Differences of masses and widths of the charged and neutral $\rho(770)$, $\rho(1450)$, $\rho(1700)$ mesons from data on electro-weak processes

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Abstract

The $\rho(770)$, $\rho(1450)$, $\rho(1700)$ mesons exist in three charged states ρ^0, ρ^+ and ρ^-, whereby masses of positively charged mesons are identical with masses of negatively charged mesons, due to the CPT theorem. However, there is no reason for the identity of charged meson masses with neutral meson masses. For determination of differences of masses and decay widths of charged and neutral $\rho(770)$, $\rho(1450)$, $\rho(1700)$ mesons are employed the data on $e^+e^- \to \pi^+\pi^-$ an $\tau^- \to \pi^-\pi^0\nu_\tau$ processes to be analyzed by the Unitary and Analytic models of the electromagnetic and weak pion form factors, respectively.

Parameters of $\rho(770)$

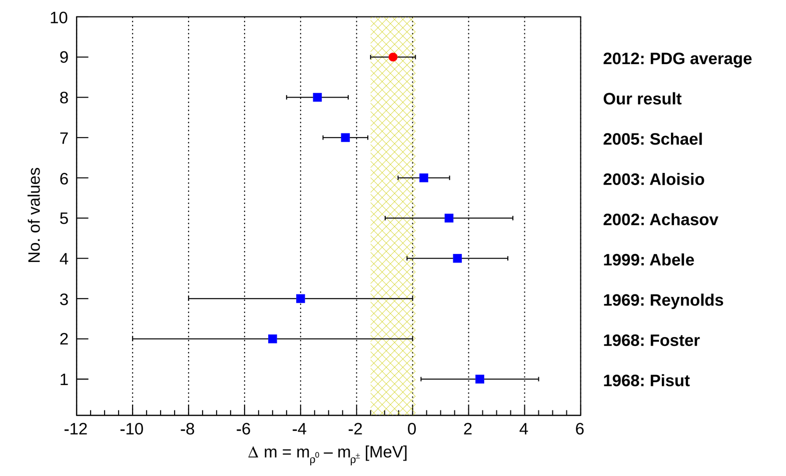
$\Gamma_{\rho^0} - \Gamma_{\rho^\pm}$ [MeV]	Processes
$3.6 \pm 1.8 \pm 1.7$	$e^+e^- \to \pi^+\pi^-\pi^0$
-0.2 ± 1.0	$\tau^- \to \pi^-\pi^0\nu_\tau$
0.3 ± 1.3	PDG average

$\Gamma_{\rho^+} - \Gamma_{\rho^-}$ [MeV]	
$1.8 \pm 2.0 \pm 0.5$	$e^+e^- \to \pi^+\pi^-\pi^0$

$m_{\rho^0} - m_{\rho^\pm}$ [MeV]	Processes
2.4 ± 2.1	$\pi^\pm p \to \rho N$
-5 ± 5	$pp \to \rho\pi$
-4 ± 4	$\pi^- p \to \rho N$
$1.6 \pm 0.6 \pm 1.7$	$pp \to \pi^+\pi^-\pi^0$
$1.3 \pm 1.1 \pm 2.0$	$e^+e^- \to \pi^+\pi^-\pi^0$
$0.4 \pm 0.7 \pm 0.6$	$e^+e^- \to \pi^+\pi^-\pi^0$
-2.4 ± 0.8	$\tau^- \to \pi^-\pi^0\nu_\tau$
-0.7 ± 0.8	PDG w. average

$J^{PC} = 1^{--}$

$$\begin{cases} \rho^+ \to \pi^+\pi^0 & u\bar{d} \\ \rho^0 \to \pi^+\pi^- & \frac{1}{\sqrt{2}}(u\bar{u}\text{-}d\bar{d}) \\ \rho^- \to \pi^-\pi^0 & \bar{u}d \end{cases}$$



Mass difference of ρ^0 and $\rho^\pm$ mesons for the state $\rho(770)$, the comparision of our and previous results.

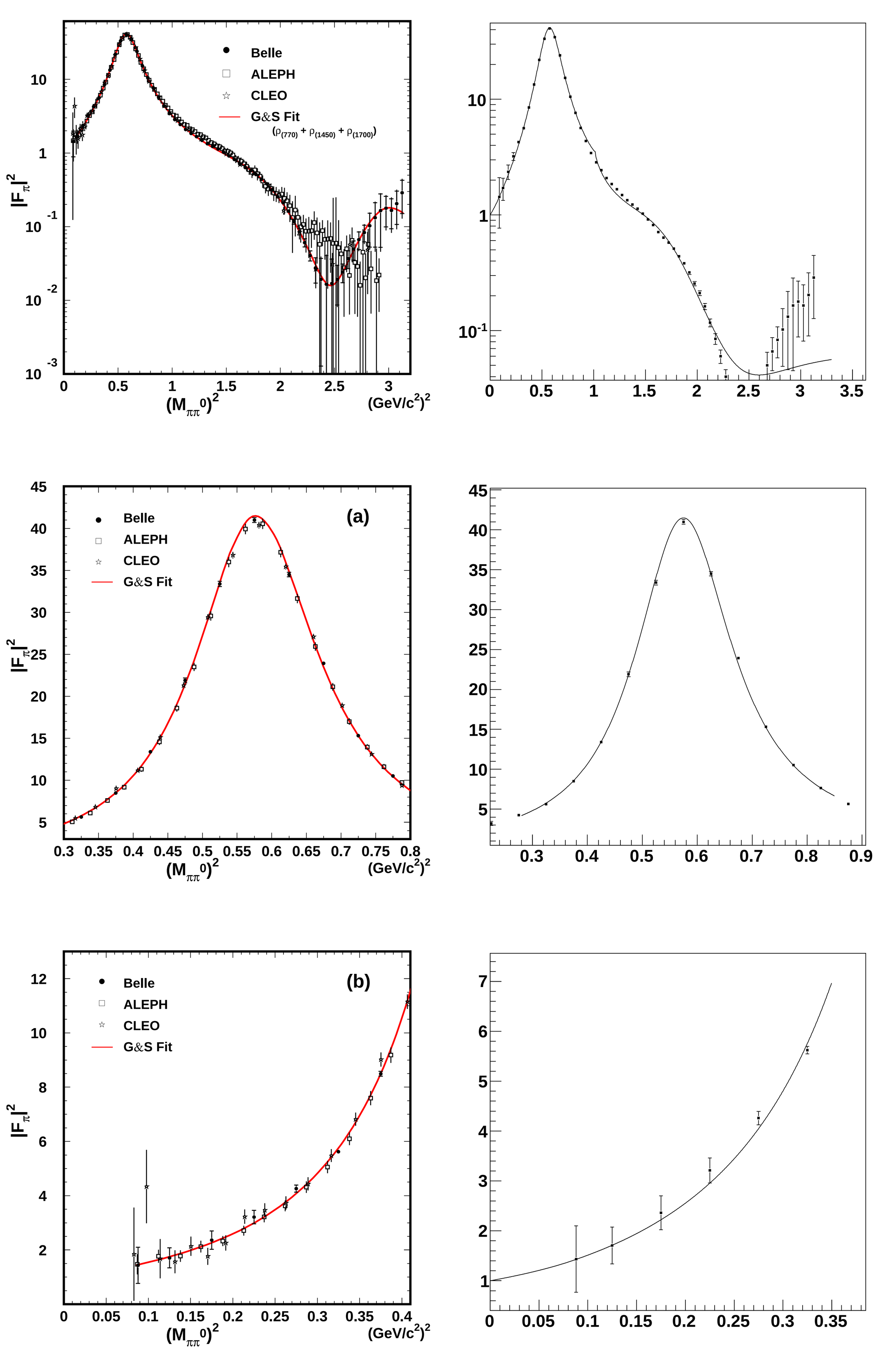
Weak and EM FF

Conserved **V**ector **C**urrrent hypothesis [1]: relation of spectral functions for systems $\pi^-\pi^0$ and $\pi^+\pi^-$

$$\sigma_{\overline{\nu}_e e^- \to \pi^-\pi^0}(t) = \frac{\pi\alpha^2}{6t}\left(1 - \frac{4m_\pi^2}{t}\right)^{3/2}\left|F_\pi^W(s)\right|^2, \qquad F_\pi^W(s) = \sqrt{2}\,F_\pi^{E,I=1}(s)$$

$$\sigma_{e^+e^- \to \pi^+\pi^-}(t) = \frac{\pi\alpha^2}{3t}\left(1 - \frac{4m_\pi^2}{t}\right)^{3/2}\left|F_\pi^{E,I=1}(s) + Re^{i\phi}\frac{m_\omega^2}{m_\omega^2 - t - im_\omega\Gamma_\omega}\right|^2$$

Comparison of fits



left column — exp. results, right column — our prediction

U&A model of pion

Main properties of Unitary &Analytic model of π

- $F_\pi(t)$ – analytic function in the whole complex t-plane besides the cut $4m_\pi^2 \to \infty$
- $|F_\pi(t)|_{t\to\infty} \sim t^{n_q - 1} \sim t^{-1}$ – asymptotic behavior of FF (n_q – number of quarks)
- $F_\pi(0) = 1$, normalization in $t = 0$, next unitarity condition
- $$\frac{1}{2i}\left\{\langle \pi^+\pi^-|J_\mu^{EM}(0)|0\rangle\langle 0|J_\mu^{EM}(0)|\pi^+\pi^-\rangle^\star\right\} = \sum_n \langle \pi^+\pi^-|T^+|n\rangle\langle n|J_\mu^{EM}(0)|0\rangle$$

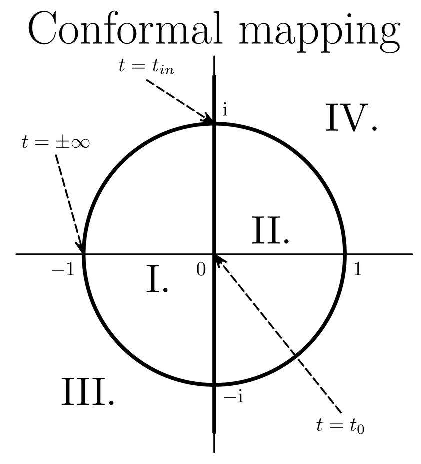
with reality condition $(F_\pi(t))^\star = F_\pi(t^\star)$ leads to elastic unitarity condition for form factor:

$$\operatorname{Im} F_\pi(t) = (A_1^1(t))^\star F_\pi(t) + \sigma(t)$$

$A_1^1(t)$ – P wave isovector elastic $\pi\pi$ scattering amplitude, $\sigma(t)$ – higher contributions

U&A model:

Conformal mapping



$$F_\pi[W(t)] = \left(\frac{1-W^2}{1-W_N^2}\right)^2 \frac{(W-W_Z)(W_N-W_P)}{(W_N-W_Z)(W-W_P)}$$
$$\times\left\{\frac{(W_N-W_\rho)(W_N-W_\rho^*)}{(W-W_\rho)(W\_W_\rho^*)}\frac{(W_N-1/W_\rho)(W_N-1/W_\rho^*)}{(W-1/W_\rho)(W-1/W_\rho^*)}\left(\frac{f_{\rho\pi\pi}}{f_\rho}\right)\right.$$
$$\left.+\sum_{v=\rho',\rho''}\left[\frac{(W_N-W_v)(W_N-W_v^*)}{(W-W_v)(W\_W_v^*)}\frac{(W_N+W_v)(W_N+W_v^*)}{(W+W_v)(W+W_v^*)}\right]\left(\frac{f_{v\pi\pi}}{f_v}\right)\right\},$$

$$0 < W_{Z,P} < 1, \quad W_N \ldots t = 0, \quad \left(\frac{f_{\rho'\pi\pi}}{f_{\rho'}}\right), \left(\frac{f_{\rho''\pi\pi}}{f_{\rho''}}\right) \sim \left(\frac{f_{\rho\pi\pi}}{f_\rho}\right)$$

$$W(t) = i\frac{\sqrt{q_{in}+q} - \sqrt{q_{in}-q}}{\sqrt{q_{in}+q} + \sqrt{q_{in}-q}}, \quad q = \sqrt{\frac{t-t_0}{4}}, \quad q_{in} = \sqrt{\frac{t_{in}-t_0}{4}}$$

10 parameters: t_{in}, m_ρ, Γ_ρ, $m_{\rho'}$, $\Gamma_{\rho'}$, $m_{\rho''}$, $\Gamma_{\rho''}$, $f_{\rho\pi\pi}/f_\rho$, W_Z, W_P (number comparable with Belle)

Main goal:

- Analyse of e^+e^- data → **electromagnetic** form factor of π → masses of **neutral** ρ, ρ', ρ'' mesons
- Analyse of τ^- data → **weak** form factor of π → masses of **charged** ρ, ρ', ρ'' mesons

Results of calculations:

Parameter	ρ^0 [MeV] (e^+e^- data)	$\rho^\pm$ [MeV] (τ^- data)	Δ (ρ^0-$\rho^\pm$) [MeV]
$m_{\rho(770)}$	758.23 ± 0.46	761.60 ± 0.95	-3.37 ± 1.06
$m_{\rho(1450)}$	1342.31 ± 46.62	1373.83 ± 11.37	-31.53 ± 47.99
$m_{\rho(1700)}$	1718.50 ± 65.44	1766.80 ± 52.36	-48.30 ± 83.81
$\Gamma_{\rho(770)}$	144.56 ± 0.80	139.90 ± 0.46	4.66 ± 0.85
$\Gamma_{\rho(1450)}$	492.17 ± 138.38	340.87 ± 23.84	151.30 ± 140.42
$\Gamma_{\rho(1700)}$	489.58 ± 16.95	414.71 ± 119.48	74.87 ± 120.67

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