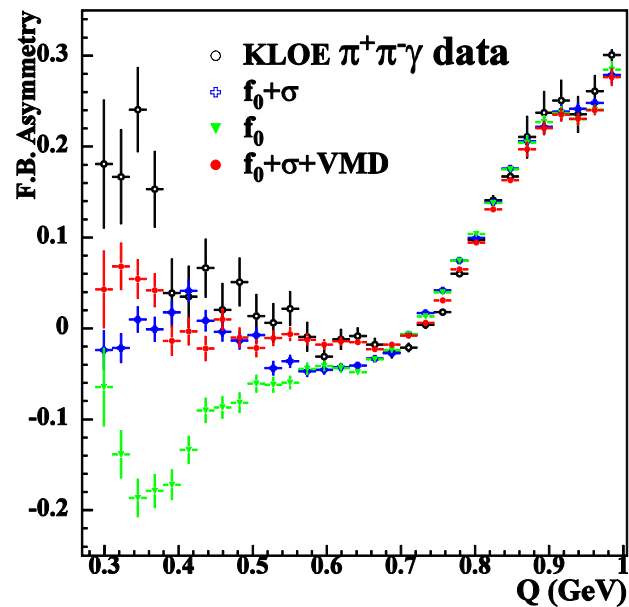
ISR+sQED



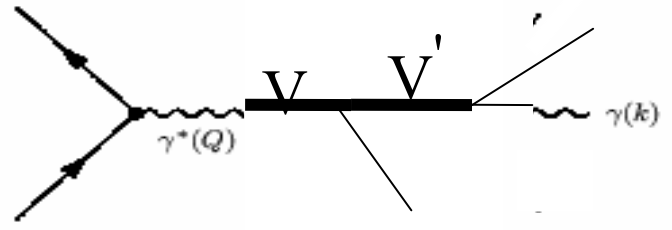
$(\text{ISR+sQED}+f_0+\rho\pi)/(\text{ISR+sQED}) - 1$



ISR+FSR



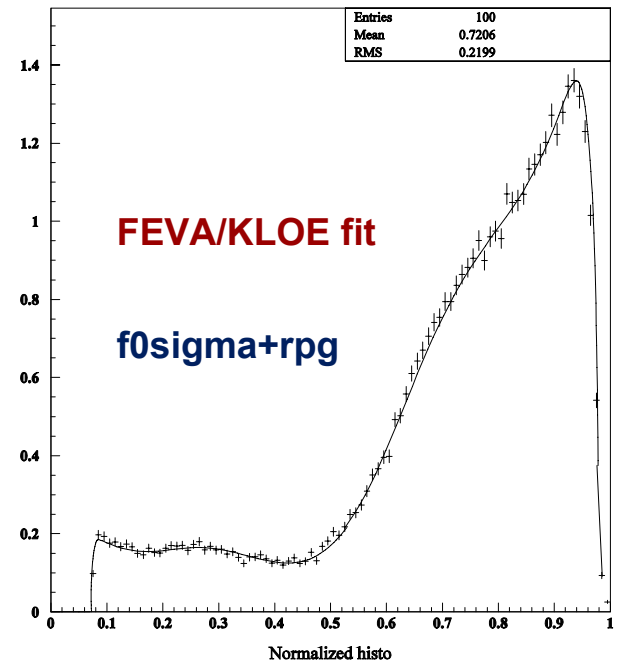
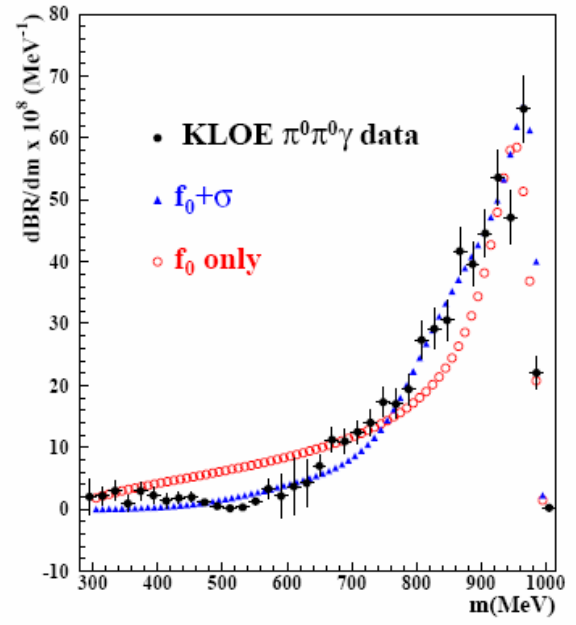
$$\phi \rightarrow \rho \pi \rightarrow \pi^+ \pi^- \gamma$$



$$\phi \rightarrow ((f_\phi; f_0 + \sigma)\gamma) \rightarrow \pi^+ \pi^- \gamma$$

$$f_1^{scal} = \frac{g_{\phi\gamma} f_\phi(Q^2)}{Q^2 - m_\phi^2 + im_\phi \Gamma_\phi}$$

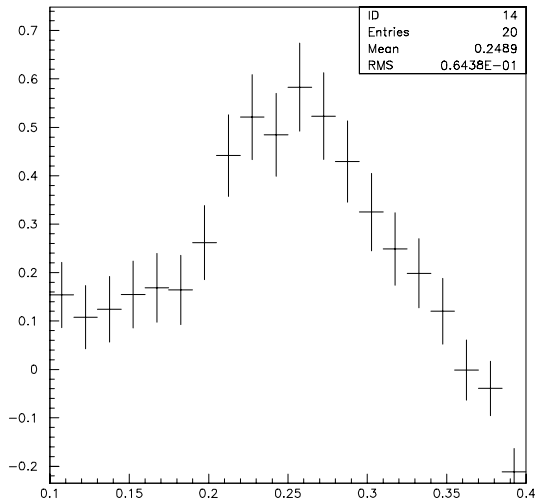
$$f_\phi^{f_0+\sigma}(Q^2) = \frac{g_{\phi K^+ K^-} e^{i(\delta_{\pi\pi}(Q^2) + \delta_{KK}(Q^2))}}{2\pi^2 m_K^2} I\left(\frac{m_\phi^2}{m_K^2}, \frac{Q^2}{m_K^2}\right) * \left(\sum_{R,R'} g_{RK^+ K^-} G_{RR}^{-1} g_{R'\pi^+ \pi^-} \right), \quad G_{RR} = \begin{pmatrix} D_{f_0} & -\Pi_{f_0\sigma} \\ -\Pi_{f_0\sigma} & D_\sigma \end{pmatrix}$$



$$\underline{\phi \rightarrow \rho\pi \rightarrow \pi^+ \pi^- \gamma}$$

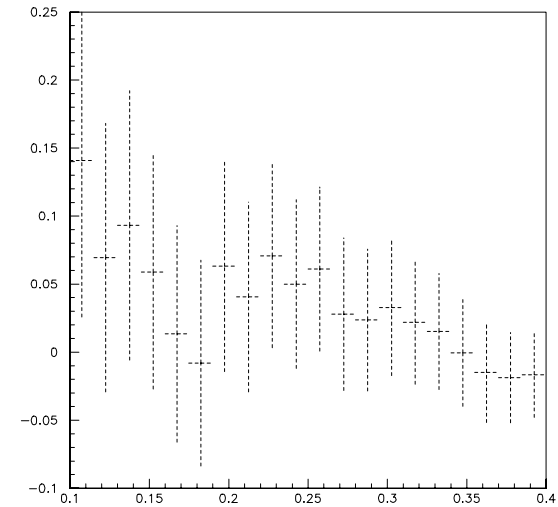
FSR(sQED+f0sig+rpg)/FSR(sQED+f0sig)-1

2008/04/11 11.48



Tot(ISR+sQED+f0sig+rpg)/Tot(ISR+sQED+f0sig)-1

2008/04/11 11.49



$$50 < \theta_\gamma, \theta_\pi < 130$$

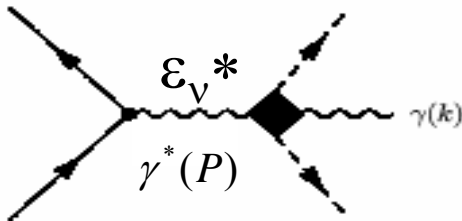
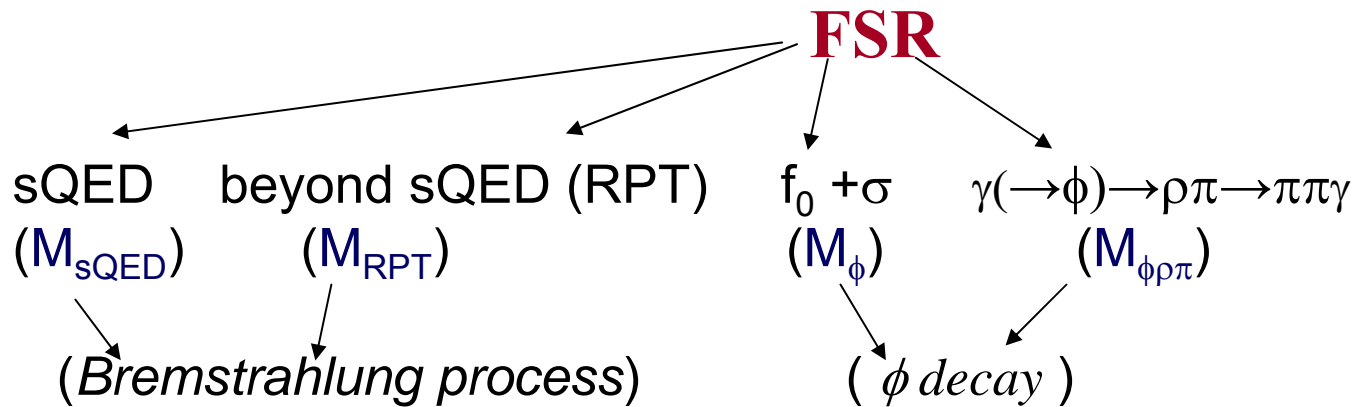
For 1% accuracy $\phi \rightarrow \rho\pi \rightarrow \pi^+ \pi^- \gamma$ should be included

ISR

Method SF: factorization soft+virtual+collinear photons

To correct the transformation of angles

To compare with **Phokhara** prediction NLO



$$M_F^{\mu\nu} = f_1 \tau_1^{\mu\nu} + f_2 \tau_2^{\mu\nu} + f_3 \tau_3^{\mu\nu}$$

C* ---> 1 0=initial state radiation only 0 1=fsr only 1 1=interference isr+fsr

KIND 0 1

C* Model for the Pion form factor --> KS GS SV

FPKIND 3

C*FSR---> sqed bsqed f0 VMD rhotopig

rhokind 0 0 1 0 0

C*f0KIND phi decay model

f0KIND 5

C*-----> Parameters of the Pion Form factor

C*PSV*MRHO GAMMARHO MRHOL GRHOL MOMEGA GOMEGA pi_rho FV

C*KS*MRHO GAMMARHO MRHOL GRHOL MOMEGA GOMEGA AL BE

C*GS*MRHO GAMMARHO MRHOL GRHOL MOMEGA GOMEGA AL BE arg(AL)

C*-----> Parameters of Scalar contribution (f0,f0+sigma) in FSR

C*F0 Gf0_k+k- Gf0_p+p- Gphi_k+k- phase(deg) f0MASS msigma gsigpp gsigkk Cf0sig

C*F0+SIGMA Gf0_k+k- Gf0_p+p- Gphi_k+k- phase(deg) f0MASS msigma gsigpp gsigkk Cf0sig

C*f0phase F0+SIGMA m0k m2k LambdaK b0p b1p b2p Lambdap

C*-----> Parameters of VMD contribution in FSR g_rhopig g_phirpi

C*VMDPAR g_rhopig g_phirpi prhores beta_bro beta_wphi

C* ---> histo output file

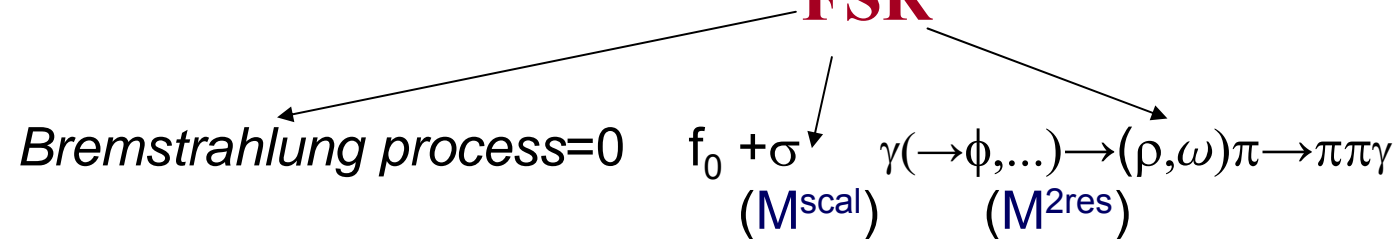
ENES 1.039202865 EMIN 0.02

QMIN 0.9 GMIN 0.02 ACUT 1. 179. 0. 180.

$\pi^0 \pi^0 \gamma$ final state

ISR=0

FSR



$$\sigma(\text{charged}) = 2\sigma(\text{neutral})$$

A possibility to have common fit for $\pi^0 \pi^0 \gamma$ and $\pi^+ \pi^- \gamma$

FEVA

Final state radiation for MC EVA

- **Final State Radiation**

- block structure \Rightarrow can be modified easy
- the most important contributions are included

- **Cross section and asymmetry calculation**

- **Common fit for $\pi^+ \pi^- \gamma$ and $\pi^0 \pi^0 \gamma$ FS**

To include

- 2nd photon emission (exact) ; HO RC by SF

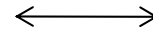
A. Arbuzov, A. Astakhov, E.Kuraev, N.Merenkov, L.Trentadue, E. Zemlyanaya, Nucl. Phys. B 483

B. V. Khoze, M.Konchatnyj, N. Merenkov, G. Pancheri, L. Trentadue, O.Shekhovtsova, EPJC 18(2001)

PHOKHARA 6.1

Phokhara_6.0 +corrected
version for f0sigma contribution

+ $\phi \rightarrow \rho\pi \rightarrow \pi^+ \pi^- \gamma$



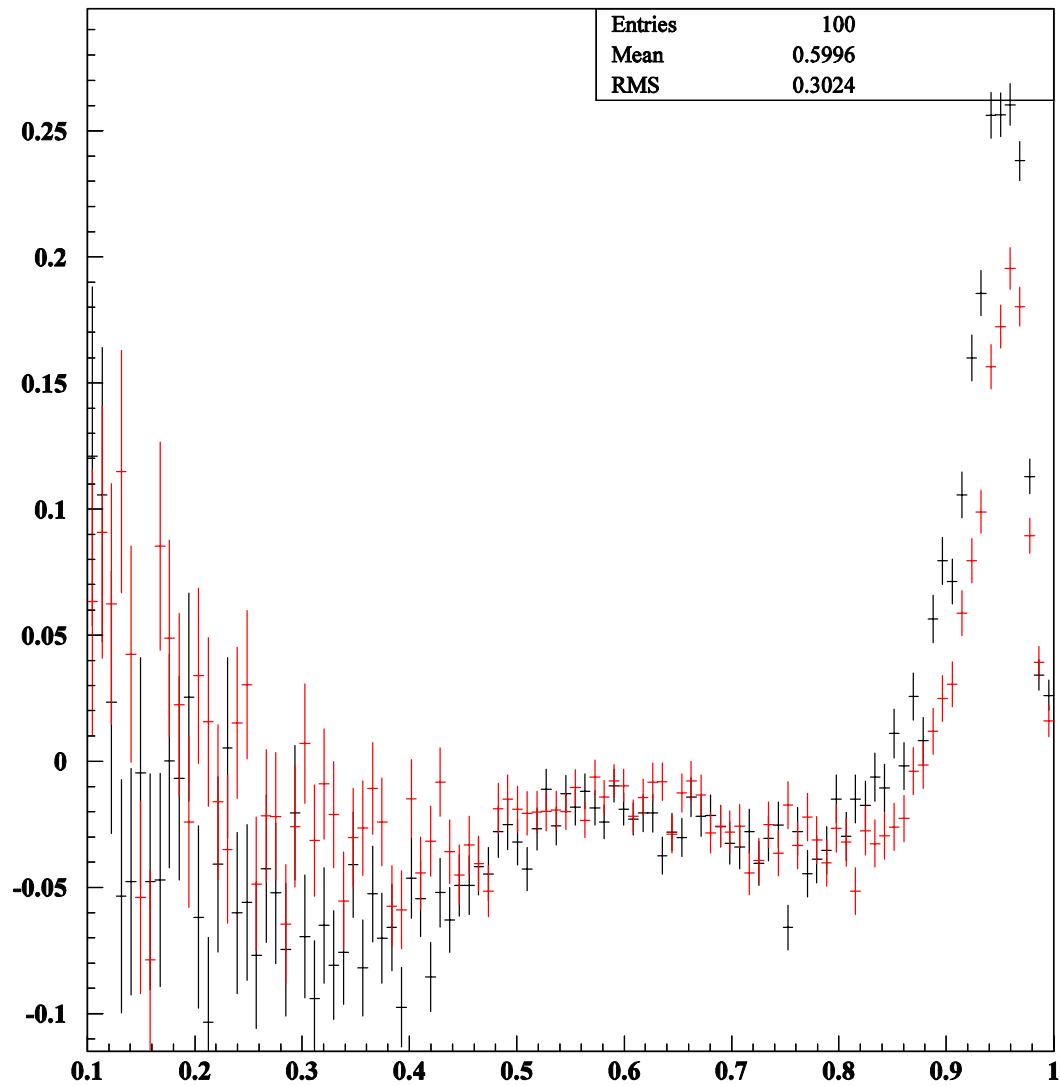
FEVA corrected for
angle transformation

$$50 < \theta_\gamma, \theta_\pi < 130$$

....accuracy should be compatible

IFSNLO

**(2 ISR photons+
1ISR and 1FSR
photon)**



NLO

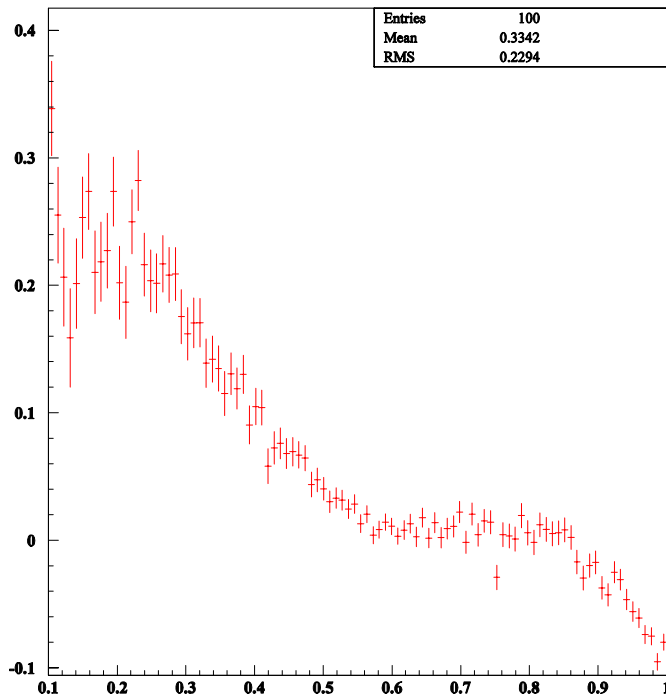
(2 ISR photons)

PHOKHARA 6.1

IFSNLO(2photons ISR +1 ISR and 1 FSR photons) -- NLO(2photons ISR)

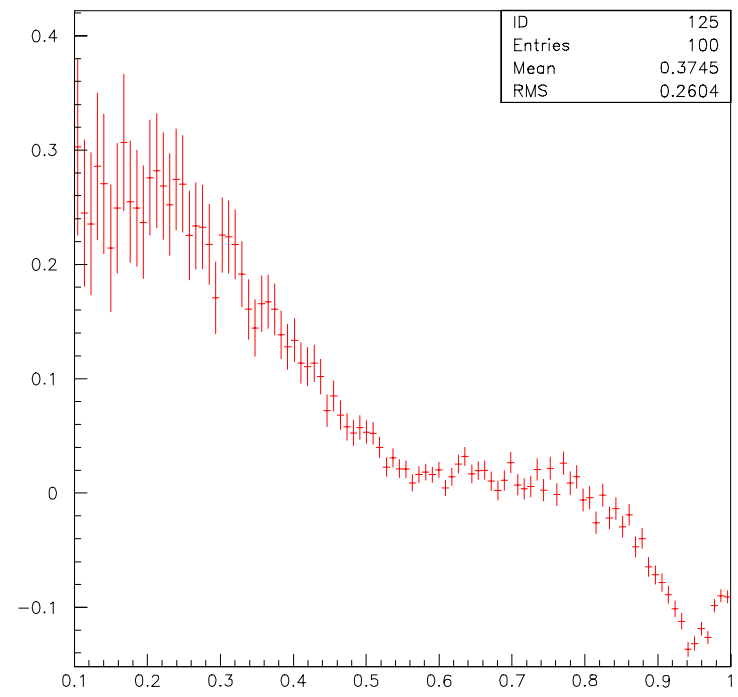
ISR+sQED

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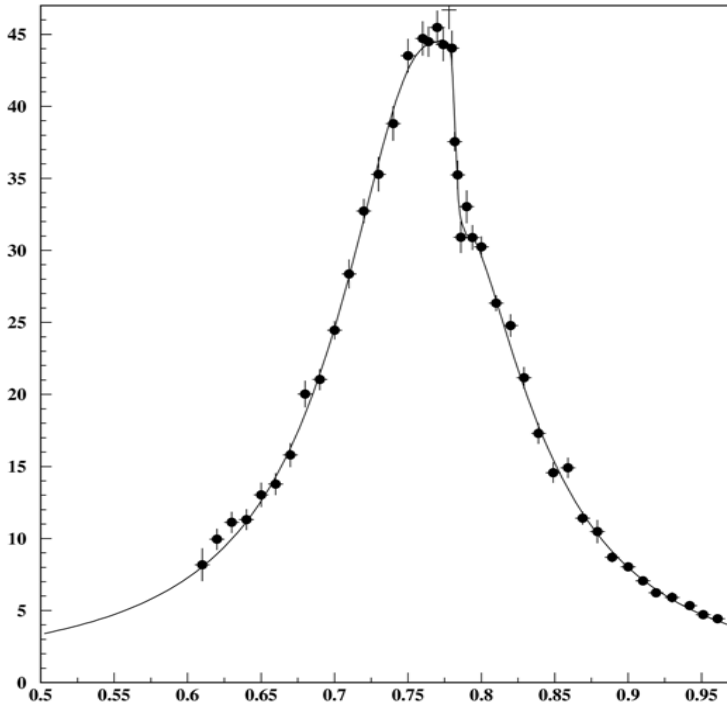
ISR+sQED+f0sig+rpg

2008/04/11 14.39



Back-up

Pion Form Factor with ρ - ω mixing



$$F_{\pi}(q^2) = 1 + \frac{F_V G_V}{f_{\pi}^2} F_{\rho}(q^2) \left(1 - \frac{\Pi_{\rho\omega}}{3q^2} F_{\omega}(q^2) \right) + \sum_i \frac{F_{V_i} G_{V_i}}{f_{\pi}^2} F_{\rho_i}(q^2)$$

$$F_{res}(q^2) = \frac{q^2}{m_{res}^2 - q^2 - im_{res}\Gamma_{res}(q^2)}$$

$$\Gamma_{res}(q^2) = \Gamma \sqrt{\frac{m_{res}^2}{q^2} \left(\frac{q^2 - m_{res}^2}{m_{res}^2 - 4m_{\pi}^2} \right)^{3/2}} \Theta(q^2 - m_{\pi}^2),$$

$$\Gamma_{\omega} = 8.68 \text{ MeV}, \quad m_{\omega} = 782.7 \text{ MeV}$$

Our fit Novosibirsk CMD-2 data gives us

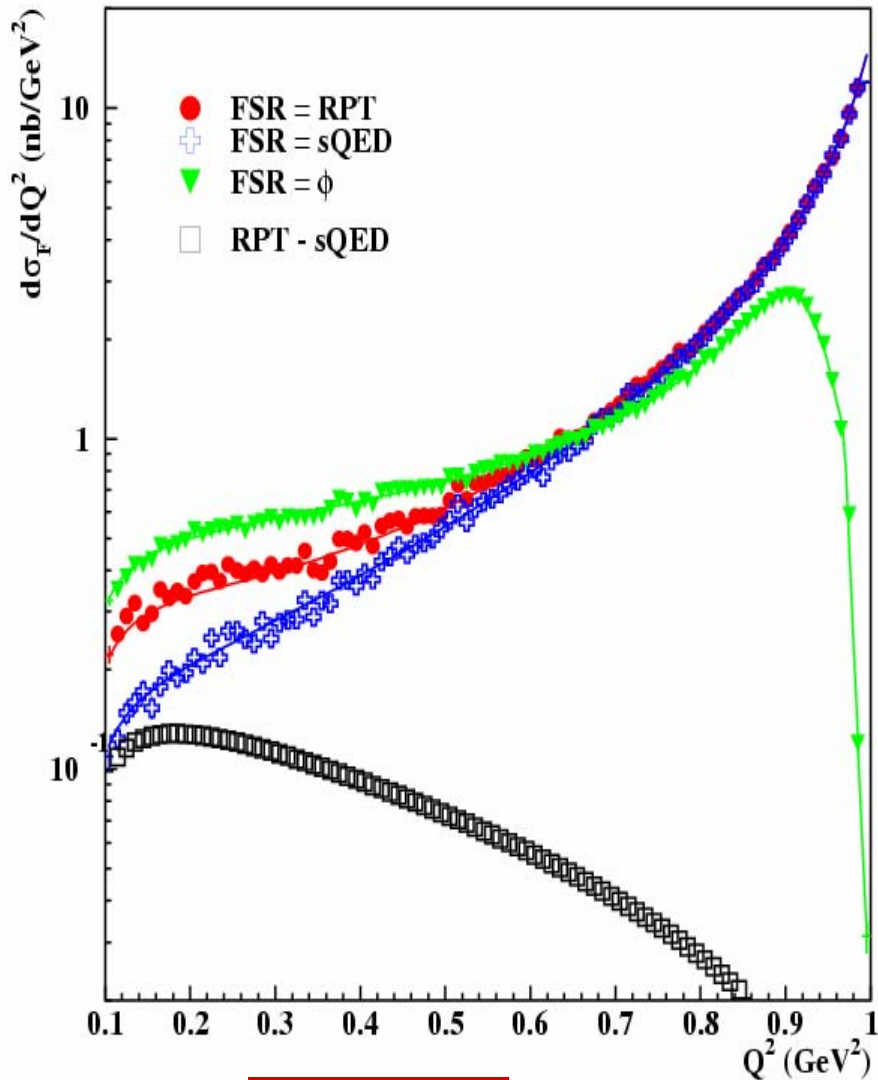
$$m_{\rho} = 774.97 \pm 1.4 \text{ MeV}, \quad F_V = 154.22 \pm 0.5 \text{ MeV}$$

$$\Gamma_{\rho} = 145.21 \pm 2.6 \text{ MeV}, \quad \Pi_{\rho\omega} = -2774 \pm 291.2 \text{ MeV}^2$$

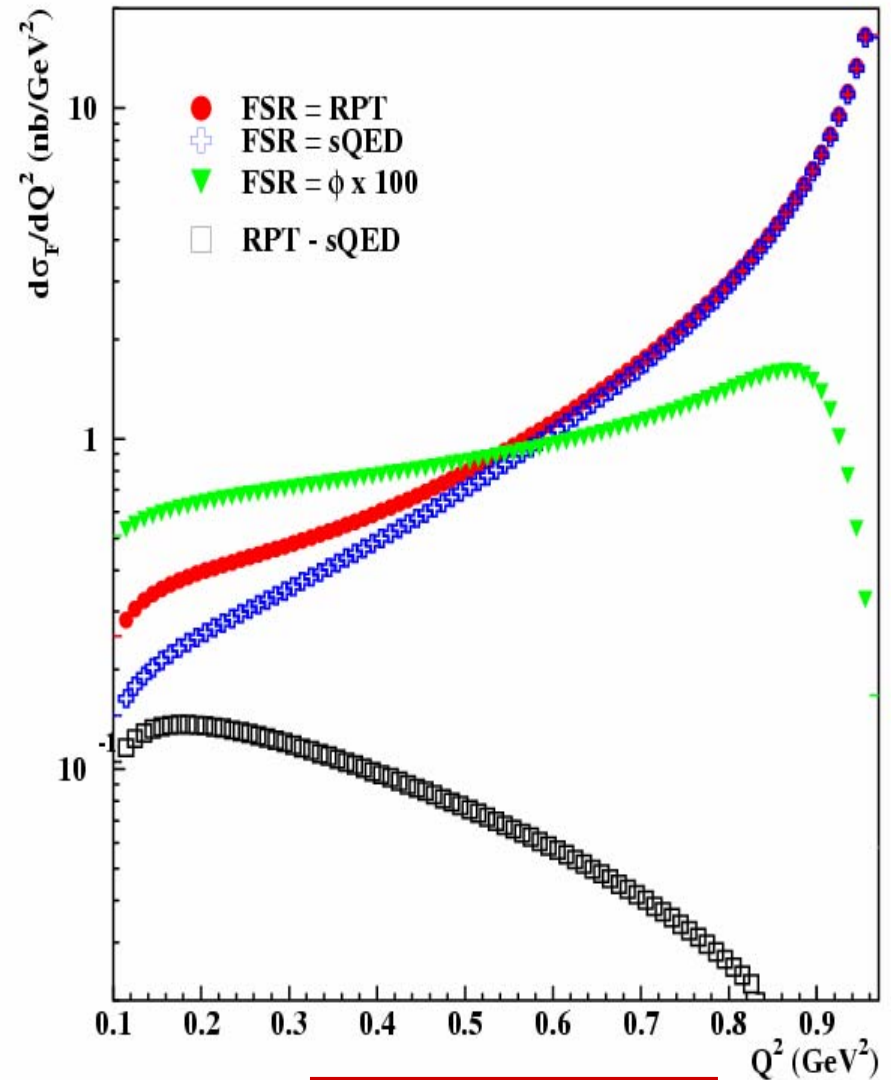
$$m_{\rho'} = 1.2 \pm 0.2 \text{ GeV}, \quad \Gamma_{\rho'} = 400 \pm 200 \text{ MeV}$$

$$\chi^2 = 0.853$$

Comparison MC with analytical functions



$$s = m_\phi^2$$



$$s = 1 \text{ GeV}^2$$