Two-meson form factors from dispersion relations

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Future Challenges in Non-Leptonic B Decays: Theory and Experiment

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CONTENTS

- INTRODUCTION
- $\pi\pi$ VFF
- Other two-meson VFFs
- SUMMARY

INTRODUCTION

Three-Body I

08:30 – 09:20	Thomas Edward Latham	**Experimental results from *B* decays to charmless and open-charm 3-body final states**
09:20 – 10:10	Thomas Mannel	**Three-body non-leptonic *B* decays and QCD Factorization**

CPV

α,γ

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Two-pion systems

13:50 – 14:40	Pablo Roig Garcés	**Two-meson form factors from dispersion relations**
14:40 – 15:30	Pere Masjuan	**Padé Theory: A toolkit for hadronic form factors**

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16:00 – 16:45	Bastian Kubis	**Dispersive methods in heavy-meson decays**
16:45 – 17:30	Ignacio De Bediaga Hickman	**CP violation and CPT invariance in charmless three-body *B* decays**
17:30 – 18:15	Hai-Yang Cheng	**Branching fractions and CP violation in hadronic three-body *B* decays**
18:15 – 18:30	Patricia Magalhães	**Final state interaction on B+ → pi+pi-pi+**

Mixed Two/Three Body

08:30 – 09:20	Luis Alejandro Perez Perez	**Phenomenology of *B*->Kpipi modes and prospects with LHCb and Belle II data**
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Kπ

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ππ VFF

- Disclaimer: Talk focused in DRs using χPT (+Res) input

  Other approaches: Gounaris-Sakurai ‘68, Heyn-Lang ‘81, Truong’88, Kühn-Santamaría ‘90, Hannah ’96-’97,
  Domínguez ‘01, Cillero-Pich ‘03, Bruch-Khodjamirian-Kühn ‘05, Czyz-Grzelinska-Kühn ‘10,
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VFF

$\tau^- \to \nu_\tau \pi^- \pi^0$

$e^+ e^- \to \pi^+ \pi^-$

(s>0, B/Φ factories)

$e^- \pi^+ \to e^- \pi^+$

(s<0, NA7)

$\pi^+ \pi^- \to \pi^+ \pi^-$

(Via Watson’s FSI Th.)

SU(2)$_I$

Cirigliano-Ecker-Neufeld ‘01,’02
Descotes-Genon—Moussallam ‘14

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→ *These data are very useful input but still not enough to allow complete reconstruction of **VFF** (**modulus & phase**)*

→ The approximate **χ symm**etry of low-E **QCD** determines the **VFF** and is a good starting point to reach GeV energies

ππ VFF

Near threshold, $SU(n_f)_L xSU(n_f)_R \to SU(n_f)_V$, **χPT**, determines the low-energy expansion of the VFF:

(Gasser-Leutwyler ‘85)

$$F(s)^{\mathrm{ChPT}} = 1 + \frac{2L_9^r(\mu)}{f_\pi^2} s - \frac{s}{96\pi^2 f_\pi^2} \times \left[A\left(m_\pi^2/s, m_\pi^2/\mu^2\right) + \frac{1}{2} A\left(m_K^2/s, m_K^2/\mu^2\right) \right]$$

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To enlarge the domain of applicability, **DRs** and unitarization techniques (Oller-Oset-Palomar ’01, De Trocóniz-Ynduráin ’02) have been employed

(Guerrero-Pich ’97, Pich-Portolés ’01, Gómez-Dumm—PR ‘13, Celis-Cirigliano-Passemar ’14)

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- F(s) is **analytic** except for a cut starting at ππ threshold, disc(Im[F(s)])≠0.

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- **Unitarity** in the elastic región implies

(Omnès '58)

$$F_V^\pi(s) = P_n(s) \exp\left\{ \frac{s^n}{\pi} \int_{s_{\mathrm{thr}}}^\infty ds' \frac{\delta_1^1(s')}{(s')^n (s' - s - i\epsilon)} \right\} \qquad \log P_n(s) = \sum_{k=0}^{n-1} \alpha_k \frac{s^k}{k!}$$

(Watson's FSI Th.)

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Then, our approach is to obtain $F_V^{\pi(0)}(s)$ from **χPT with resonances** (Pich-Portolés ’01, Gómez-Dumm—PR ‘13, Celis-Cirigliano-Passemar ’14).

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ρV_μ $\qquad$ $\rho\pi\pi$

$$F_V^\pi(s) = 1 + \frac{F_V G_V}{F_\pi^2} \frac{s}{M_V^2 - s}$$

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$$F_V^\pi(s) = 1 + \frac{F_V G_V}{F_\pi^2} \frac{s}{M_V^2 - s} \xrightarrow{s\to\infty} 0 \longrightarrow F_V G_V = F_\pi^2 \longrightarrow F_V^\pi(s) = \frac{M_\rho^2}{M_\rho^2 - s}$$

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$$F(s)^{\text{ChPT}} = 1 + \frac{2L_9^r(\mu)}{f_\pi^2} s - \frac{s}{96\pi^2 f_\pi^2} \times \left[A(m_\pi^2/s, m_\pi^2/\mu^2) + \tfrac{1}{2} A(m_K^2/s, m_K^2/\mu^2) \right]$$ (Gasser-Leutwyler '85)

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- Matching to the $O(p^4)$ χPT result gives $$F_V^\pi(s) = \frac{M_\rho^2}{M_\rho^2 - s} - \frac{s}{96\pi^2 F^2}\left[A_\pi(s) + \frac{1}{2} A_K(s)\right]$$

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The corresponding Omnès solution would be $$F_V^\pi(s) = \frac{M_\rho^2}{M_\rho^2 - s} \exp\left\{ -\frac{s}{96\pi^2 F^2}\left[A_\pi(s) + \frac{1}{2} A_K(s)\right]\right\}$$

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Naïve inclusión of resonance width leads to analyticity breakdown (replace $M^2 - s$ by $M^2 - s - iM\Gamma(s)$)

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Guerrero-Pich'97 delays breaking

$$F(s) = \frac{M_\rho^2}{M_\rho^2 - s - iM_\rho\Gamma_\rho(s)}\exp\left\{\frac{-s}{96\pi^2 f_\pi^2}\times\left[\mathrm{Re}\, A\left(m_\pi^2/s, m_\pi^2/M_\rho^2\right) + \tfrac{1}{2}\mathrm{Re}\, A\left(m_K^2/s, m_K^2/M_\rho^2\right)\right]\right\}$$

$$\Gamma_\rho(s) = -\frac{M_\rho s}{96\pi^2 F_\pi^2}\,\mathrm{Im}\left[A_\pi(s) + \frac{1}{2}A_K(s)\right] = \frac{sM_\rho}{96\pi F_\pi^2}\left[\theta(s-4m_\pi^2)\sigma_\pi^3(s) + \frac{1}{2}\theta(s-4m_K^2)\sigma_K^3(s)\right]$$

ππ VFF

$$F_V^\pi(s) = P_n(s)\exp\left\{\frac{s^n}{\pi}\int_{s_{\rm thr}}^\infty ds'\,\frac{\delta_1^1(s')}{(s')^n(s'-s-i\epsilon)}\right\} \qquad \log P_n(s) = \sum_{k=0}^{n-1}\alpha_k\frac{s^k}{k!}$$ (Omnès '58)

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$$F(s) = \frac{M_\rho^2}{M_\rho^2 - s - iM_\rho\Gamma_\rho(s)}\exp\left\{\frac{-s}{96\pi^2 f_\pi^2}\times\left[\mathrm{Re}\,A\left(m_\pi^2/s, m_\pi^2/M_\rho^2\right) + \tfrac{1}{2}\mathrm{Re}\,A\left(m_K^2/s, m_K^2/M_\rho^2\right)\right]\right\}$$

Instead we **resum** the **loop functions** in the **effective propagator** (Gómez-Dumm—PR '13, Celis-Cirigliano-Passemar '14)

$$F_V^{\pi(0)}(s) = \frac{M_\rho^2}{M_\rho^2[1+\frac{s}{96\pi^2F_\pi^2}(A_\pi(s)+\frac{1}{2}A_K(s))]-s} = \frac{M_\rho^2}{M_\rho^2[1+\frac{s}{96\pi^2F_\pi^2}\mathrm{Re}(A_\pi(s)+\frac{1}{2}A_K(s))]-s-iM_\rho\Gamma_\rho(s)}$$

$$\Gamma_\rho(s) = -\frac{M_\rho s}{96\pi^2F_\pi^2}\,\mathrm{Im}\left[A_\pi(s)+\frac{1}{2}A_K(s)\right] = \frac{sM_\rho}{96\pi F_\pi^2}\left[\theta(s-4m_\pi^2)\sigma_\pi^3(s)+\frac{1}{2}\theta(s-4m_K^2)\sigma_K^3(s)\right]$$

(See Guerrero'98 for the reproduction of NNLO χPT results by this resummation)

ππ VFF

$$F_V^\pi(s) = P_n(s)\exp\left\{\frac{s^n}{\pi}\int_{s_{\rm thr}}^\infty ds'\,\frac{\delta_1^1(s')}{(s')^n(s'-s-i\epsilon)}\right\} \qquad \log P_n(s) = \sum_{k=0}^{n-1}\alpha_k\frac{s^k}{k!}$$ (Omnès '58)

$$\tan\delta_1^1(s) = \frac{\mathrm{Im}\,F_V^{\pi(0)}(s)}{\mathrm{Re}\,F_V^{\pi(0)}(s)}$$ (Boito-Escribano-Jamin '09)

Guerrero-Pich'97 delays breaking

$$F(s) = \frac{M_\rho^2}{M_\rho^2 - s - iM_\rho\Gamma_\rho(s)}\exp\left\{\frac{-s}{96\pi^2 f_\pi^2}\times\left[\mathrm{Re}\,A\left(m_\pi^2/s, m_\pi^2/M_\rho^2\right) + \tfrac{1}{2}\mathrm{Re}\,A\left(m_K^2/s, m_K^2/M_\rho^2\right)\right]\right\}$$

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And we use the DR with n=3

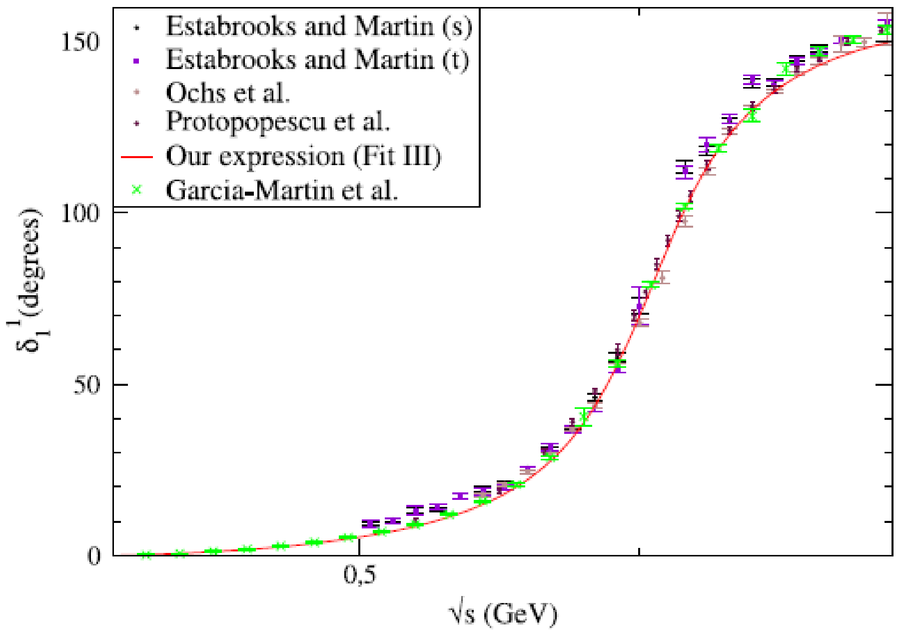
(See Guerrero'98 for the reproduction of NNLO χPT results by this resummation)

$$F_V^\pi(s) = \exp\left[\alpha_1 s + \frac{\alpha_2}{2}s^2 + \frac{s^3}{\pi}\int_{s_{\rm thr}}^\infty ds'\,\frac{\delta_1^1(s')}{(s')^3(s'-s-i\epsilon)}\right] \qquad \delta_1^1(s\to\infty) = \pi$$

ππ VFF

As a result of this setting, good description of phaseshift data (from ππ scattering) is found [same for the modulus, which is shown later]

$F_V^{\pi}(s)$ is fitted and $\delta^1_1(s)$ is prediction



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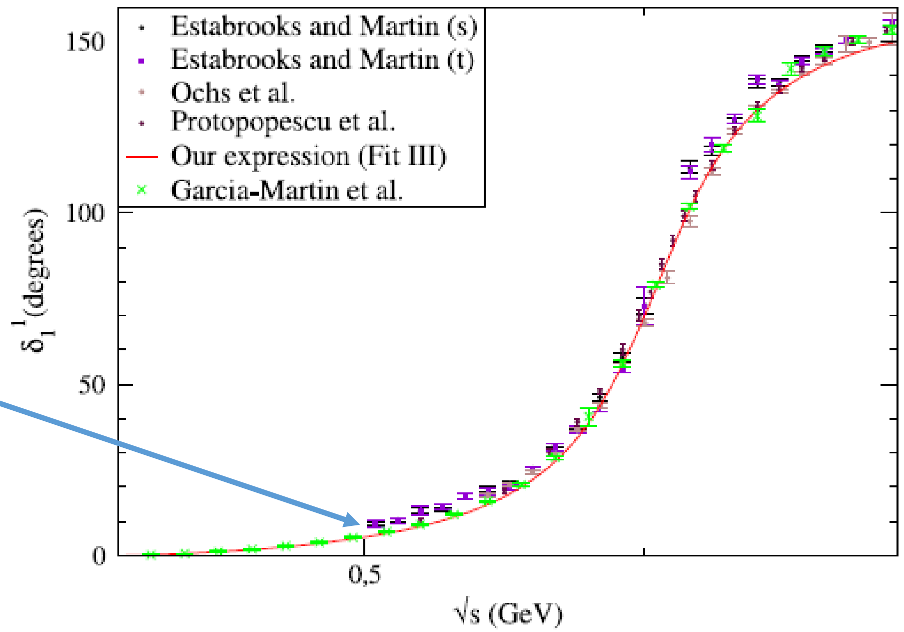
$\sqrt{s_{\pi/2}} = (775.0 \pm 0.2)$ MeV Our result

$\sqrt{s_{\pi/2}} = (774 \pm 3)$ MeV Bern group



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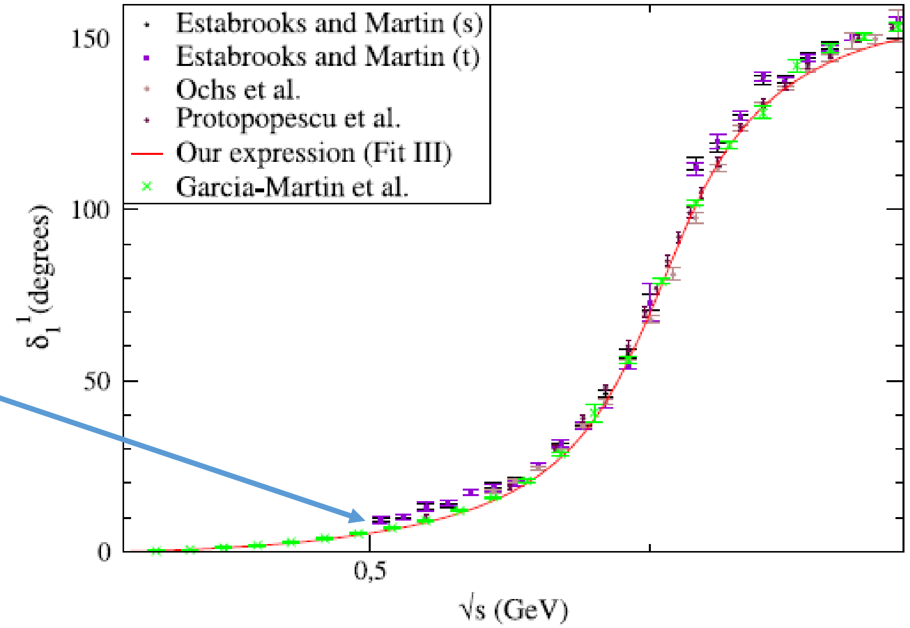
$$F_V^{\pi}(s) = 1 + \frac{1}{6}\langle r^2\rangle_V^{\pi} s + c_V^{\pi} s^2 + d_V^{\pi} s^3 + \cdots \qquad \langle r^2\rangle_V^{\pi} = 6\alpha_1, \qquad c_V^{\pi} = \frac{1}{2}(\alpha_2 + \alpha_1^2)$$

Our values agree well with previous determinations

$$d_V^{\pi} = \frac{1}{6}(\alpha_3 + 3\alpha_1\alpha_2 + \alpha_1^3) = 9.84 \pm 0.05 \text{ GeV}^{-6}$$

Previous determinations (GeV^{-6}): 9.70 ± 0.40, 10.18 ± 0.27



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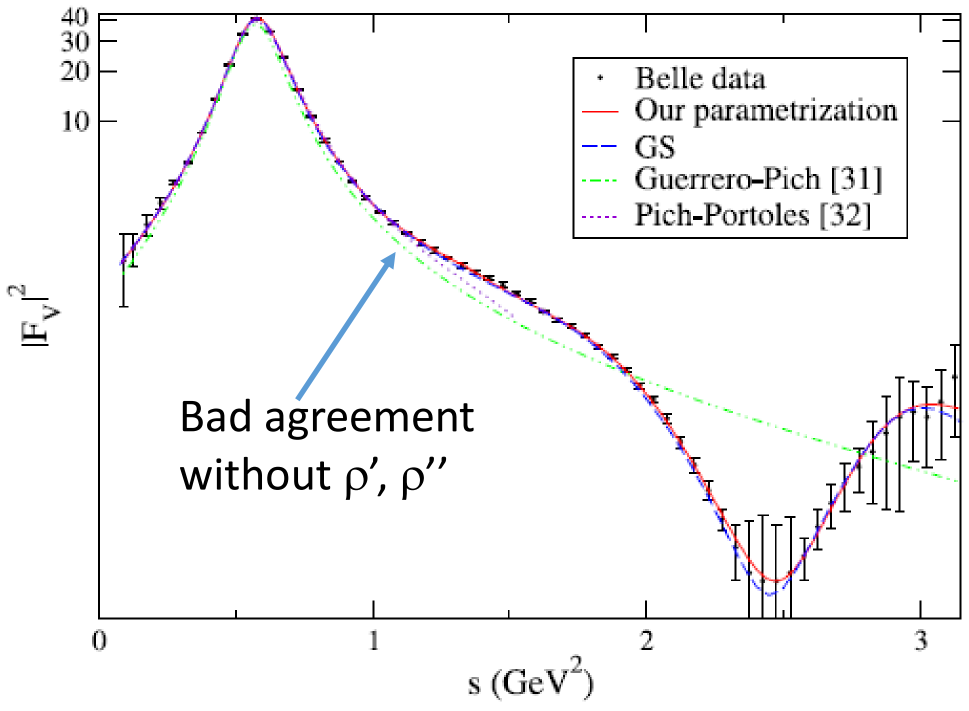

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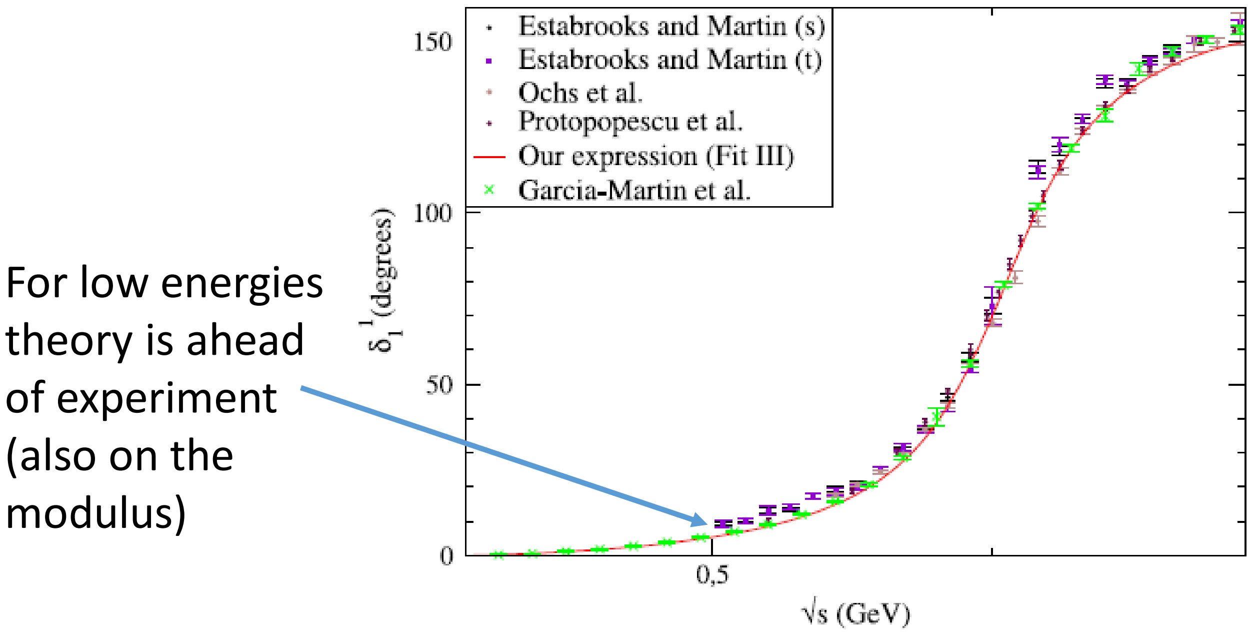

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(Gómez-Dumm—PR ‘13, Celis-Cirigliano-Passemar ’14)

$$F_V^\pi(s) = \frac{M_\rho^2 + (\alpha' e^{i\phi'} + \alpha'' e^{i\phi''})s}{M_\rho^2[1 + \frac{s}{96\pi^2 F_\pi^2}(A_\pi(s) + \frac{1}{2}A_K(s))] - s} - \frac{\alpha' e^{i\phi'} s}{M_{\rho'}^2[1 + sC_{\rho'}A_\pi(s)] - s} - \frac{\alpha'' e^{i\phi''} s}{M_{\rho''}^2[1 + sC_{\rho''}A_\pi(s)] - s}$$

$$C_R = \frac{\Gamma_R}{\pi M_R^3 \sigma_\pi^3(M_R^2)}$$

$M_\rho^{\text{pole}} = (760 \pm 2)$ MeV, $\Gamma_\rho^{\text{pole}} = (147 \pm 6)$ MeV

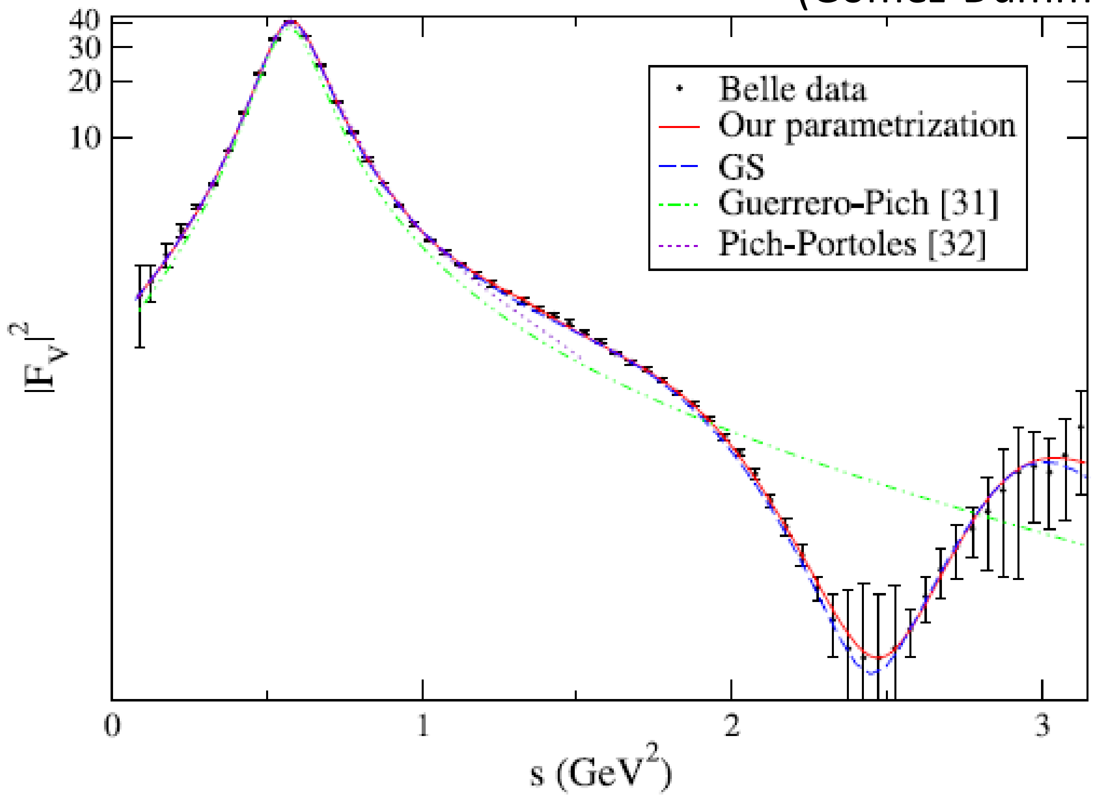
$M_{\rho'}^{\text{pole}} = (1.44 \pm 0.08)$ GeV, $M_{\rho''}^{\text{pole}} = (1.72 \pm 0.09)$ GeV, $\alpha' = 0.08^{+0.03}_{-0.01}$, $\phi' = 0.14^{+0.10}_{-0.08}$,

$\Gamma_{\rho'}^{\text{pole}} = (0.32 \pm 0.08)$ GeV, $\Gamma_{\rho''}^{\text{pole}} = (0.18 \pm 0.09)$ GeV, $\alpha'' = 0.03 \pm 0.01$, $\phi'' = 3.14^{+0.50}_{-0.06}$.

→ One can also use the DR up to some energy and match it to $F_V^{\pi(0)}(s)$. Results are almost undistinguishable [see later].

ππ VFF

(Gómez-Dumm—PR ‘13, Celis-Cirigliano-Passemar ’14)



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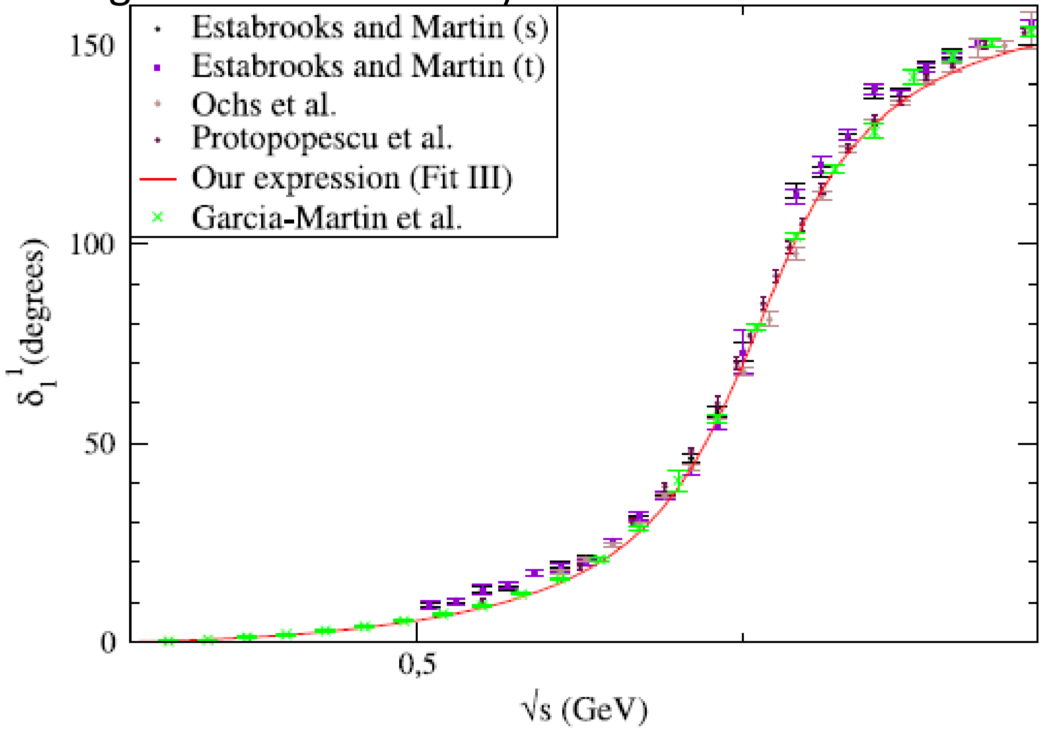

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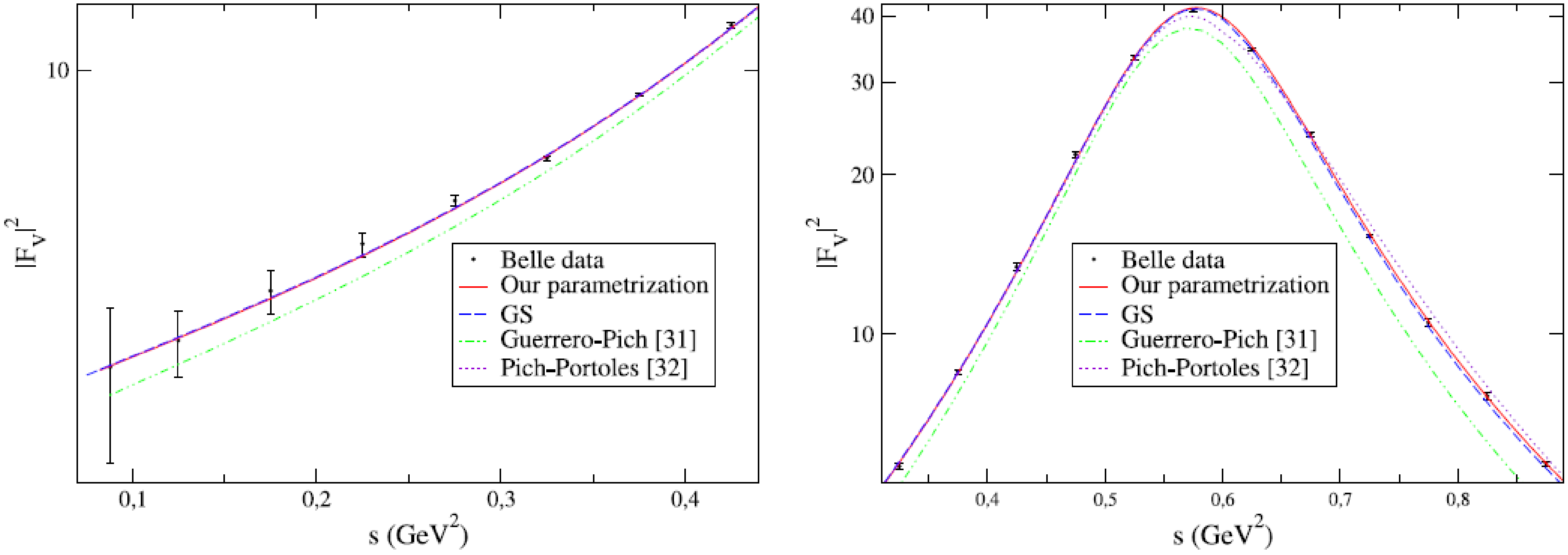
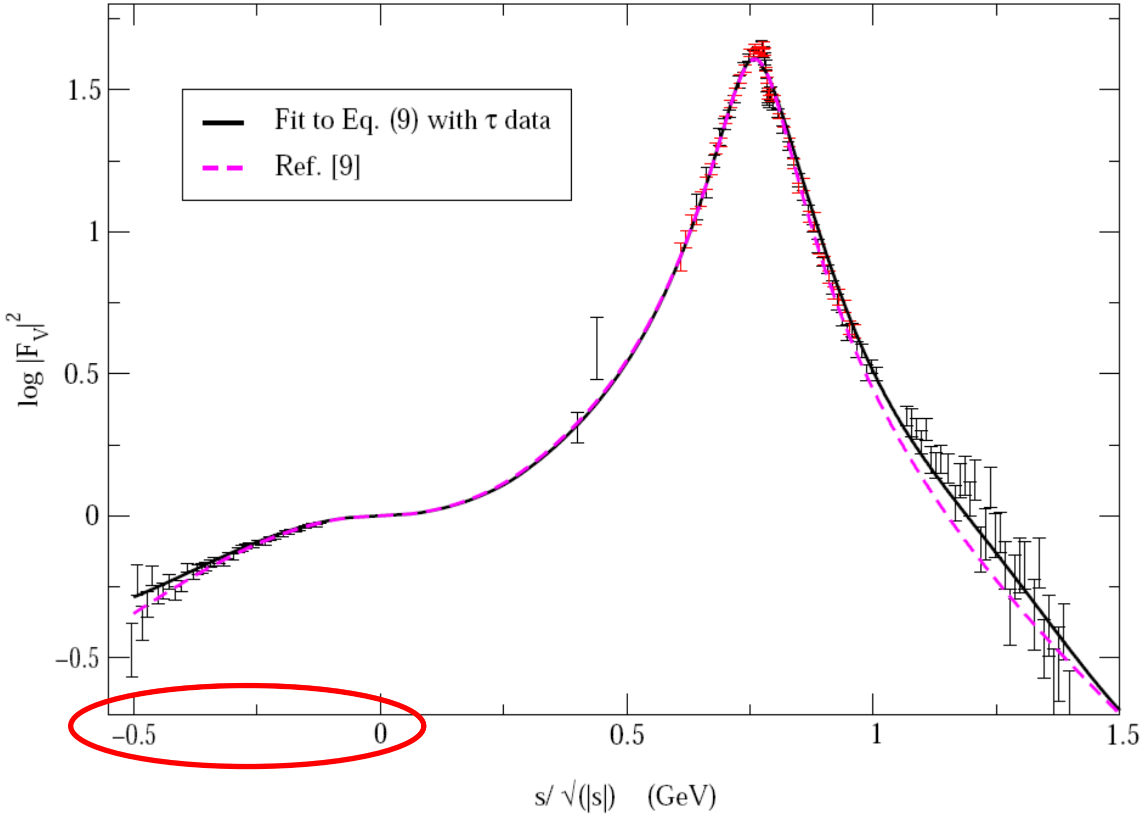


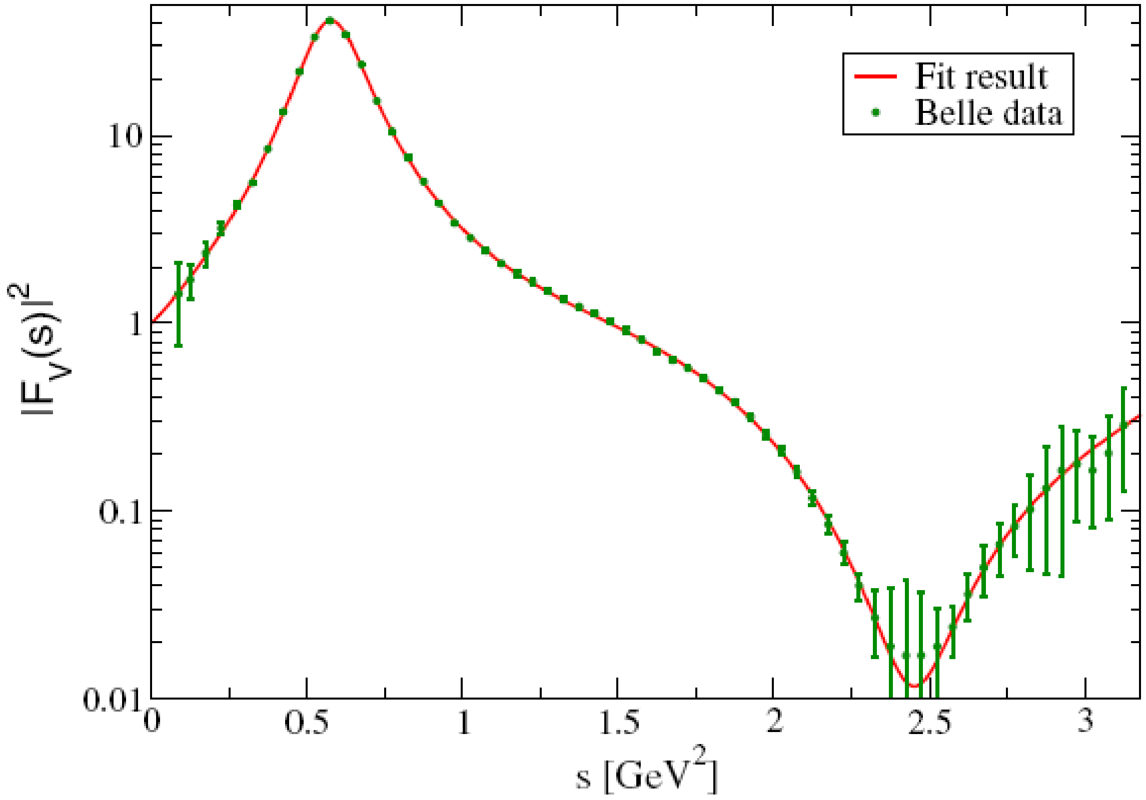
Fig. 3 Two close-ups of Fig. 2 are displayed, corresponding to the low-energy region (*left panel*) and the peak region (*right panel*)

N.B. : GS has wrong phaseshift, bad high-E behaviour, excited resonances do not decouple at low-E (χ limit is lost), …

ππ VFF

(Pich-Portolés '01,Gómez-Dumm—PR '13, Celis-Cirigliano-Passemar '14)





ππ VFF

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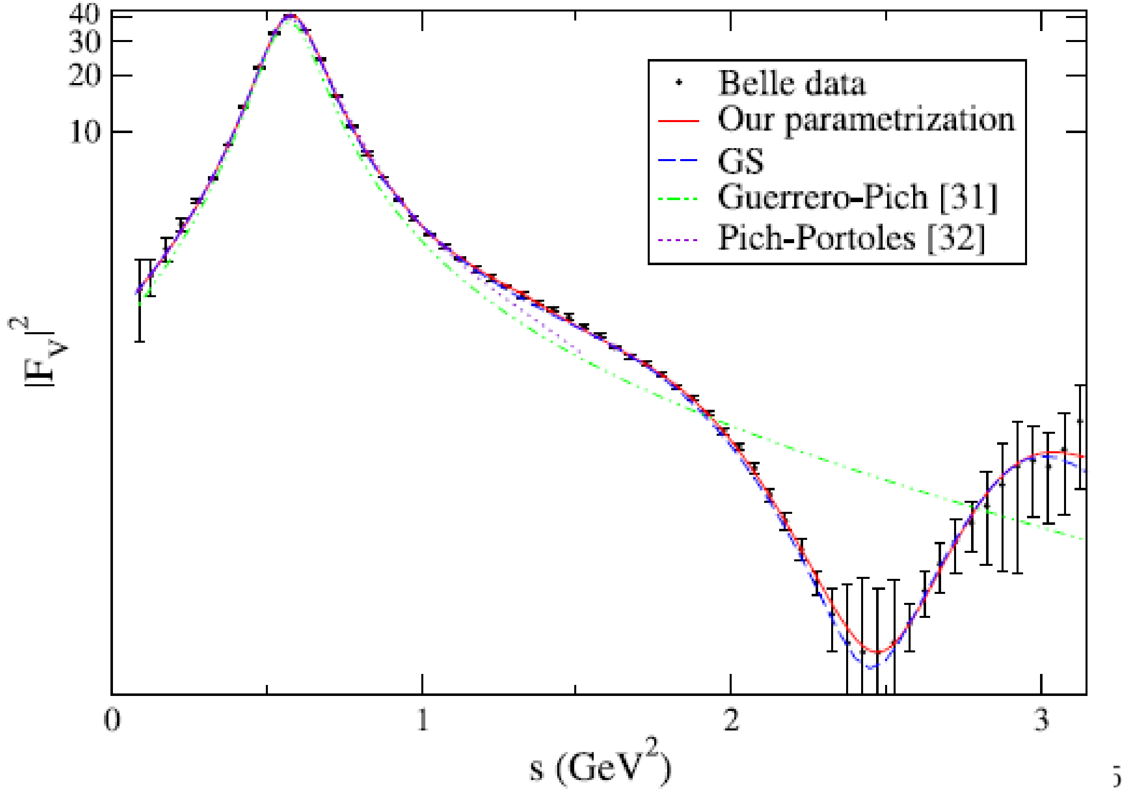

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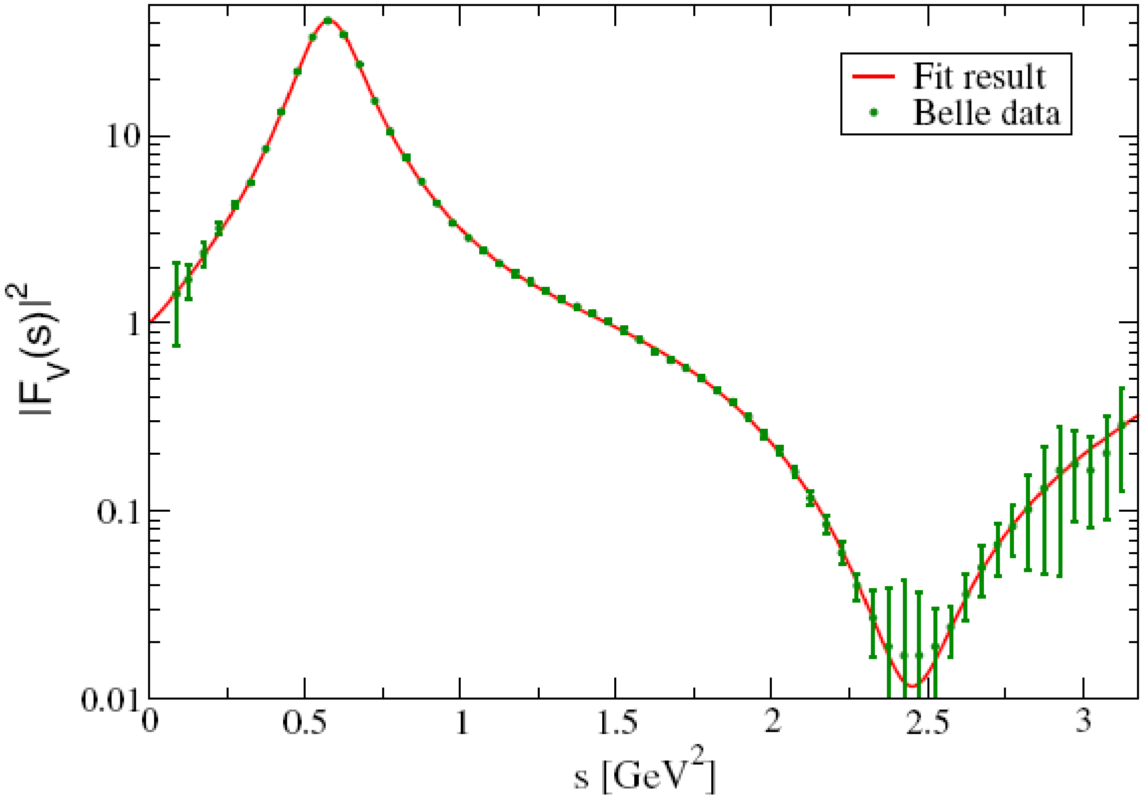

$\pi\pi$ VFF

(Gómez-Dumm—PR ‘13, Celis-Cirigliano-Passemar ’14)

→ According to data it might seem that little else remains to be done (ρ-ω mixing & other isospin corrections are ‘easy’).

ππ VFF

(Gómez-Dumm—PR '13, Celis-Cirigliano-Passemar '14)

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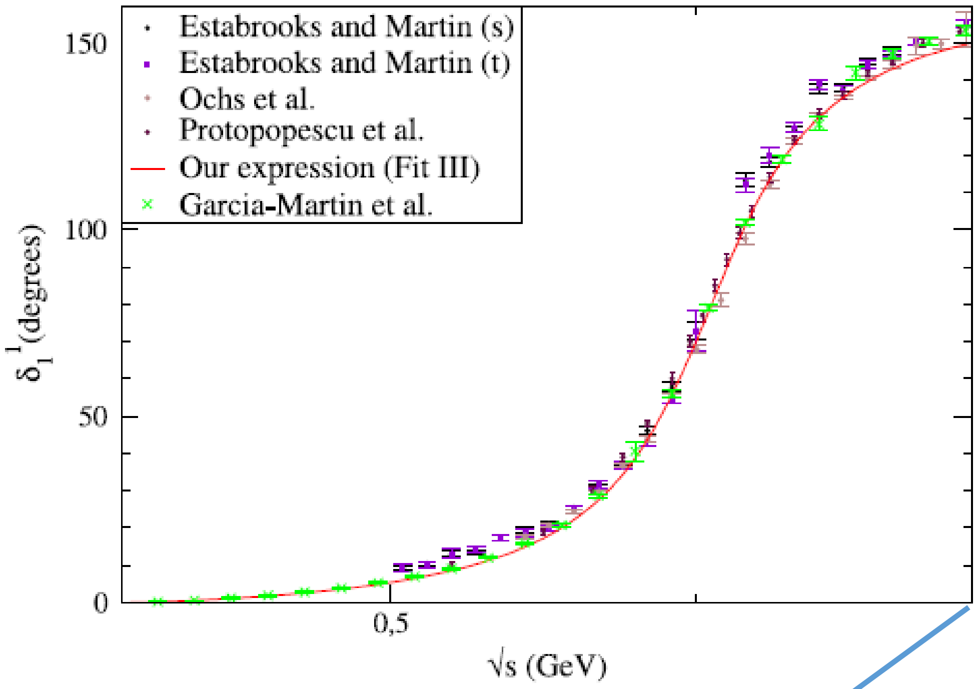

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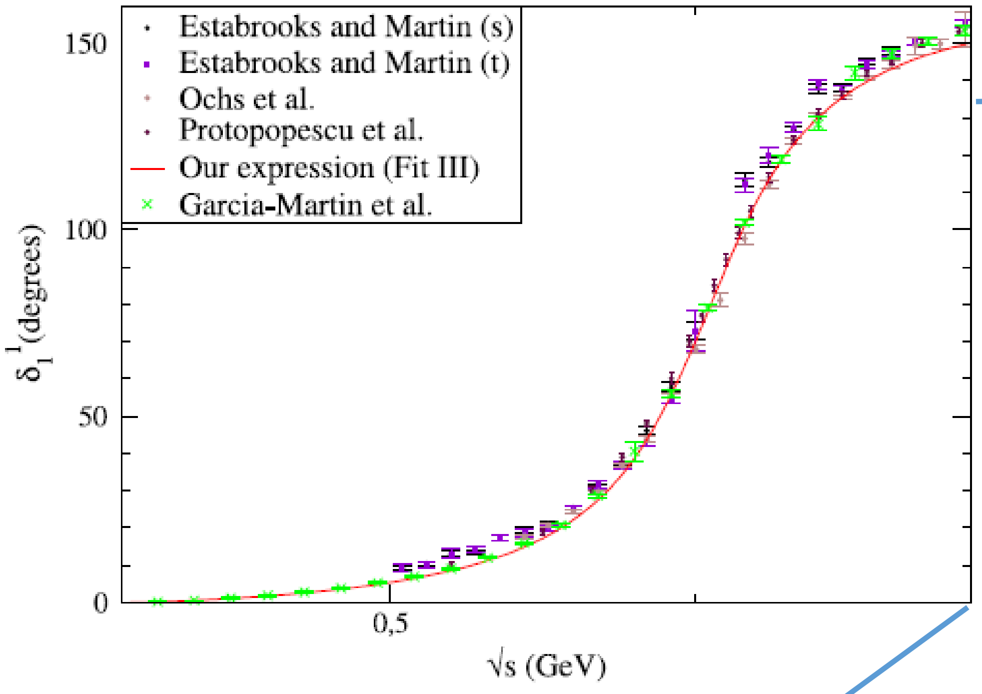

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Inelasticities need to be included & a **coupled-channels** treatment is needed!

According to our experience in SFFs I believe that is feasible and, moreover, quite fast (see also Moussallam '08 and Kubis et. al.).

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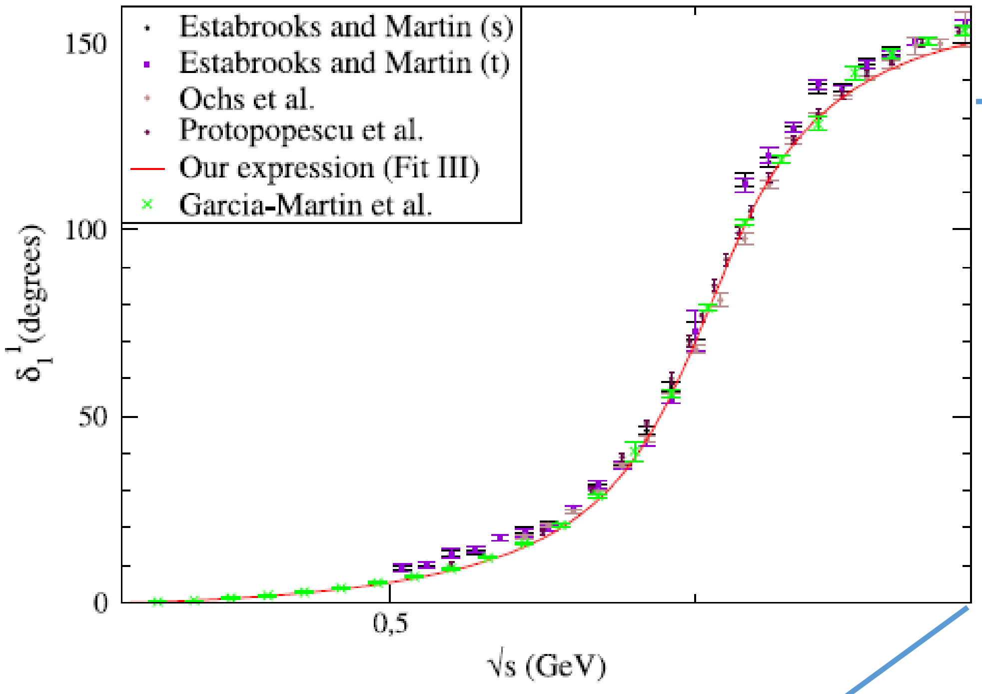

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As a by-product we would get the unitarized KK VFF

$$F_V^{K^+K^-}(s) = \frac{1}{2}\frac{M_\rho^2}{M_\rho^2 - s - iM_\rho\Gamma_\rho(s)}\exp\left[2\,Re\left(\tilde{H}_{\pi\pi}(s)\right) + Re\left(\tilde{H}_{KK}(s)\right)\right] + \frac{1}{2}\left[\sin^2\theta_V \frac{M_\omega^2}{M_\omega^2 - s - iM_\omega\Gamma_\omega} + \cos^2\theta_V \frac{M_\phi^2}{M_\phi^2 - s - iM_\phi\Gamma_\phi}\right] \times \exp\left[3\,Re\left(\tilde{H}_{KK}(s)\right)\right]$$

$$F_V^{K^0\bar{K}^0}(s) = -\frac{1}{2}\frac{M_\rho^2}{M_\rho^2 - s - iM_\rho\Gamma_\rho(s)}\exp\left[2\,Re\left(\tilde{H}_{\pi\pi}(s)\right) + Re\left(\tilde{H}_{KK}(s)\right)\right] + \frac{1}{2}\left[\sin^2\theta_V \frac{M_\omega^2}{M_\omega^2 - s - iM_\omega\Gamma_\omega} + \cos^2\theta_V \frac{M_\phi^2}{M_\phi^2 - s - iM_\phi\Gamma_\phi}\right] \times \exp\left[3\,Re\left(\tilde{H}_{KK}(s)\right)\right]$$

(Arganda-Herrero-Portolés ‘08, Guerrero-Oller ‘99)

Other two-meson VFFs: Kπ, (KK)

Again, a lot of work on the subject: Jamin-Pich-Portolés '06, '08; Moussallam '08; Boito-Escribano-Jamin '09, '10; Escribano--González-Solís—Jamin--Roig '14;; Jamin-Oller-Pich '00, '00, '02,'06; Bernard-Kaiser-Meissner '91, (Buettiker)--Descotes-Genon—Moussallam ('04), '06

$$\widetilde{f}_+^{K\pi}(s) = \exp\left[\alpha_1 \frac{s}{M_{\pi^-}^2} + \frac{1}{2}\alpha_2 \frac{s^2}{M_{\pi^-}^4} + \frac{s^3}{\pi}\int_{s_{K\pi}}^{s_{\rm cut}} {\rm d}s' \frac{\delta_1^{K\pi}(s')}{(s')^3(s'-s-i0)}\right]$$

$$\tan\delta_1^{K\pi}(s) = \frac{{\rm Im}\widetilde{f}_+^{K\pi}(s)}{{\rm Re}\widetilde{f}_+^{K\pi}(s)}$$

$$\widetilde{f}_+^{K\pi}(s) = \frac{m_{K^*}^2 - \kappa_{K^*}\widetilde{H}_{K\pi}(0) + \gamma s}{D(m_{K^*},\gamma_{K^*})} - \frac{\gamma s}{D(m_{K^{*\prime}},\gamma_{K^{*\prime}})}$$

$$D(m_n,\gamma_n) = m_n^2 - s - \kappa_n \widetilde{H}_{K\pi}(s)$$

$$\kappa_n = \frac{192\pi}{\sigma_{K\pi}(m_n^2)^3}\frac{\gamma_n}{m_n}$$

$$\widetilde{H}_{K\pi}(s) = \frac{2}{3}\widetilde{H}_{K^0\pi^-}(s) + \frac{1}{3}\widetilde{H}_{K^-\pi^0}(s)$$

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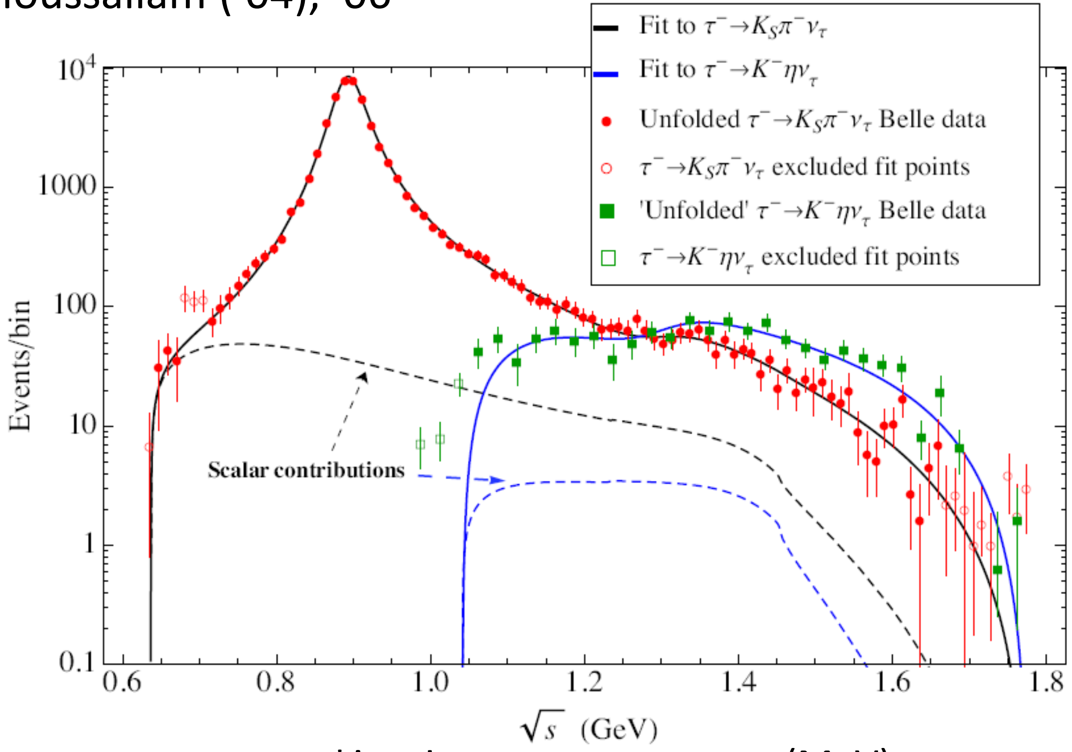

K*’ Pole: $M_{K^{*\prime}} = 1305^{+16}_{-18}$, (MeV) $\Gamma_{K^{*\prime}} = 168^{+65}_{-59}$

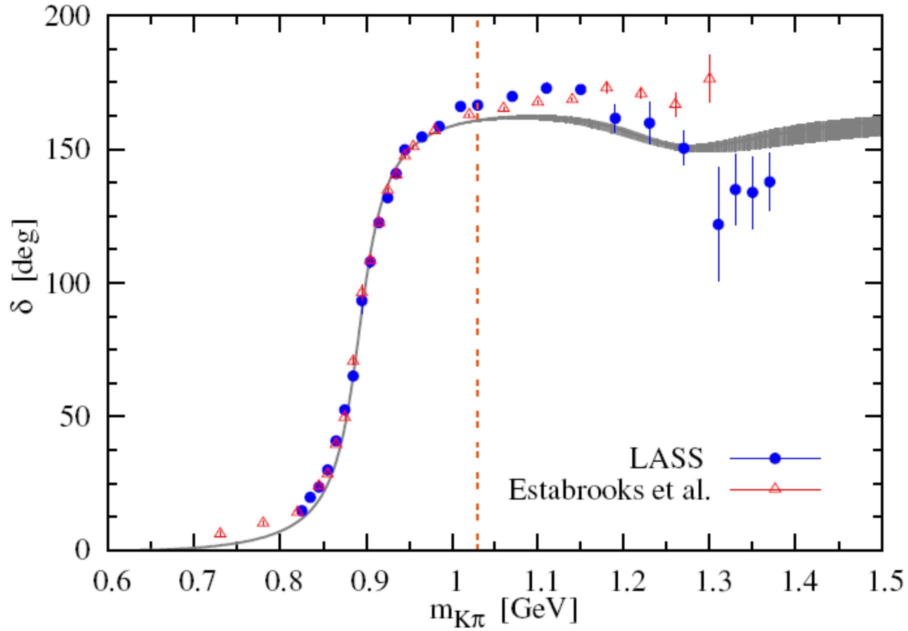

Figure 2: Phase of the form factor $F_+(s)$ together with experimental results from LASS [46] and Estabrooks *et al.* [47]. The opening of the first inelastic channel, $K^*\pi$, is indicated by the dashed vertical line. The gray band represents the extrema from the fits of Tab. 3.

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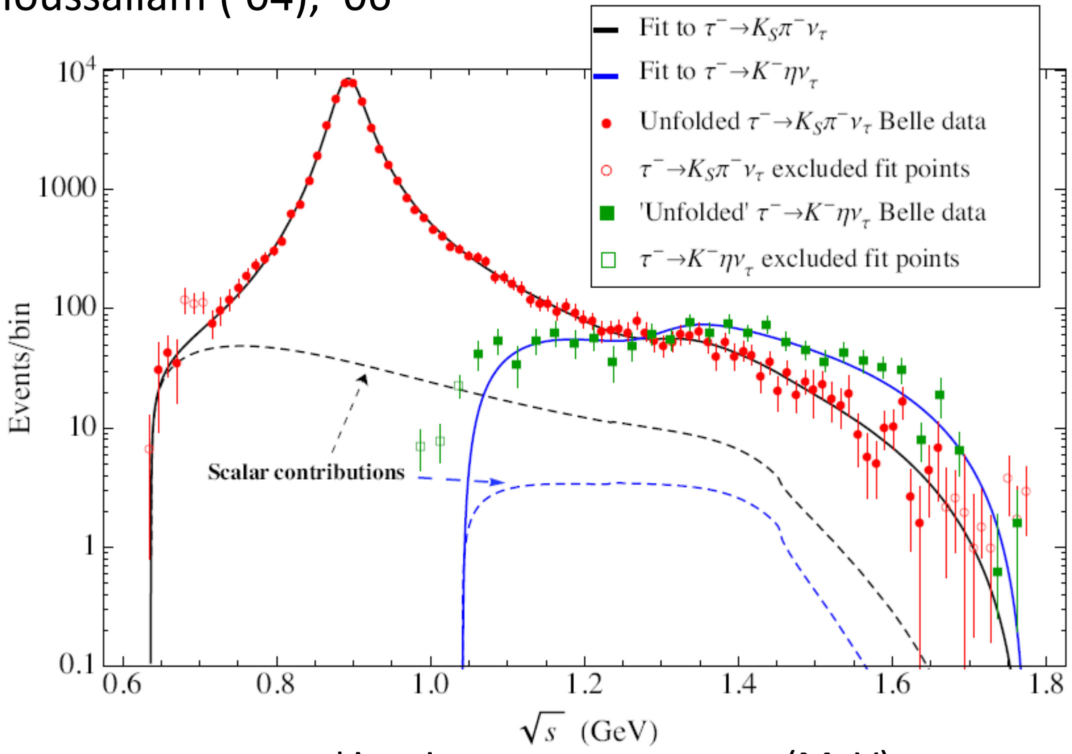

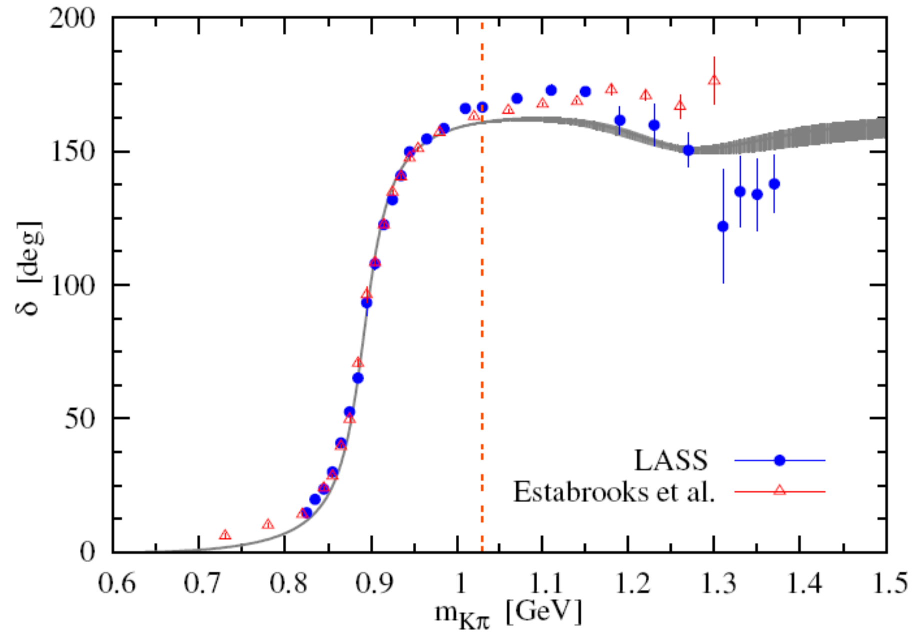

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K*’ Pole: $M_{K^{*\prime}} = 1305^{+16}_{-18}$, (MeV) $\Gamma_{K^{*\prime}} = 168^{+65}_{-59}$

→ A coupled-channel analysis was done for the SFF(s) but remains to be done for the VFF(s)

Other two-meson VFFs: Kπ, (KK)

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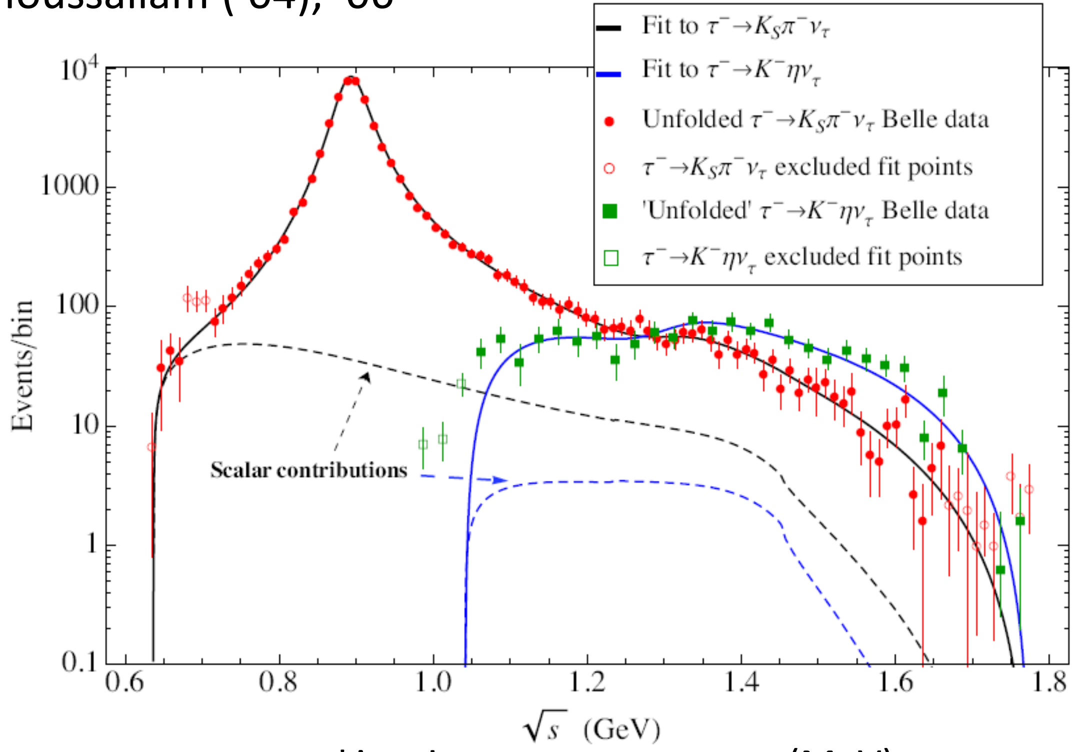

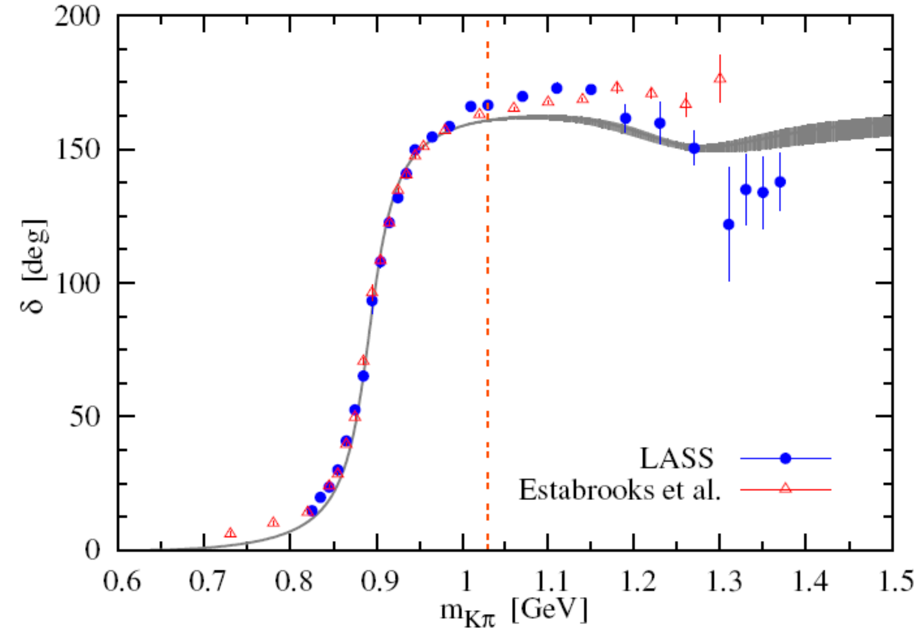

Figure 2: Phase of the form factor $F_+(s)$ together with experimental results from LASS [46] and Estabrooks *et al.* [47]. The opening of the first inelastic channel, $K^*\pi$, is indicated by the dashed vertical line. The gray band represents the extrema from the fits of Tab. 3.

K*’ Pole: $M_{K^{*\prime}} = 1305^{+16}_{-18}$, (MeV) $\Gamma_{K^{*\prime}} = 168^{+65}_{-59}$

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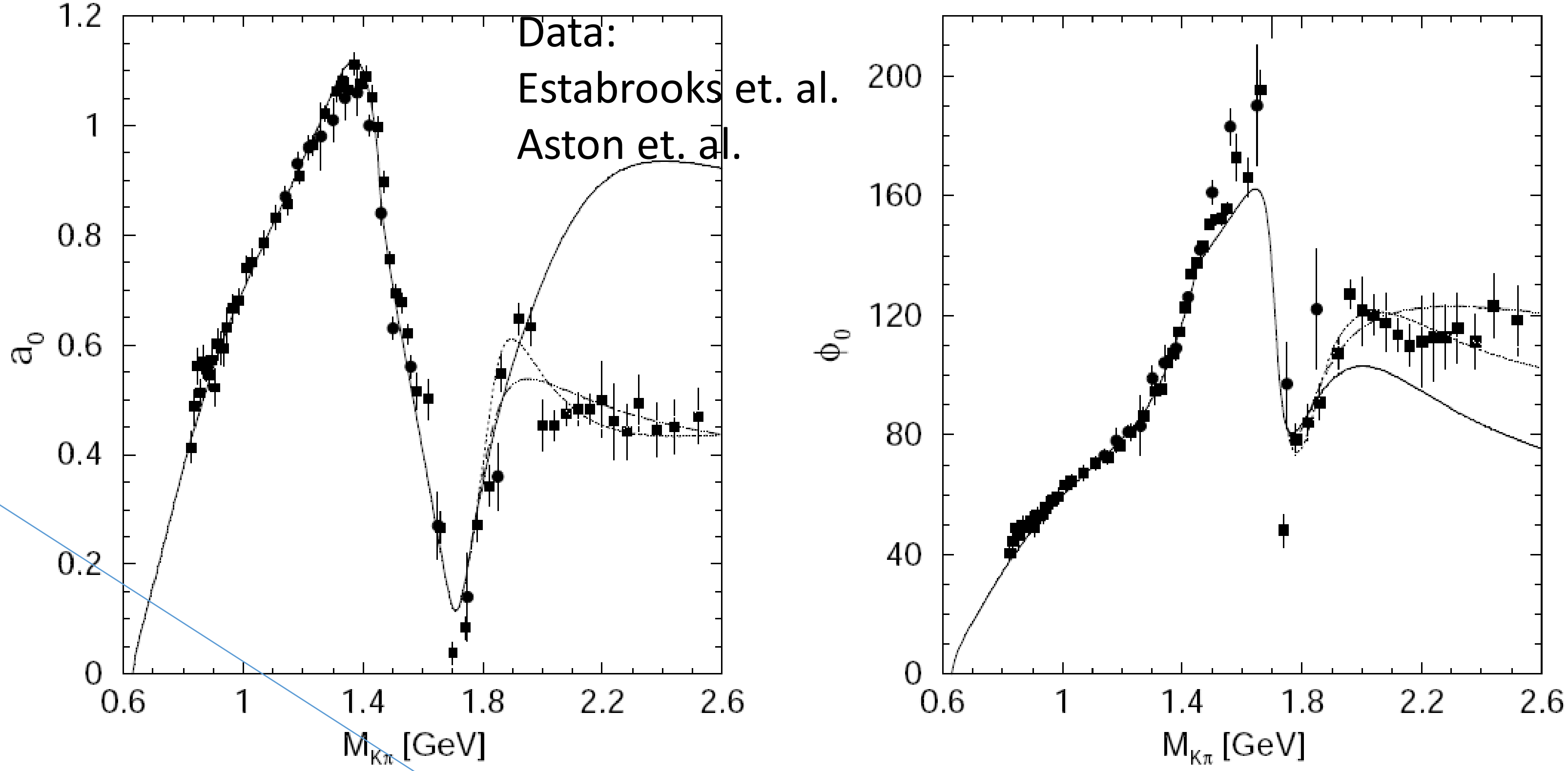
Data:
Estabrooks et. al.
Aston et. al.

Kπ SFF:



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- All corresponding SFFs obtained within c-c are at your disposal.

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LatinoAmerican Workshop on High Energy Physics: Particles and Strings

Havana, 15-21 July 2012

Me gusta 0 Tweet

Overview

The **Latinoamerican Workshop on High Energy Physics: Particles and Strings** aims to bring together scientist of Europe and Latin-american countries with the purpose of develop and strengthen scientific links and collaborations between the various physics communities. The program of the conference will include a set of review lectures on the following topics:

- Physics of the Standard Model and Beyond.
- Theories of fundamental interactions: QCD, Nuclear physics, Astrophysics, Dark matter.
- LHC: Experiments and first signatures.
- String phenomenology
- D-branes, holography, black hole physics.

The program will also includes informal talks given by young scientist from Latin-American countries and short talks by other participants in the meeting. Open discussions on scientific areas of common interests will be included.

Special Information

- This is the Workshop Programme
- Workshop Poster.
- Full Talk List and Materials.
- Picture Gallery 2012.

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Latin-American Conference on High Energy Physics: Particles and Strings II

Havana, 18-22 July 2016

Home | Program | Registration | Participants | The Venue | Accommodation

Overview

The **Latin-American Conference on High Energy Physics: Particles and Strings II,** aims to bring together scientist of Europe and Latin-american countries with the purpose of develop and strengthen scientific links and collaborations between the various physics communities. The program of the conference will include a set of review lectures on the following topics:

- Physics of the Standard Model and Beyond.
- Theories of fundamental interactions: QCD.
- LHC: Experiments and first signatures.
- String phenomenology, amplitudes.
- D-branes, holography, black hole physics.

The program will also include short talks, informal discussion sessions and a student gong show.

The conference is the second of a conference series starting with the "Latin-American Workshop on High Energy Physics: Particle Strings", Havana, July 21, 2012.

Special Information

- Registration from December 01, 2015
- Registration deadline: May 31, 2016

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Scientific Program

The program of the conference will include review lectures, short talks, discussion sessions and a student gong show.We request speakers to keep all talks at the pedagogical level, focusing on the main conceptual insights and results in the field reviewed in accessible and self-consistent terms.

Invited Speakers (confirmed):

- **Albert De Roeck** (CERN) " *Searches at the LHC: present and future* "
- **Michelangelo Mangano** (CERN) " *Future Circular Collider* "
- **Mark Wise** (Caltech) " *Effective Theories and Physics Beyond the Standard Model* "
- **Fernando Quevedo** (ICTP) "String Phenomenology"
- **Dieter Lust (ICTP)** (MPIP) "Classical and Quantum Black Hole Hair"
- **Eva Silverstein** (Stanford) " *Horizon physics in string theory* "
- **Burt Ovrut** (Pennsylvania) "The Minimal Supersymmetric B-L Model--from Unification to the LHC"
- **Massimo Bianchi** (Rome) "(Soft) String amplitudes"
- **Margarete Muehlleitner** (KIT) " *Phenomenology of Beyond the Standard Model at the LHC* "
- **Thomas Mueller** (KIT) " *Collider physics and detector performance: present and future accelerators* "
- **Jonas Rademacker** (Bristol) " *Heavy flavour physics at the LHC* "
- **Gino Isidori** (Zurich) "Flavor Physics beyond the SM"
- **Jose Ocariz** (CERN/LPNHE) "*Higgs Physics at the LHC* "
- **Sameer Murthy** (King's college) "Quantum black holes in string theory"
- **Rafael Nepomechie** (Miami) "Integrability in AdS/CFT"

Invited speakers (to be confirmed):

- **Michael Peskin** (SLAC) " *Standard Model and Symmetry Breaking* "
- **Lisa Randall** (Harvard) " *TBA*"
- **Joseph Lykken** (Fermilab) " *Neutrino Physics* "
- **Marcela Carena** Fermilab/Chicago) " *Phenomenology of Higgs boson models at the LHC* "
- **Javier Redondo** (Zaragoza) "Dark matter candidates: Axions"
- **Sean Hartnoll** (Stanford) " *TBA*"
- **Alberto Lerda** (Turin/Alessandria) " *TBA*"

We'll have it in Mexico in summer 2017!!

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Cinvestav | Scientific Program | Latin-...

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THANK YOU!