lnf 3/1/05
Radiative meeting

Studying FSR at threshold for $\pi\pi\gamma$ events

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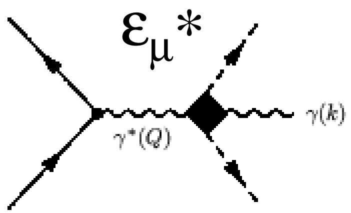
Disclaimer: everything is preliminary!!!

Generalization of FSR amplitude: we need 3 form factors f_i.



$$<\pi^+\pi^-\gamma \,|\, j^\mu \,|\, 0> = ie^2\varepsilon_\nu^* M_F^{\mu\nu}$$

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

Each form factor depends by 3 independent variables (one is ***s***)

$$\lim_{k\to 0} f_1 = f_1^{sQED} = \frac{2k\cdot QF_\pi(s)}{(k\cdot Q)^2-(k\cdot l)^2}$$

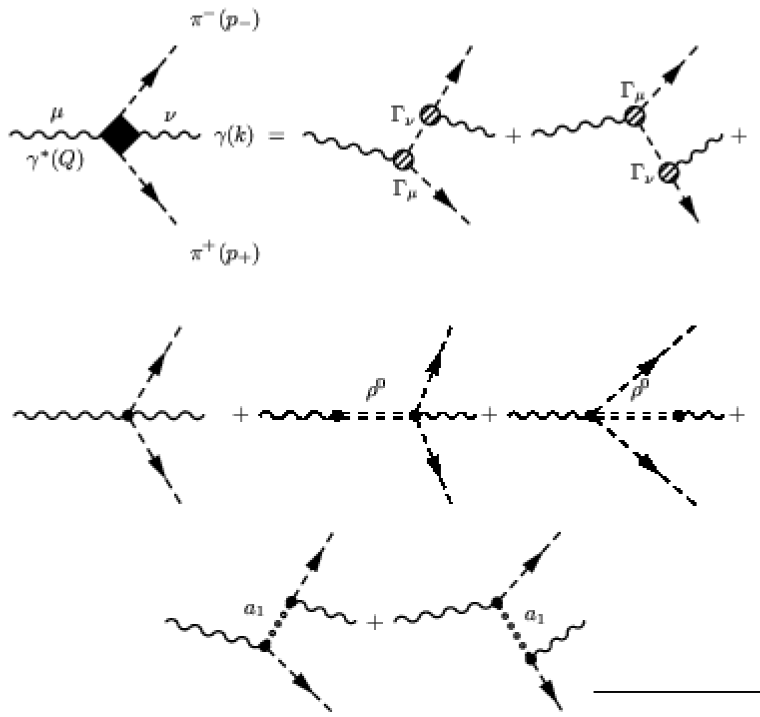
$$\lim_{k\to 0} f_2 = f_2^{sQED} = \frac{2F_\pi(s)}{(k\cdot Q)^2-(k\cdot l)^2}$$

$$\lim_{k\to 0} f_3 = f_3^{sQED} = 0$$

Limit of soft photon (what we call sQED)

At threshold (very hard photon) this approximation could not work

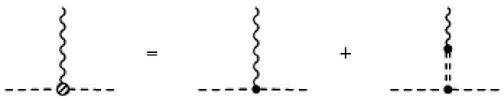
A model for FSR, based on χPT



(S. Dubinsky et al,hep-ph/041113)

$f_i = f_i^{sQED} + \Delta \boldsymbol{f_i}$

The contribution with $\rho^{+,-}$ (instead of a_1), turns out to be negligible



Meson	M(GeV)	G_V (GeV)	F_V (GeV)	F_A (GeV)
ρ	0.775	0.0066	0.156	-
a_1	1.23	-	-	0.122

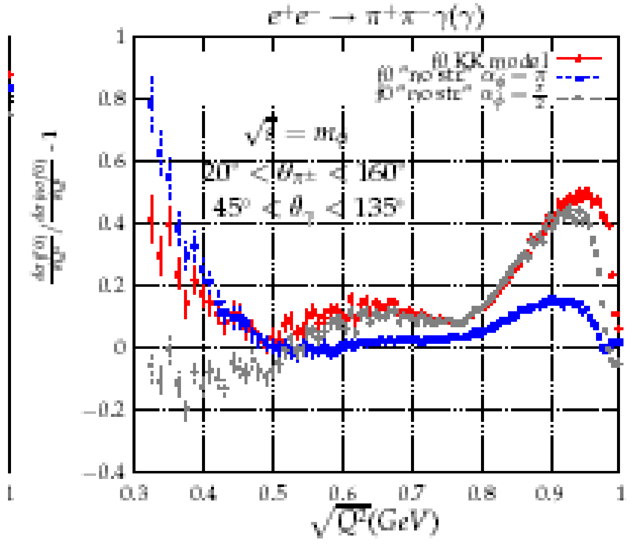
•The model is a first step in the direction of a generalization of the FSR amplitude.

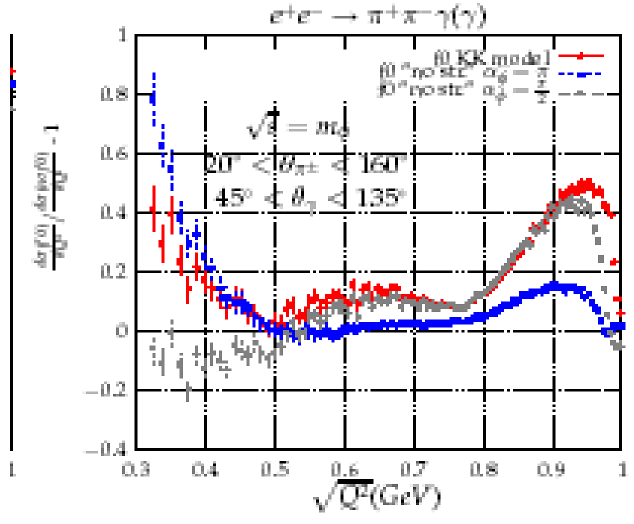
However, the calculation (at the moment) is approximate since:

- it doesn't take into account other mesons (like ω and ρ')
- it doesn't include the $\phi \to \pi^+ \pi^- \gamma$ decay
- ….

What about $\phi \to \pi^+ \pi^- \gamma$ decay ?

Recently H. Czyz et al. (hep-ph/0412239) showed that this decay can be important also at low Q^2 region. This contribution can be quite different depending by the model. Charge asymmetry can help.



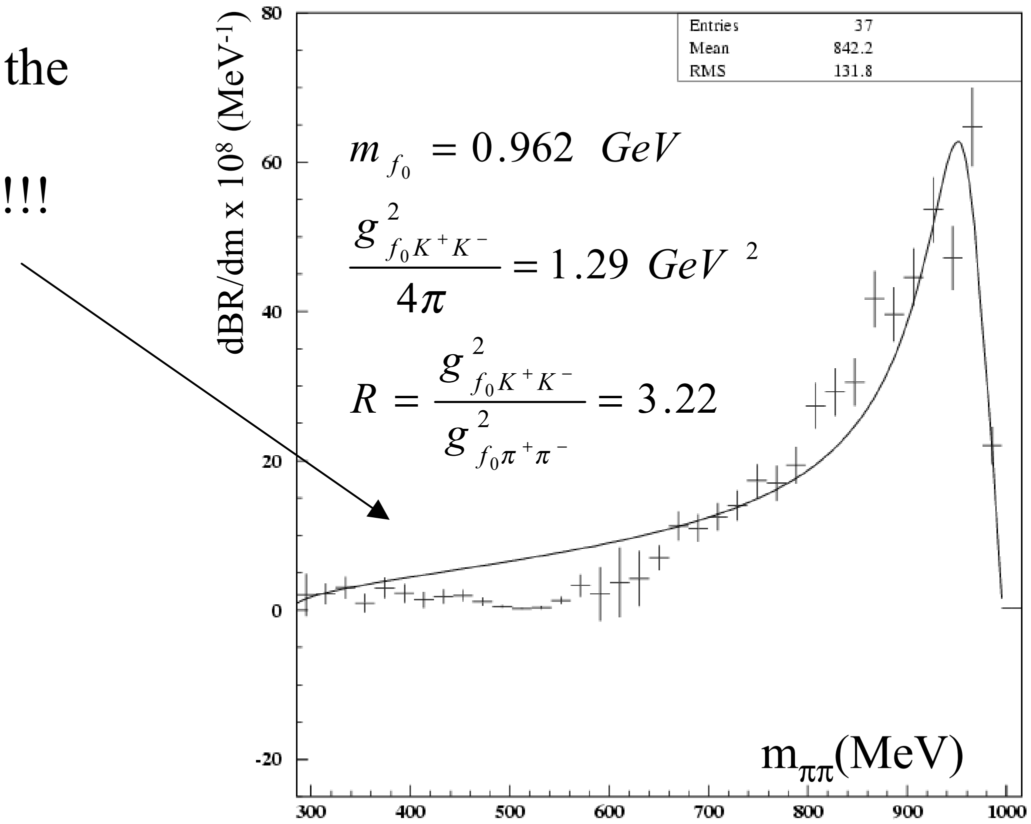


How to include $\phi\to\pi^+\pi^-\gamma$ decay in our calculation?

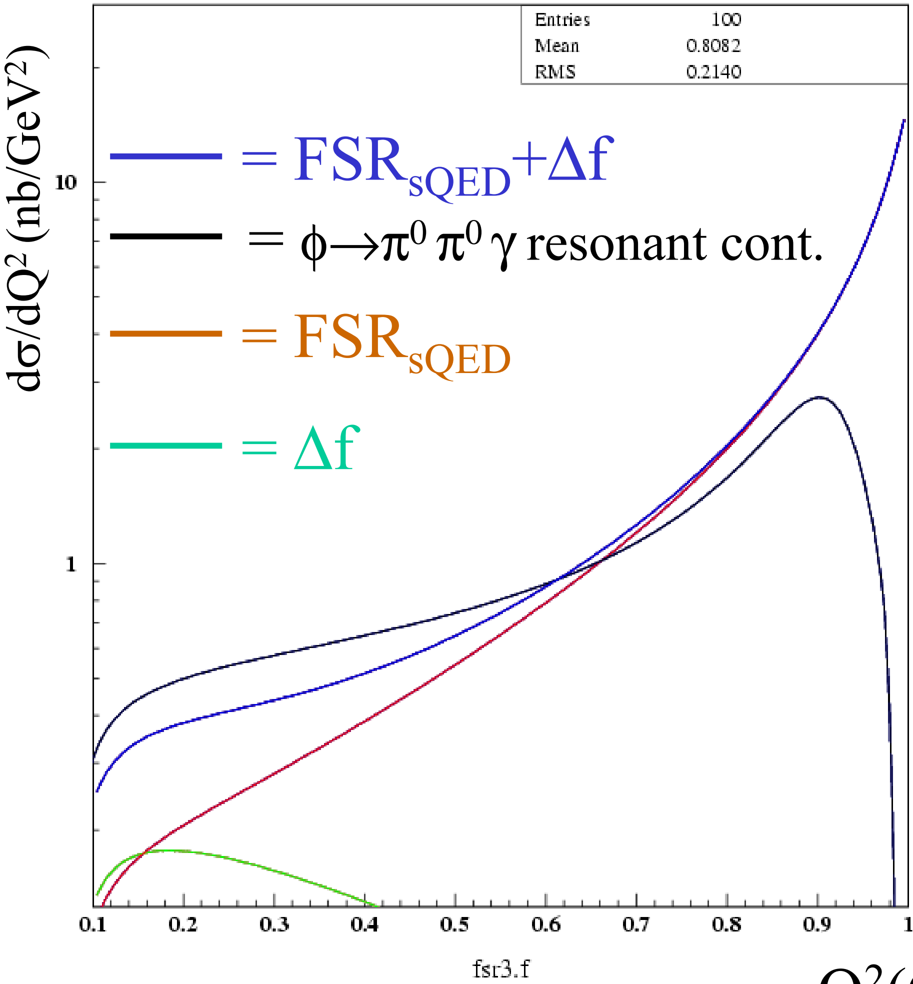
- $\phi\to\pi^+\pi^-\gamma$ is related to $\phi\to\pi^0\pi^0\gamma$ by the same matrix element (a part a factor ½). We use the Achasov 4q parametrization with the parameters of the model taken from the fit of the kloe data $\phi\to\pi^0\pi^0\gamma$.

$$f(Q^2)=\frac{g_{\varphi K^+K^-}\,g_{f_0K^+K^-}\,g_{f_0\pi^+\pi^-}}{2\pi^2 m_K^2}\,I\left(\frac{m_{\varphi^2}}{m_K^2},\frac{Q^2}{m_K^2}\right)\frac{e^{i\delta_B(Q^2)}}{(m_{f_0}^2-Q^2+\mathrm{Re}\,\Pi_{f_0}(m_{f_0}^2)-\Pi_{f_0}(Q^2))}$$

For the moment we consider only the contribution of f_0 (no σ meson). This could be too crude at low Q^2 !!!



(Analitical) Comparisons (at $s=m_\phi^2$):



$Q^2(GeV^2)$

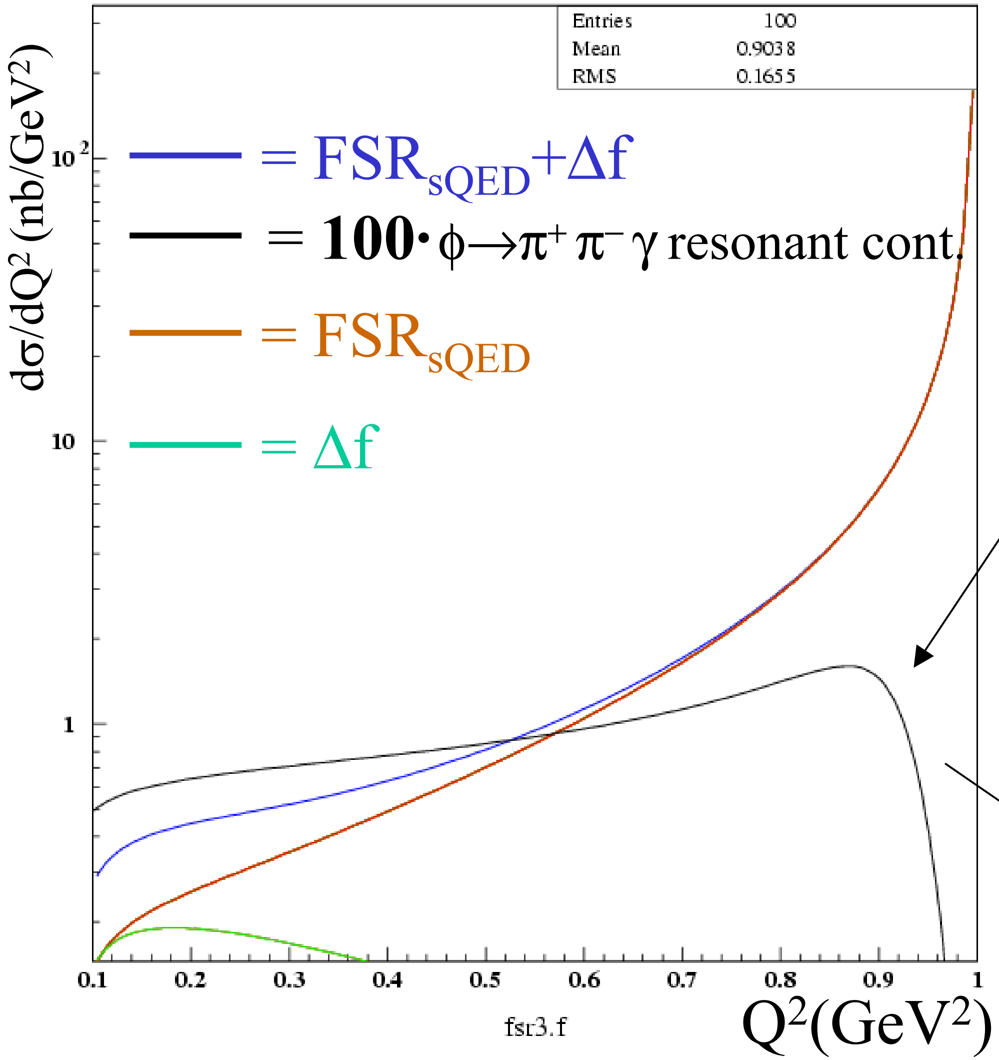
$0^o < \theta_\pi < 180^o$

$0^o < \theta_\gamma < 180^o$

Since $M_{FSR} * M_\phi \sim |M_\phi|^2$ at low Q^2 Δf can be relevant only for **destructive**. interference (we will consider only this case in the following)

What happens for $s<m_\phi^2$?

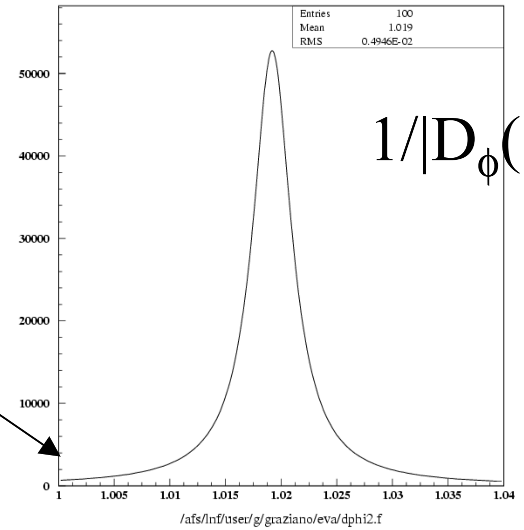
The comparison at $s=1$ GeV^2:



$0^o < \theta_\pi < 180^o$

$0^o < \theta_\gamma < 180^o$

Multiplied by a factor 100



$1/|D_\phi(s)|^2$

In this case the interference $M_{FSR}{}^*M_\phi$ is expected to be $>>|M_\phi|^2$

The following matrix element has been introduced in a MC, for $e^+e^- \rightarrow \pi^+\pi^-\gamma$ (based on EVA structure):

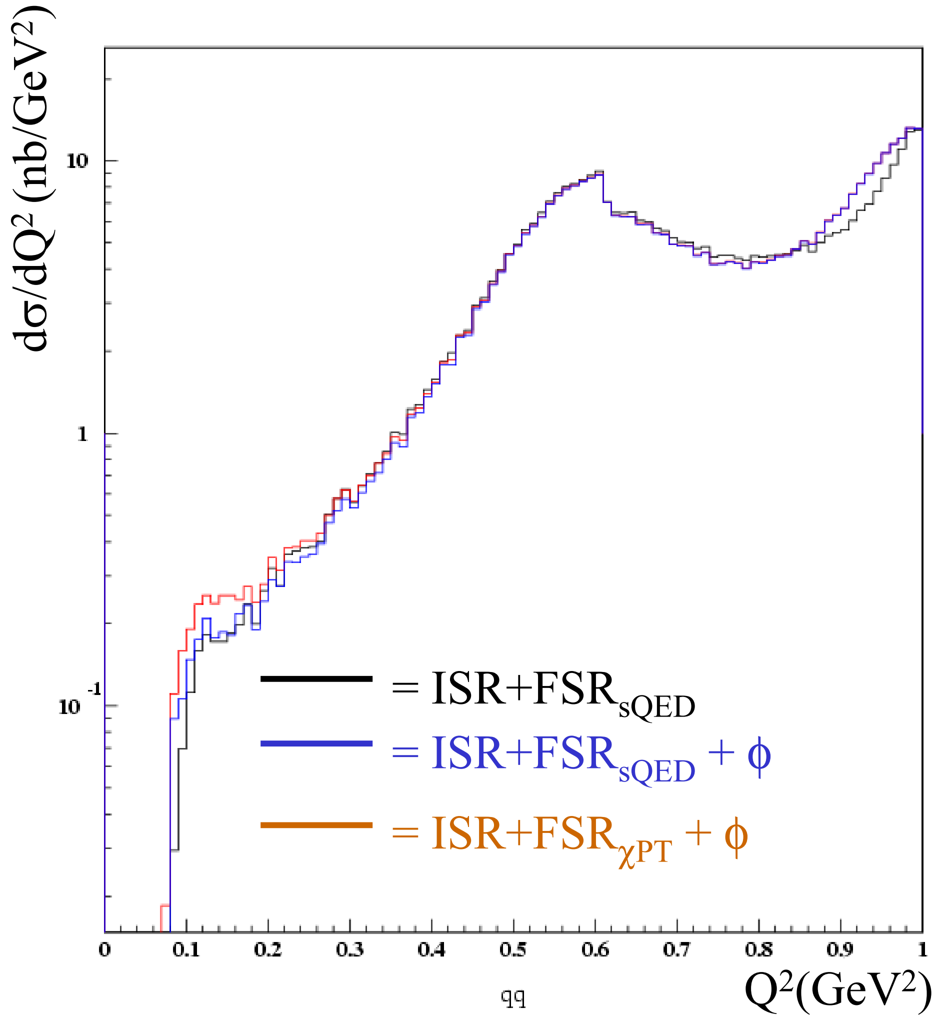
$$d\sigma \approx |M_{ISR} + M_{FSR_{\chi PT}} + M_{\varphi}|^2 \cong |M_{ISR} + M_{FSR_{\chi PT}}|^2 + |M_{\varphi}|^2 +$$

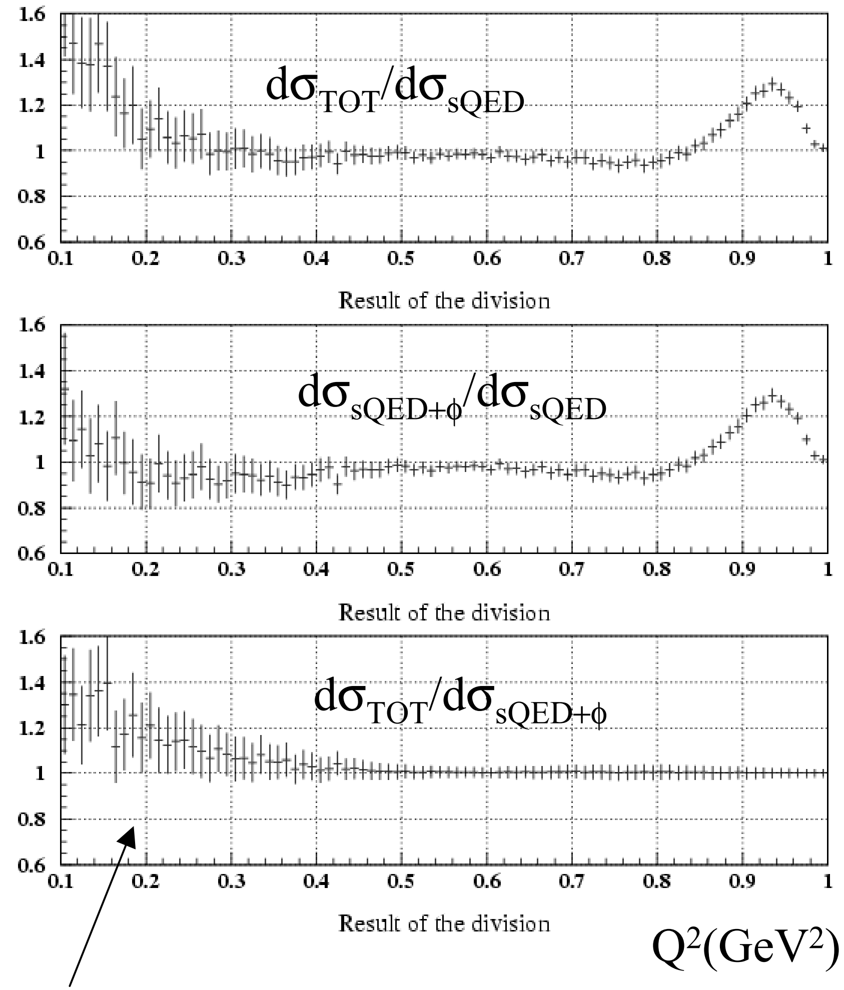
$$2\,\mathrm{Re}((M_{ISR} + M_{FSR_{sQED}}) \bullet M_{\varphi}^{*})$$

- We neglect the contributions from $\gamma^* \rightarrow \rho\pi \rightarrow \pi^+\pi^-\gamma$ *(found negligible in hep-ph/0411113)*
- We consider destructive interference between FSR_{sQED} and ϕ
- We consider large angle analysis: $50^o < \theta_\gamma < 130^o$, $50^o < \theta_\pi < 130^o$

Numerical results: differential cross section…

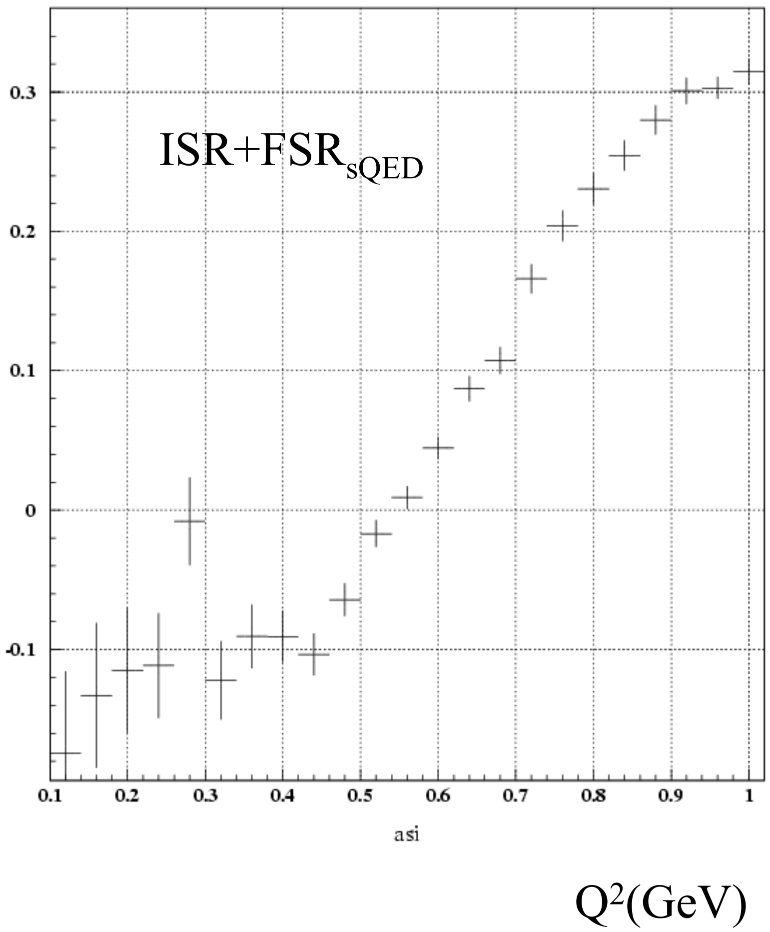
$50^o < \theta_\pi < 130^o$
$50^o < \theta_\gamma < 130^o$

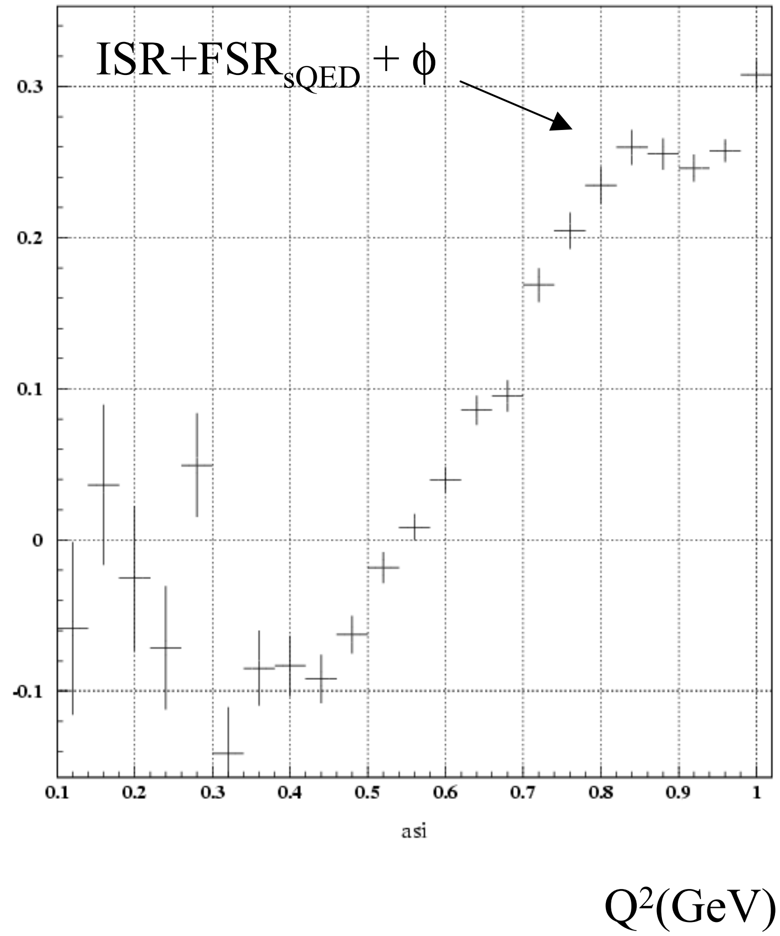




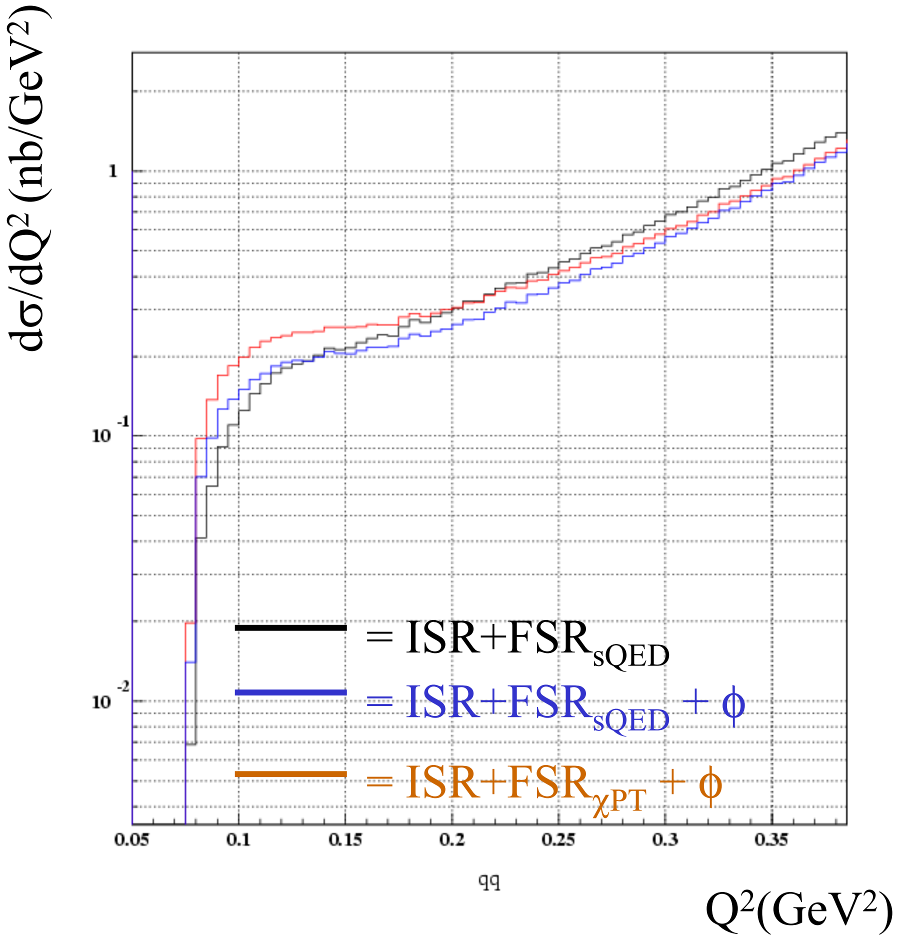
Effect al low Q^2…however the contribution of ϕ is not much accurate (no interference with σ has been taken into account)

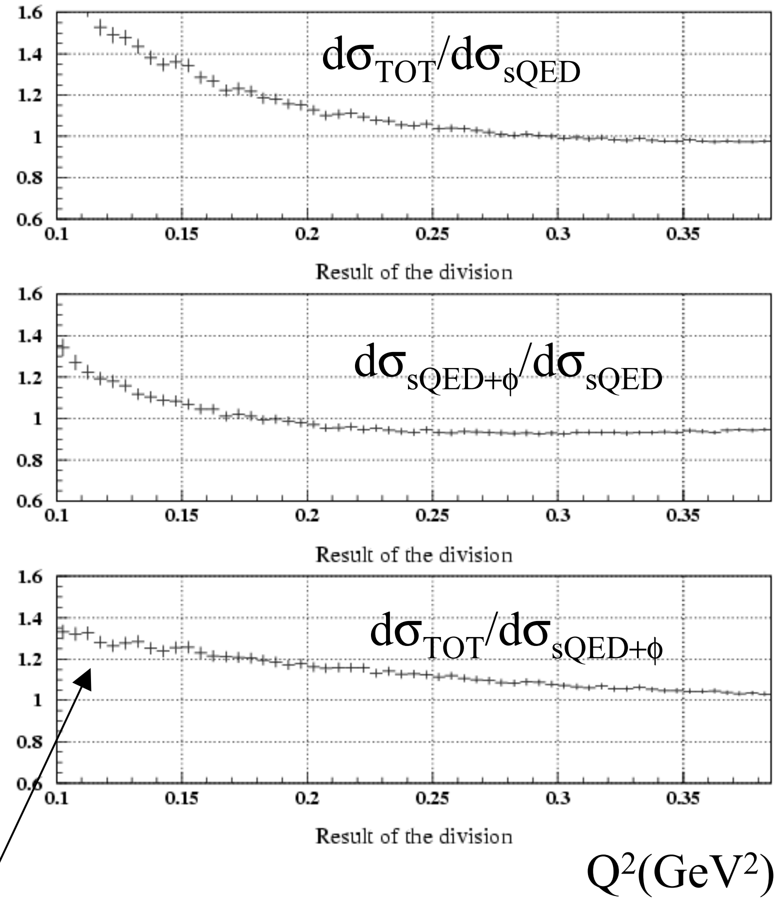
And asymmetry….





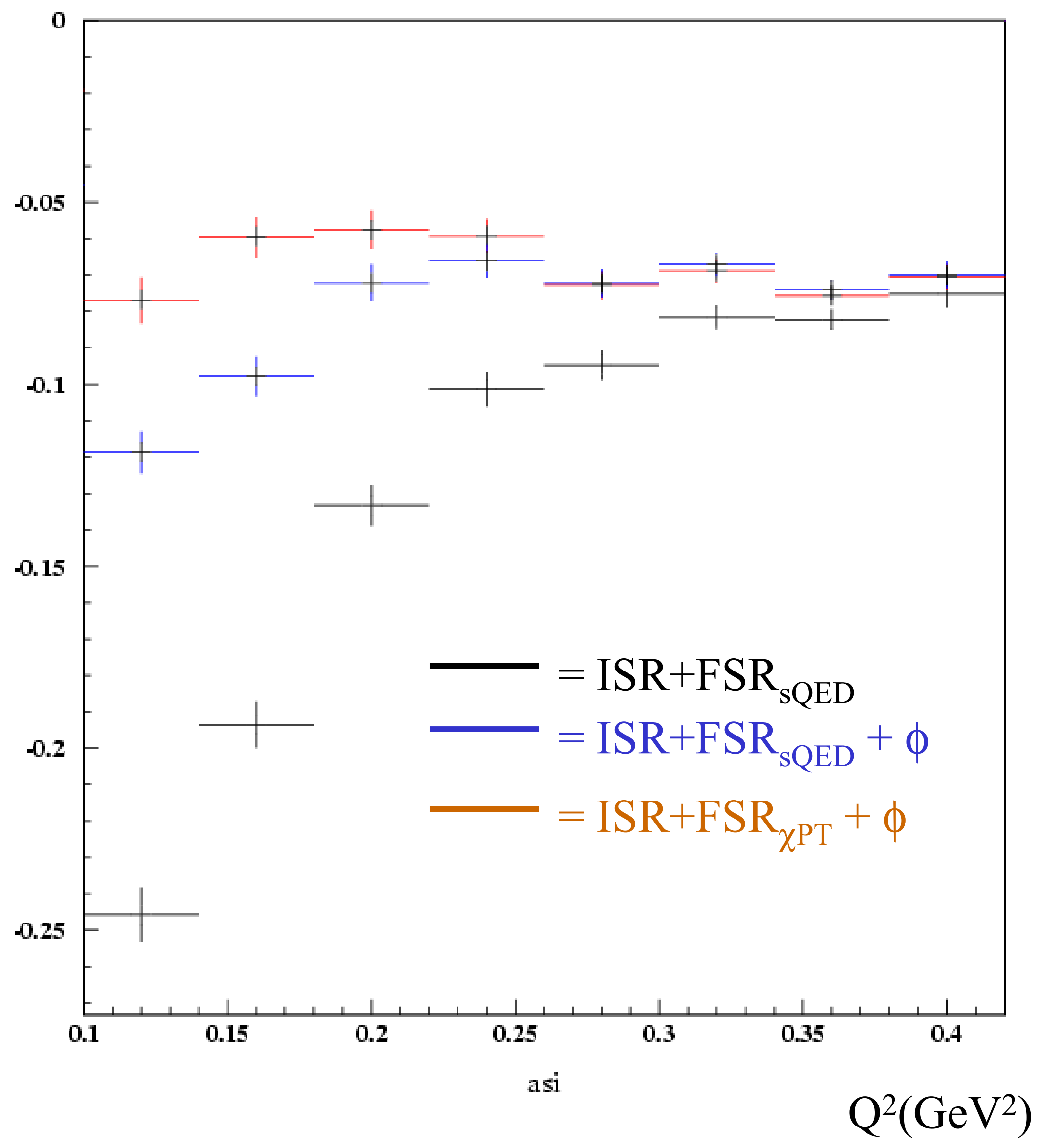
Zoom on the threshold region:





Up to 30% of contribution beyond sQED
at the threshold

And asymmetry…



Conclusions and outlook

- First MC results on a generalization of FSR using χPT have been presented.
- A sizeable effect can be seen on the cross section (at low Q^2).
- The situation on the asymmetry is less clear, but it strongly depends on the parametrization of the ϕ direct decay

- For the near future:
    - Improve the simulation:
        - better parametrization of ϕ (including also the σ meson)
        - consistency between the various parameters of the models in MC
    - Try to disentangle the various contributions:
        - Improve the knowledge on the phi decay (in particular at low Q^2):
        - Constraint fit with the neutral channel
        - asymmetry,and other kinematical variables (angular distributions)
        - <u>Work off resonance</u>
    - Model independent analysis of f_i?