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Resonances in the Meson and Higgs Sectors: Analysing Multichannel Data

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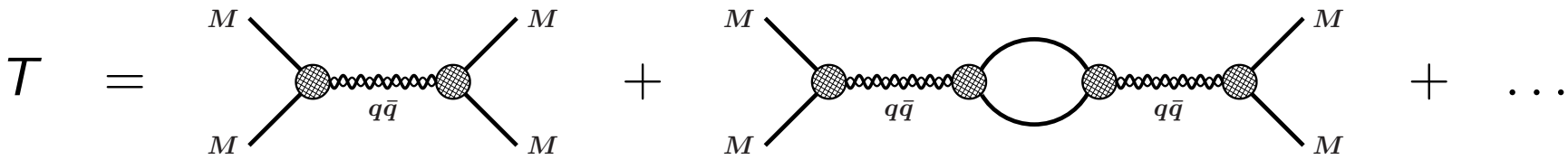
Contribution to *European Strategy for Particle Physics*

- RSE Model for Meson Spectroscopy and Production
- Evidence of a second SM Higgs resonance at about 690 GeV

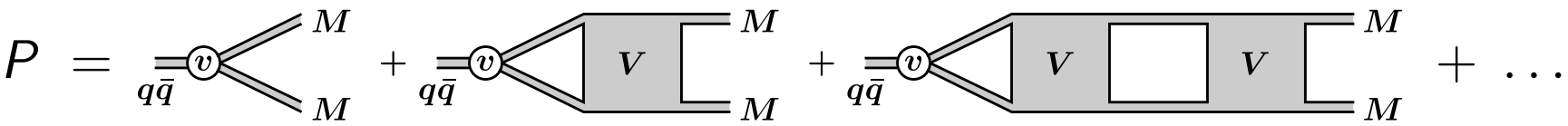
Resonance-Spectrum Expansion for Non-Exotic Mesons

Multichannel meson-meson scattering:



E. van Beveren, GR, Annals Phys. **324** (2009) 1620 [0809.1149]

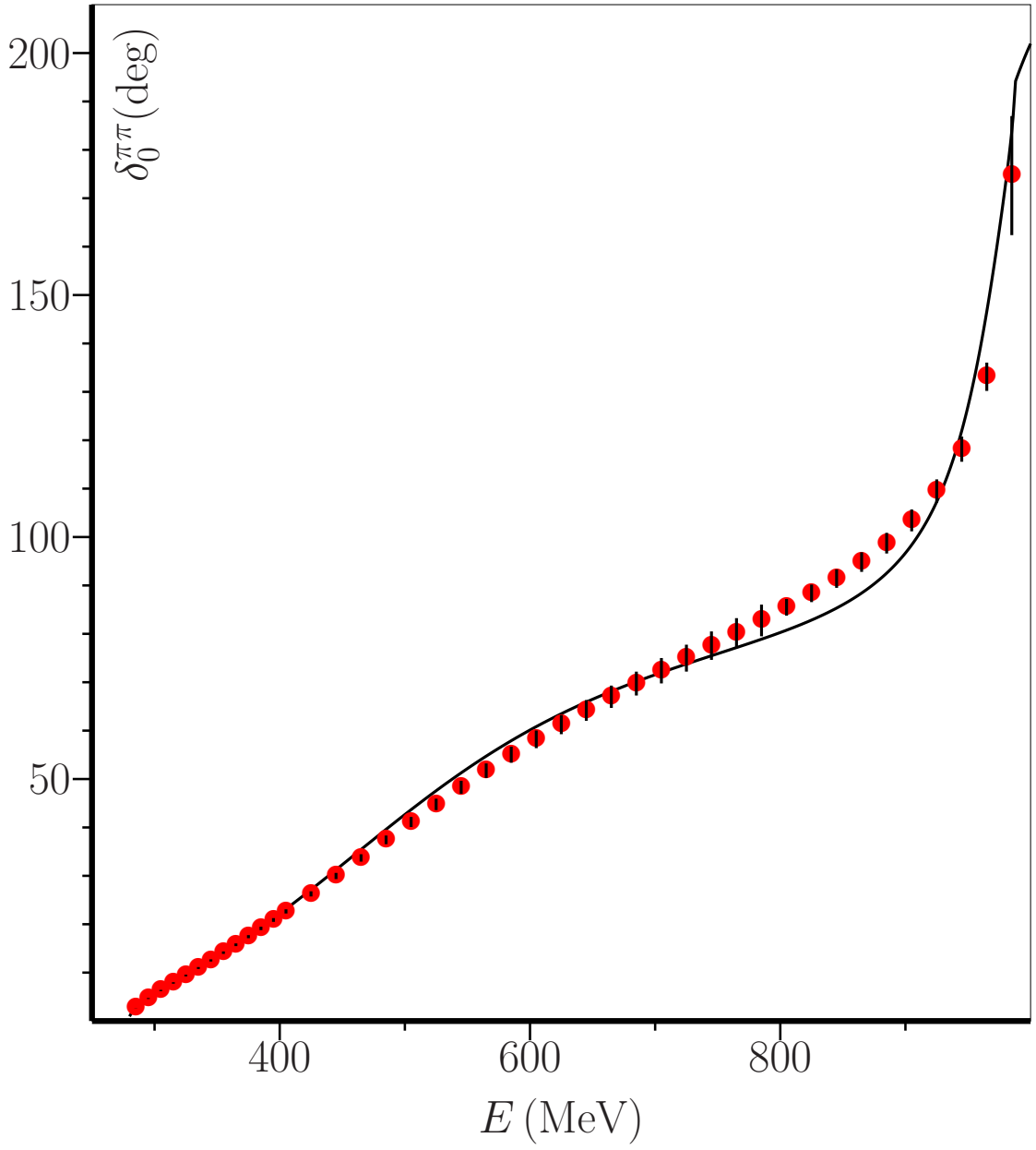
Multichannel meson production:



E. van Beveren, GR, Annals Phys. **323** (2008) 1215 [0706.4119]

Also see:

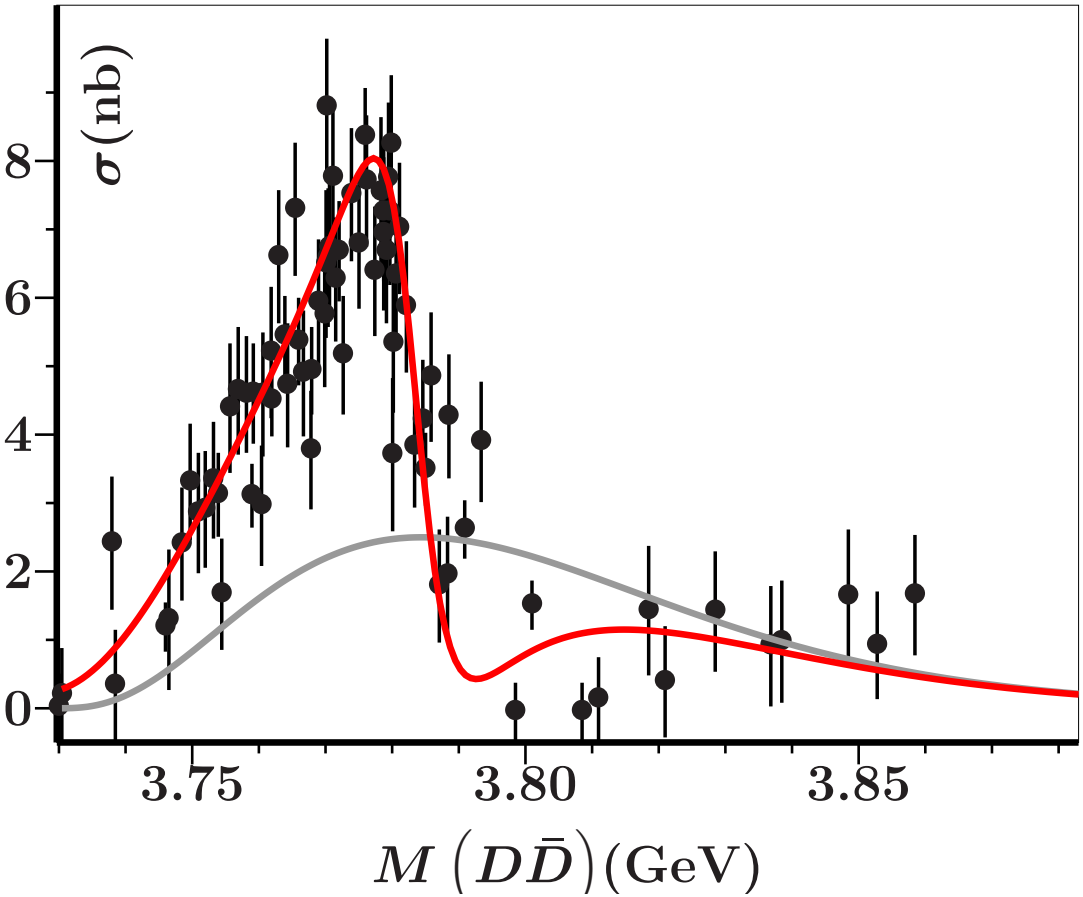
J. H. Alvarenga Nogueira *et al.*, 1605.03889 [hep-ex], pp. 36–39.



Three-parameter RSE fit to S-wave $\pi\pi$ phase shifts.

Dynamical resonances $f_0(500)$ (alias σ) and $f_0(980)$ found in analytic S-matrix at $(460 - i222)$ MeV and $(978 - i37.2)$ MeV, respectively, compatible with PDG values.

Figure from GR, Phys. Rev. D **109** (2024) 054003 [2401.08379].



Empirical fit with Breit-Wigner $\psi(3770)$ resonance plus RSE-inspired production amplitude to BES $e^+e^- \to D\bar{D}$ data.

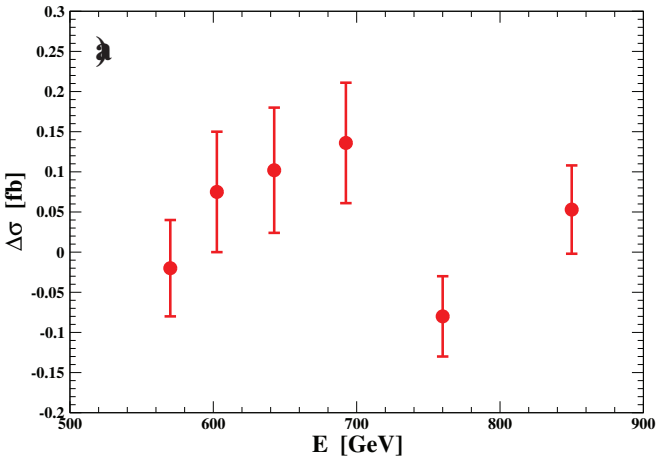
No need to introduce an additional, exotic resonance, while also explaining the small BES width as compared to the PDG average.

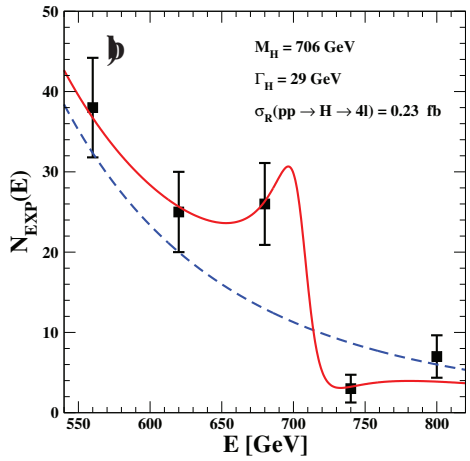
Figure from

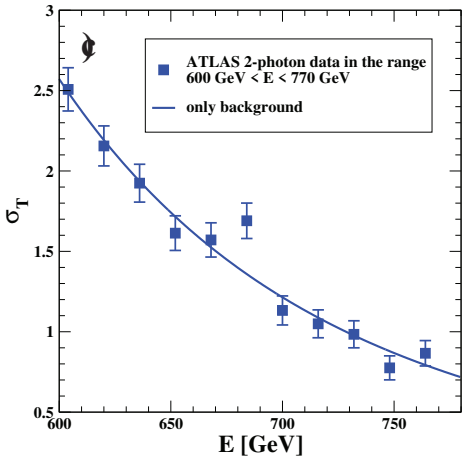
E. van Beveren, GR, Phys. Rev. D **80** (2009) 074001 [0908.0242].

Remarks for CERN experiments in hadronic physics

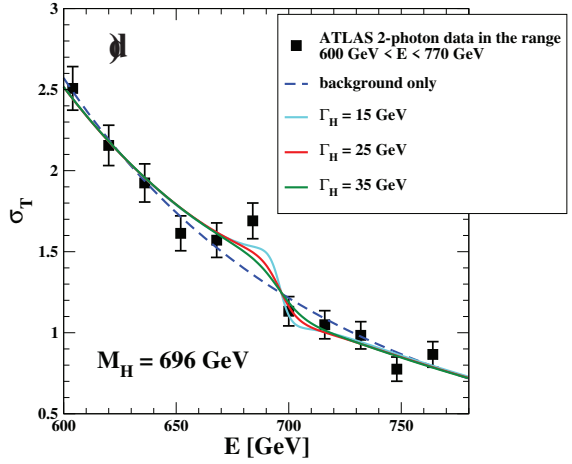
- The RSE formalism provides a fully unitary and analytic approach to analyse data in meson spectroscopy, including broad, overlapping, and dynamical resonances, besides those close to thresholds.
- The practical and very successful applications of the RSE have so far been carried out with specific model inputs, but a model-independent generalisation for data analysis is straightforward.
- This would require replacing the $q\bar{q}$–two-meson vertices based on string breaking by form factors with fit parameters, as well as the bare $q\bar{q}$ spectrum by a few adjustable real energy levels.
- It would require fewer parameters to describe meson resonances.
- A further generalisation to tetraquark candidates is also possible, probably needing a different kind of form factors for the vertices.







Fit with interference of a background + resonance



ATLAS four-lepton (panels a, b) and $\gamma\gamma$ (panels c, d) data, systematically showing a clear enhancement close to 700 GeV, in remarkable agreement with our theoretical and lattice prediction.

Figures from

M. Consoli, GR, Eur. Phys. J. C **84** (2024) 951 [2308.01429]

and

M. Consoli, L. Cosmai, F. Fabbri, GR, 2501.03708 [hep-ph, hep-ex].

Remarks for CERN experiments searching for new Higgses

- A non-perturbative treatment of Φ^4 theory and lattice simulations of the 4D Ising model strongly suggest the existence of two states in the scalar sector of the SM.
- The lighter mass is defined by the quadratic shape of the effective potential at its minimum, representing the observed Higgs boson at 125 GeV, while the heavier one at about 690 GeV is associated with the potential's zero-point energy.
- Several ATLAS and CMS data of four-lepton, $\gamma\gamma$, $t\bar{t}$, and $b\bar{b}\gamma\gamma$ events show enhancements close to 690 GeV, with a combined statistical significance of more than 5σ. Owing to our definite theoretical prediction, this significance is not downgraded by the "look-elsewhere" effect.
- Contrary the a ZZ and W^+W^- width of hundreds of GeV for a heavy Higgs with a mass of about 700 GeV in the standard perturbative approach, we predict partial widths of only a few GeV. So if the heavy Higgs is not or only weakly observed in these channels, it only reinforces our picture.