Study of hadronic form factors relating Kloe and BaBar

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BaBar Collaboration

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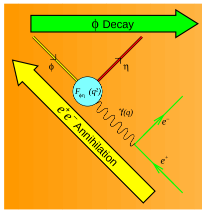
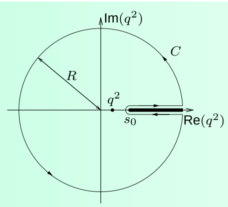
Outline

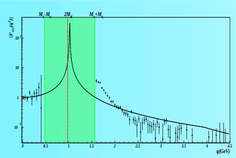
To test the power of our dispersive analytic continuation method, we apply this procedure to the $\phi\eta$ transition form factor (tff) data, obtained by collecting one third of the total statistics.



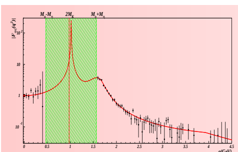
Extracting the tff from the data



Dispersion relations



First model of the $\phi\eta$ tff



A more complete approach

$\phi(1630)$	
M	$(1634 \pm 16)\ MeV$
Γ	$(213 \pm 20)\ MeV$
Fase	$(0.3 \pm 0.4)\ rad$

Analysis of the results and conclusions

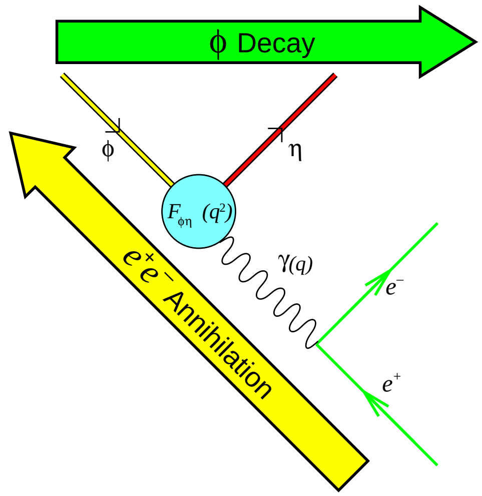
Extracting the tff from the data

$$e^+e^- \to \gamma^* \to \eta\phi$$

The cross-section is:

$$\sigma = \sigma_{\text{QED}} \cdot |f_{\phi\eta}(q^2)|^2$$

Point like



$$\phi \to \gamma^*\eta \to e^+e^-\eta$$

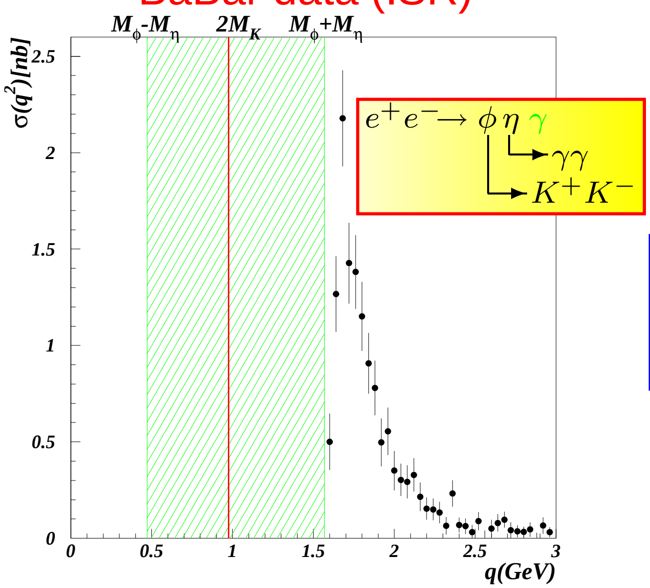
The diff. decay rate is:

$$\frac{d\Gamma}{dq^2} = \left[\frac{d\Gamma}{dq^2}\right]_{\text{QED}} \cdot |f_{\phi\eta}(q^2)|^2$$

radiative decay ($q^2 = 0$):

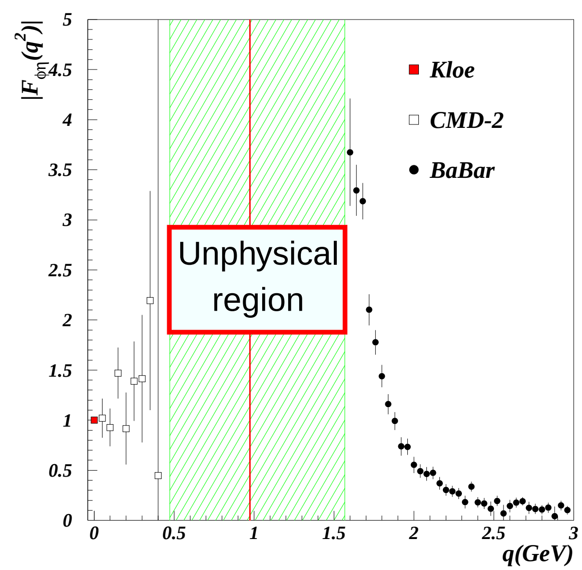
$$\Gamma = \Gamma_{\text{QED}} \cdot f_{\phi\eta}(0)^2$$

BaBar data (ISR)



$$F_{\phi\eta}(q^2) = \frac{f_{\phi\eta}(q^2)}{f_{\phi\eta}(0)}$$

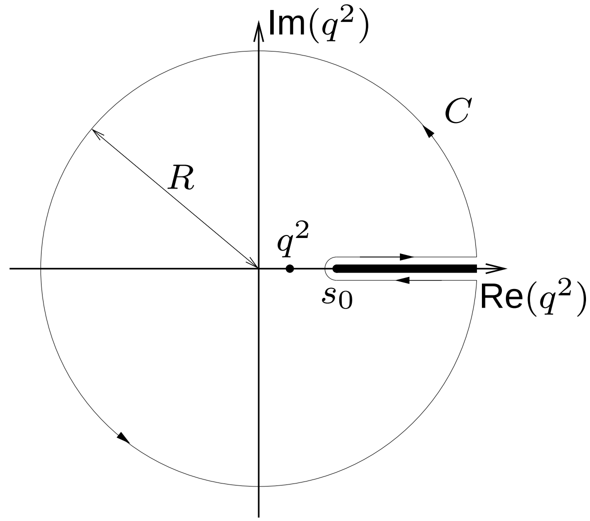
Data for the tff



Dispersion Relations

- Analyticity and Dispersion Relations connect the data below and above the threshold and constrain the value of the tff in the unphysical region.

$$f(q^2) = \frac{1}{\pi}\int_{s_0}^{\infty} \frac{\mathrm{Im} f(s)}{s - q^2} ds, \qquad q^2 < s_0 = (2M_K)^2$$



- The modulus $|f(s)|$ only is measured by BaBar $\Rightarrow$ dispersion relations on $\ln(f)$, if no important zero in the physical sheet (check in the following):

$$\ln f(q^2) = \frac{\sqrt{s_0 - q^2}}{\pi}\int_{s_0}^{\infty} \frac{\ln|f(s)| ds}{(s - q^2)\sqrt{s - s_0}}$$

- Furthermore:

$$\delta(s) = -\frac{\sqrt{s - s_0}}{\pi} \mathrm{Pr}\int_{s_0}^{\infty} \frac{\ln|f(s')| ds'}{(s' - s)\sqrt{s' - s_0}}, \qquad s > s_0$$

Only by means of the phase we are able to know if a bump near the threshold is a resonance or not

First Model for $F_{\phi\eta}(q^2)$

What we know

- $\phi(1020)\eta$ final state
  Isospin $= 0$
  2 $s\bar{s}$ valence quark pairs
  $\Longrightarrow$ ϕ-recurrences only can contribute to the tff
- According to QCD the asymptotic behaviour should be: $\lim_{s\to\infty} |F_{\phi\eta}(s)| \propto \left(\frac{1}{s}\right)^2$
- The super-convergence relation (SCR): $\frac{\sqrt{s_0}}{\pi}\int_{s_0}^{\infty}\frac{\ln|F_{\phi\eta}(s)|}{s\sqrt{s-s_0}}ds \equiv 0$
- Data from BaBar, Kloe and CMD-2.

First Model
tff dominated by
the $\phi(1020)$

$$F_{\phi\eta}(s) = \begin{cases} BW_\phi(s) = a_\phi \frac{-M_\phi\Gamma_\phi}{M_\phi^2 - s - i\Gamma_\phi M_\phi} & s \le s_{\text{asy}} \\ & s_{\text{asy}} = (4.5\ GeV)^2 \\ BW_\phi(s_{\text{asy}})\left(\frac{s_{\text{asy}}}{s}\right)^2 & s > s_{\text{asy}} \end{cases}$$

χ^2 definition and first result

$$\chi^2 = \chi^2_{\text{data}} + \chi^2_{\text{DR}}$$

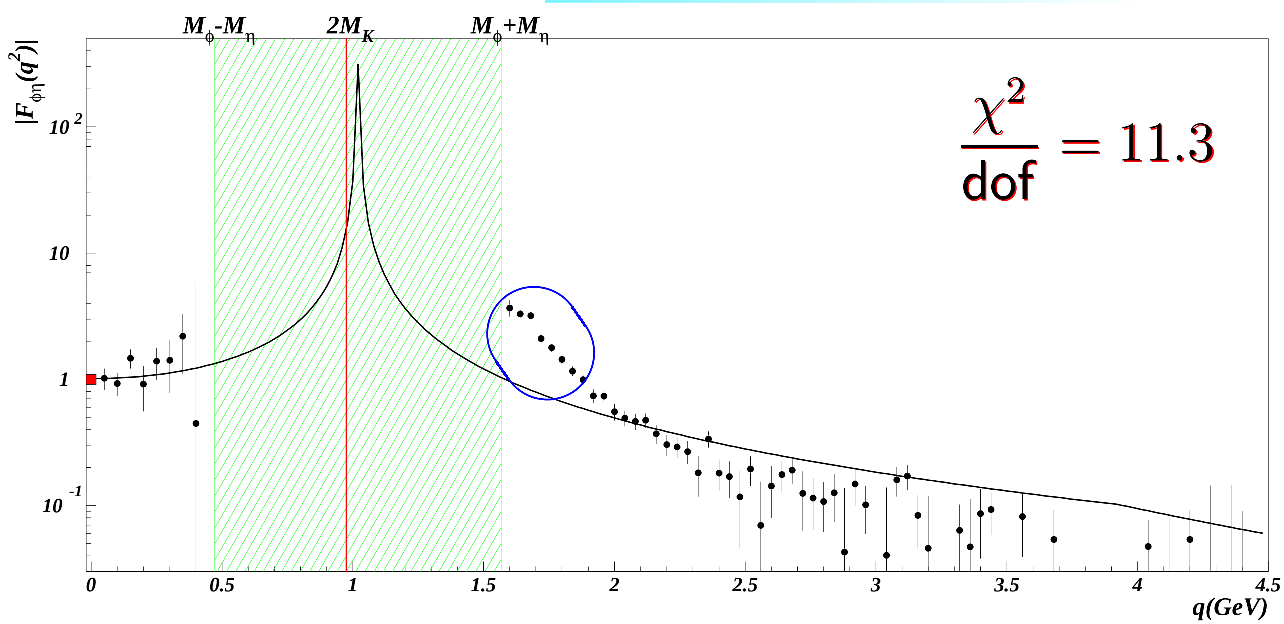
χ^2_{DR}:

- Continuity at $s = s_0$
- Super-Convergence
- Asymptotic Behaviour

χ^2_{data}:

- Kloe at $s = 0$
- CMD-2 in $[0, (M_\phi - M_\eta)^2]$
- BaBar in $[(M_\phi + M_\eta)^2, \sim (4.5\ GeV)^2]$

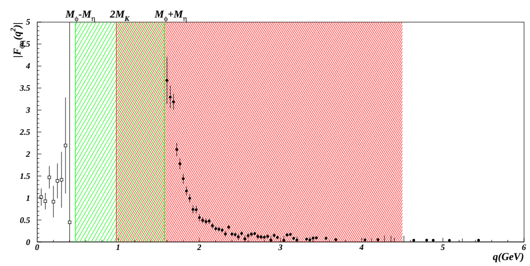
Only $\phi(1020)$



A more complete approach

- In the unphysical region above the threshold and in BaBar data region $[(2M_K)^2, (4.5\ GeV)^2]$:

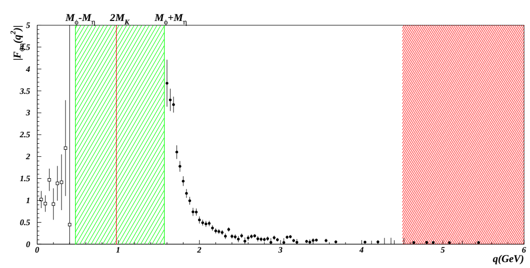
$$F(s) = BW_\phi(s) + \sum_{j=1}^{N} C_j T_j(x)$$



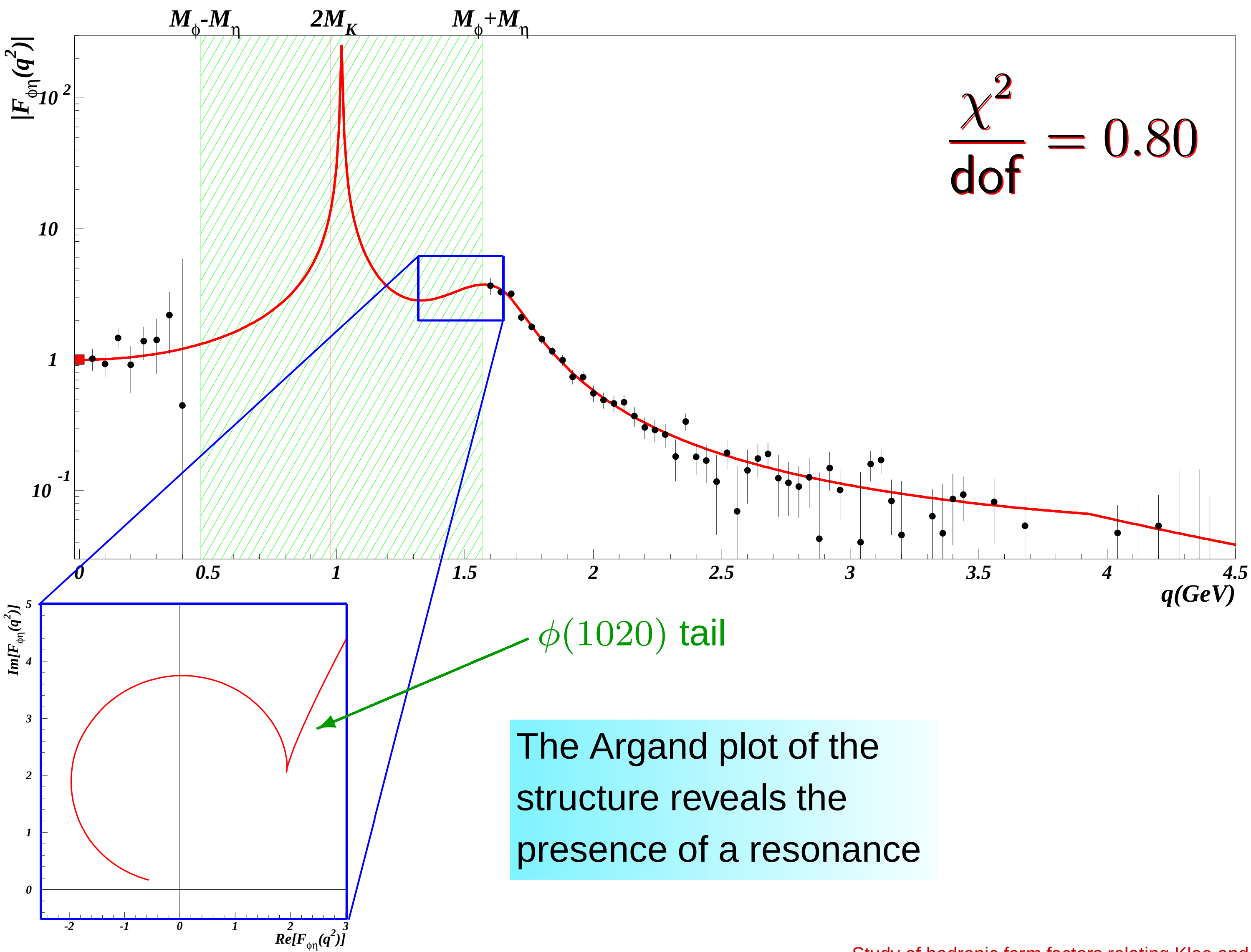
$T_j(x)$ are orthogonal Chebyshev polynomials. Every function, in a certain interval, can be approximated by a series of these polynomials. The coefficients C_j are complex numbers, i.e.: $C_j = u_j + iv_j$.

- In the asymptotic region $s > (4.5\ GeV)^2$, we use:

$$F(s) \propto \left(\frac{1}{s}\right)^2$$



Using $N = 4$ Chebyshev polynomials series



The Argand plot of the structure reveals the presence of a resonance

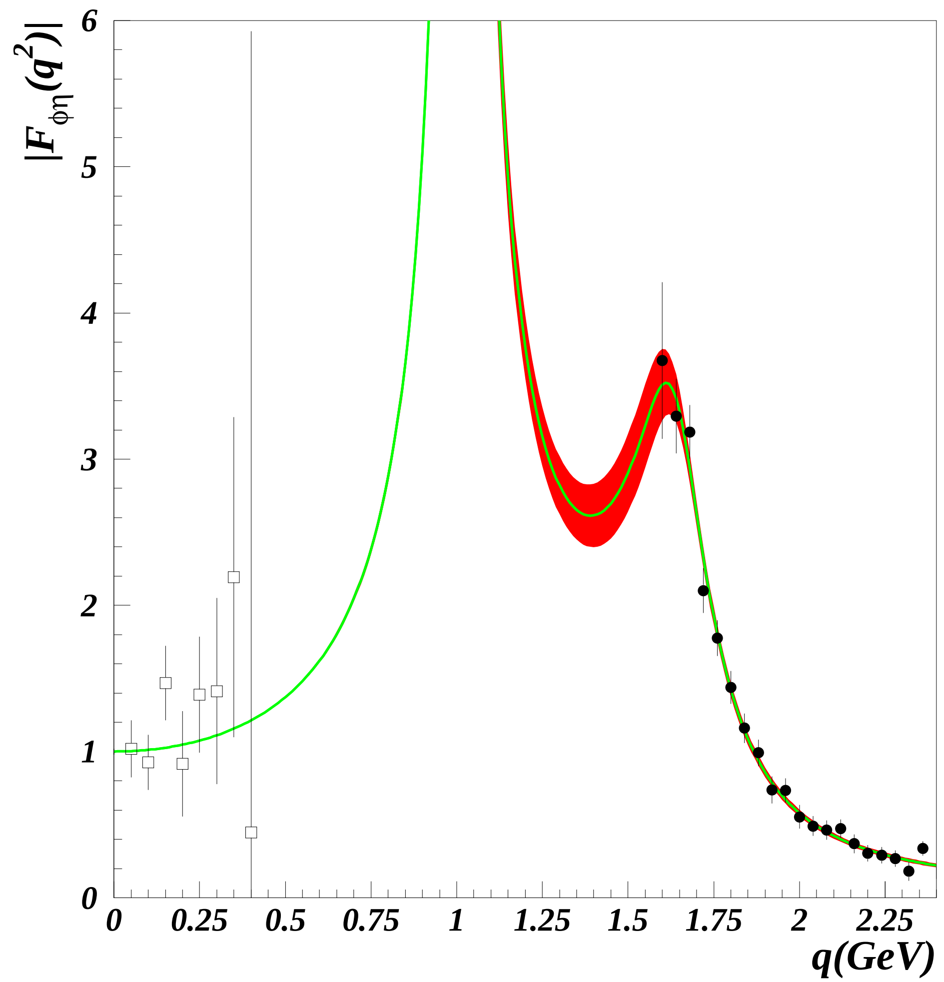
Analysis of the $\phi(1635)$ candidate

To analyze the properties of the pole we use this function:

$$F(s) = BW_\phi(s) + \frac{r_1 s + r_2}{s + r_3}$$

the coefficients r_j are complex.

$\phi(1635)$	
M	$(1634 \pm 16)\ MeV$
Γ	$(213 \pm 20)\ MeV$
Phase	$(0.3 \pm 0.4)\ rad$

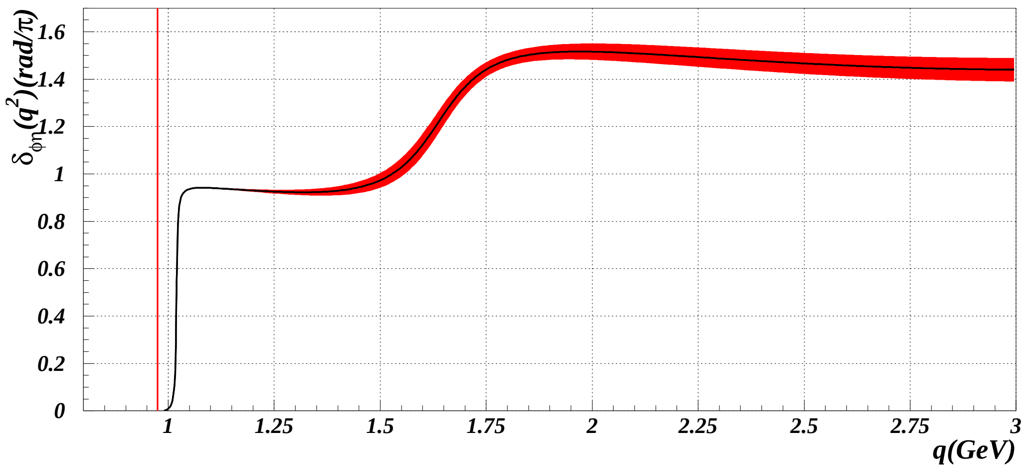


Phase and consistency check

By means of the DR:

$$\delta(s) = -\frac{\sqrt{s-s_0}}{\pi} \Pr\int_{s_0}^{\infty} \frac{\ln|F_{\phi\eta}(s')|}{(s'-s)\sqrt{s'-s_0}} ds',$$

with: $F_{\phi\eta}(s) = |F_{\phi\eta}(s)|e^{i\delta(s)}$, we have:



By means of the dispersion relation for the imaginary part, the value at $s = 0$ can be tested:

$$F_{\phi\eta}(0) = \frac{1}{\pi}\int_{s_0}^{\infty} \frac{\text{Im}F_{\phi\eta}(s)}{s} ds = 1.0010 \pm 0.0011$$

the expectation is 1.

This result is a check of:

- the self-consistency of the approach;
- the hypothesis of no important contributing zero.

Conclusions

- A general procedure has been applied to link the amplitudes of: $\phi \to M\gamma$, $\phi \to M e^+ e^-$ and $e^+ e^- \to \phi M$, where M is a generic light meson.
- In the case $M \equiv \eta$, by using the genuine Kloe, CMD-2 data and the “partial” BaBar data as inputs in a dispersive approach, the $\phi\eta$ tff has been reconstructed in the whole time-like region, in a model independent way.
- The analysis of this tff reveals a “possible” resonance, $\phi(1635)$, near by the threshold.
- The analysis of other $\phi(1635)$ decay channels like: $K^+ K^- \pi^0$, $K_s K^\pm \pi^\mp$ is in progress.

- The same procedure has been applied to the tff ratios $\phi\eta' / \phi\eta$ and $\phi f_0 / \phi\eta$, in order to study the corresponding radiative decay rates. The estimated rate, in the case of η' is in agreement with the PDG value, while, in the very interesting case of f_0, we find a strong discrepancy.