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The extraordinary case of the lightest strange resonance

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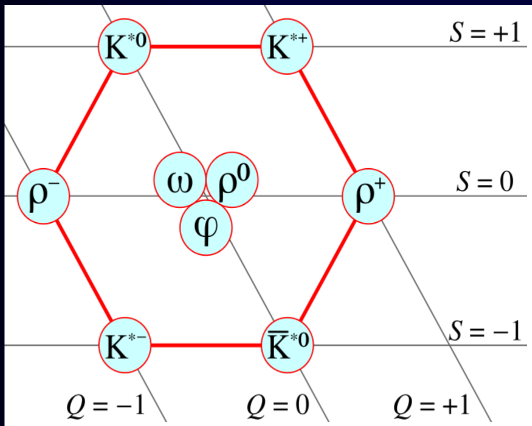
Non perturbatoive QCD 2016. Sevilla. 21st October 2016

Ordinary mesons: Spectroscopy

From naive quark model: **quark–antiquark states**

- With only 3 light quarks, grouped in SU(3) **nonets**



M_{K^*}=892 MeV

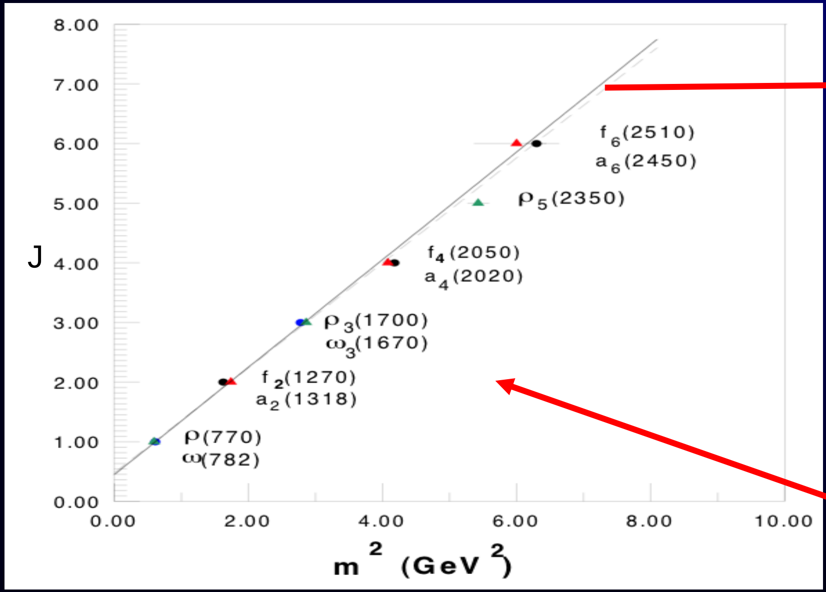
M_ρ=770 MeV
M_ω=782 MeV
M_φ=1020 MeV~$s\bar{s}$

M_{K^*}=892 MeV

$q\bar{q}$ Mass hierarchy:
These heavier because
$m_s >> m_u \sim m_d$

Not for light scalars!

- Follow linear (J,M^2) Regge trajectories



Linear (J,M^2) trajectories with Universal slope ~ 0.8-1 GeV^{-2}
(Also for baryons)

Rigid rotating rod, Stringy picture
Color flux tube… CONFINEMENT

Note no scalars there

But the very existence of some light scalars is under debate

Light scalars: Spectroscopy

Let us first see HOW MANY SCALARS EXIST (in the PDG) below 2 GeV:

- Isospin=0: $\sigma/f_0(500)$, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_0(1700)$ 5 states.

Half century-long controversy
Settled.
(Even at PDG)

Mild fading controversy

- Isospin=1: $a_0(980)$, $a_0(1450)$. 3x2=6 states

- I=1/2, S=±1, $\kappa/K_0^*(800)$, $K_0^*(1430)$ 4x2=8 states

40 yr-long controversy
Almost Settled but omitted from PDG summary tables**.**
According to PDG: **"Needs Confirmation"**

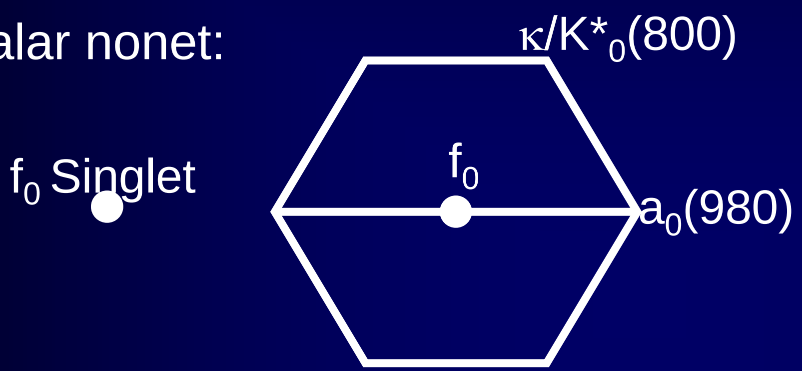
19 states… enough to form TWO NONETS
And something more.

The lightest ones should form the lightest nonet.

Non-ordinary spectroscopic classification

- Scalar SU(3) multiplets identification controversial
  - Too many resonances for many years.
    But there is an emerging picture…

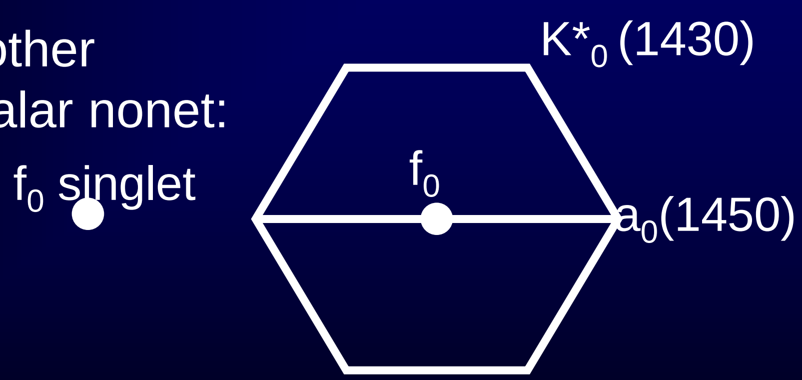
A Light scalar nonet:



Non-strange heavier!!
Inverted hierarchy problem
For quark-antiquark

$f_0(500)$ and $f_0(980)$ are
really OCTET/SINGLET mixtures

+ Another
heavier scalar nonet:



+ glueball

f_0

Enough f_0 states have been observed: $f_0(500)$, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_0(1700)$.
The whole picture is complicated by mixture between them (lots of works here)

The light scalar controversy. The theory side... NON-ORDINARY nature

By ORDINARY we mean “quark-antiquark”, but there are other possibilities

- **Tetraquarks** (Jaffe ’77) .Solves the inverted hierarchy problem (issues with chiral symmerty and excess of states),
  PROBLEM WITH SEMILOCAL DUALITY

- **Molecules** (Achasov, Jülich-Bonn, Oller-Oset) are also NON-ORDINARY,…
  May also have problem with semi-local duality

- Modified quark-antiquark models with meson interactions.
  Van Beveren, Rupp

- Some people claim/claimed some of these did/do not exist , like the very σ, the κ(800), the $f_0(1370)$,etc…
  (Minkowski, Ochs, Narison… σ as glueball supporters in general)

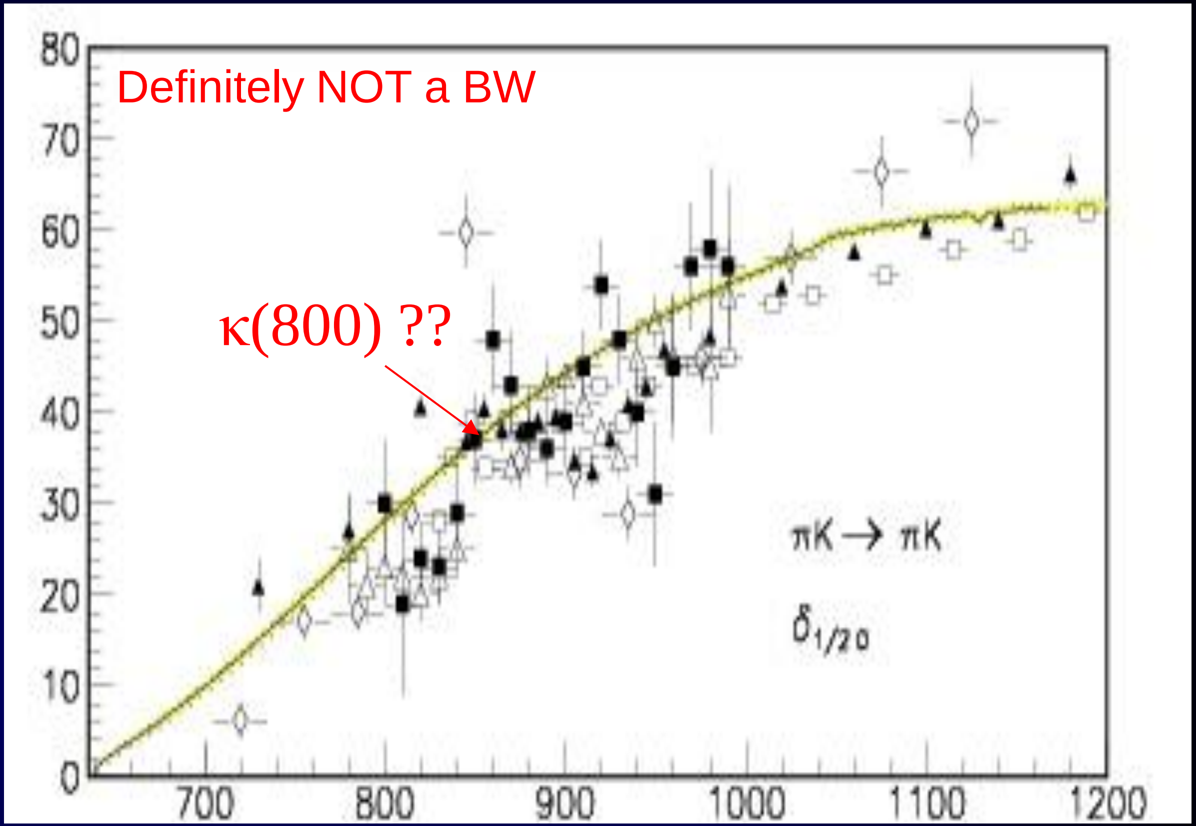
The κ controversy

- For decades, only data from

  Kπ scattering.

  But no Breit-Wigner peak

  Extremely wide resonance



Usually quoted by its pole: $\sqrt{s_{pole}} \approx M - i\,\Gamma/2$

Poles are process independent, peaks are not

Other data sources

Starting in the 2000's until today

Decays from heavier mesons

Fermilab E791, Focus, Belle, KLOE, BES,…

Very good statistics Clear initial states and different systematic uncertainties.

Strong experimental claims for wide and light σ around 500 MeV

"Strong" experimental claims for wide and light κ around 800 MeV

Very convincing for PDG, but personal caveats on BW parametrizations used, which may affect the precision and meaning of the pole parameters

- The $\sigma/f_0(500)$: similar situation, but made it to the PDG in 1996 and well established in 2002 and major revisión for precisión in 2012

Part of the problem: The theory

Many old an new studies based on crude/simple models,

Strong model dependences
Suspicion: What you put in is what you get out??

Even experimental analysis using

WRONG theoretical tools contribute to confusion

(Breit-Wigners, isobars, K matrix, ….)

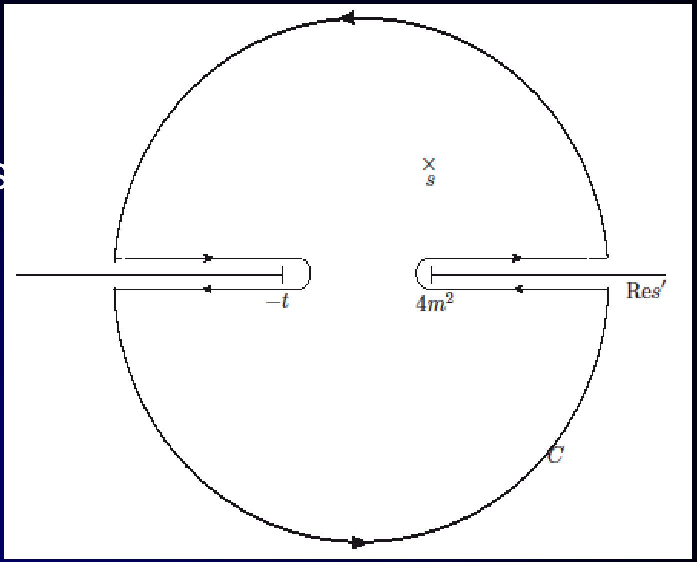
Let's revisit how the EXISTENCE of the σ was settled and if the same can be done with the κ

Fortunately, **DISPERSIVE FORMALISMS** provide the correct analytic structure, precise

AND MODEL INDEPENDENT analyses

What is a dispersion relation.? Very Briefly and for π π

CAUSALITY:
Partial waves t(s) are ANALYTIC in complex s plane with cuts due to thresholds (also in crossed channels



Cauchy Theorem determines t(s) at ANY s, from an INTEGRAL on the contour

If t->0 fast enough at high s, curved part vanishes

$$t(s) = \frac{1}{\pi}\int_{th}^{\infty} \frac{Im\, t(s')}{s - s'} ds' + LC$$

Otherwise, determined up to polynomial (subtra

Good for:
1) Calculating t(s) where there is not data
2) Constraining data analysis
3) ONLY MODEL INDEPENDENT extrapolation to complex s-plane

The real improvement: Analyticity and Effective Lagrangians

- <u>Unitarized ChPT</u>

  90's Truong, Dobado, Herrero, JRP, Oset, Oller, Ruiz Arriola, Nieves, Meissner,…

  Use ChPT amplitudes inside dispersion relation. Relatively simple, although different levels of rigour. Generates all scalars. Crossing (left cut) approximated… , not good for precision but good for understanding parameters

- **<u>Solutions of Roy-like equations</u>.**

  70's Roy, Basdevant, Pennington, Petersen…

  00's Ananthanarayan, Caprini, Colangelo, Gasser, Leutwyler, Moussallam, Decotes Genon, Lesniak, Kaminski…

  Left cut implemented with precision . Use data on all waves + high energy + ChPT for subtraction constants

$$\sigma_{pole} \approx (441^{+16}_{-8}) - i(272^{+9}_{-12.5})\text{MeV}$$

Caprini, Colangelo, Leutwyler (2006)

- **<u>Data Analyses constrained with Roy & Forward Disperion Relations</u>.**

  García-Martín, Kaminski, JRP, Ruiz de Elvira, Yndurain 00's

  Left cut implemented with precision Use data on all waves at all energies. NO ChPT.

$$\sigma_{pole} \approx (457^{+14}_{-15}) - i(279^{+11}_{-7})\text{MeV}$$

These two methods good for precision. Game changers for PDG

The consistency of dispersive approaches, and also with previous results implementing UNITARITY, ANALTICITY and chiral symmetry constraints by many people …

(Ananthanarayan, Caprini, Bugg, Anisovich, Zhou, Ishida Surotsev, Hannah, JRP, Kaminski, Loiseau, Lesniak,Oller, Oset, Dobado, Tornqvist, Schechter, Fariborz, Saninno, Van Beveren, Rupp, Zou, Zheng, etc.…)

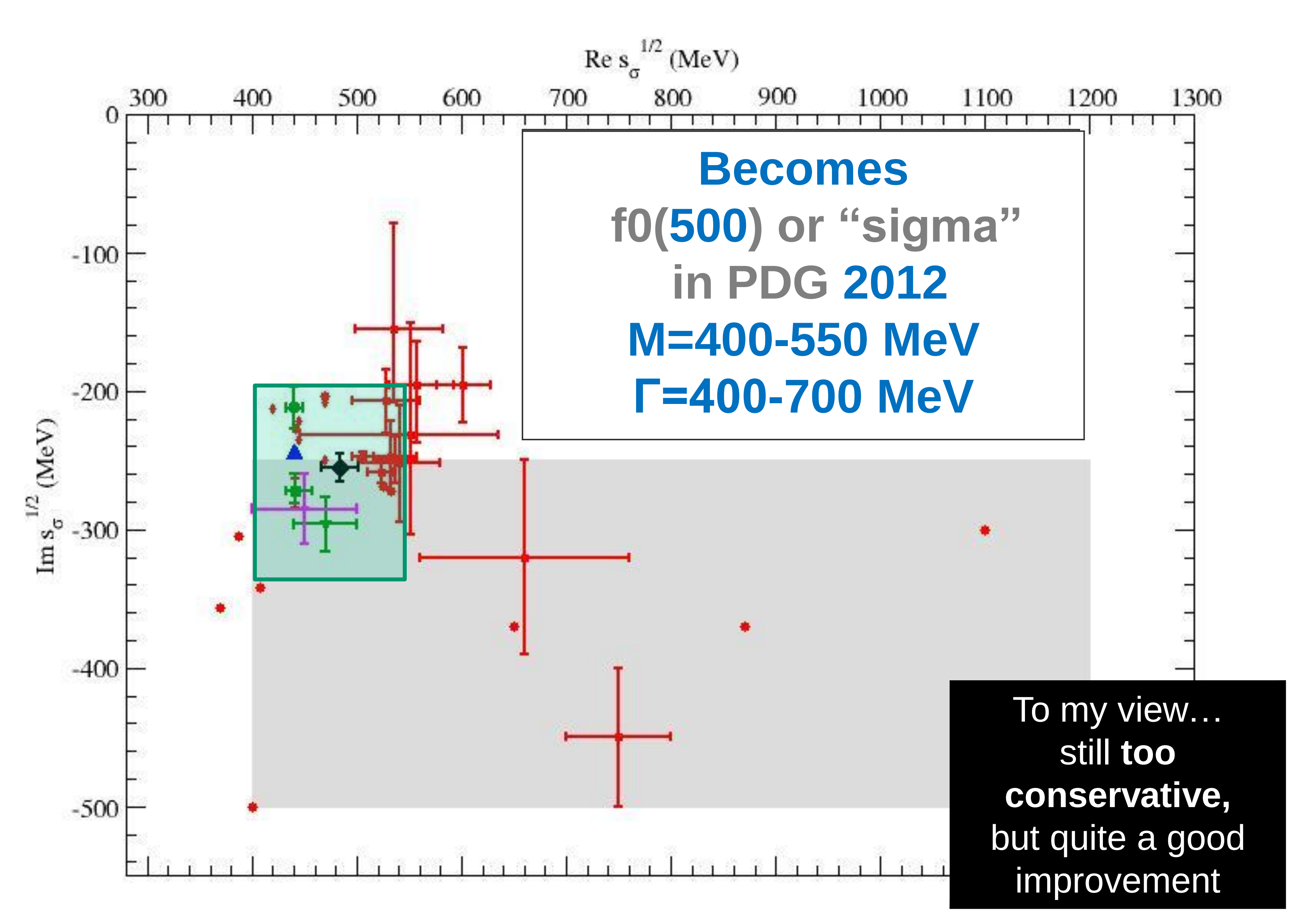
… led the PDG to neglect those works not fullfilling these constraints also restricting the sample to those consistent with NA48/2, together with results from heavy meson decays
Finally quoting in the 2012 PDG edition…

M=400-550 MeV
Γ=400-700 MeV

Accordingly THE NAME of the resonance was changed to…

$f_0(500)$

DRAMMATIC AND LONG AWAITED CHANGE ON “sigma” RESONANCE @ PDG!!

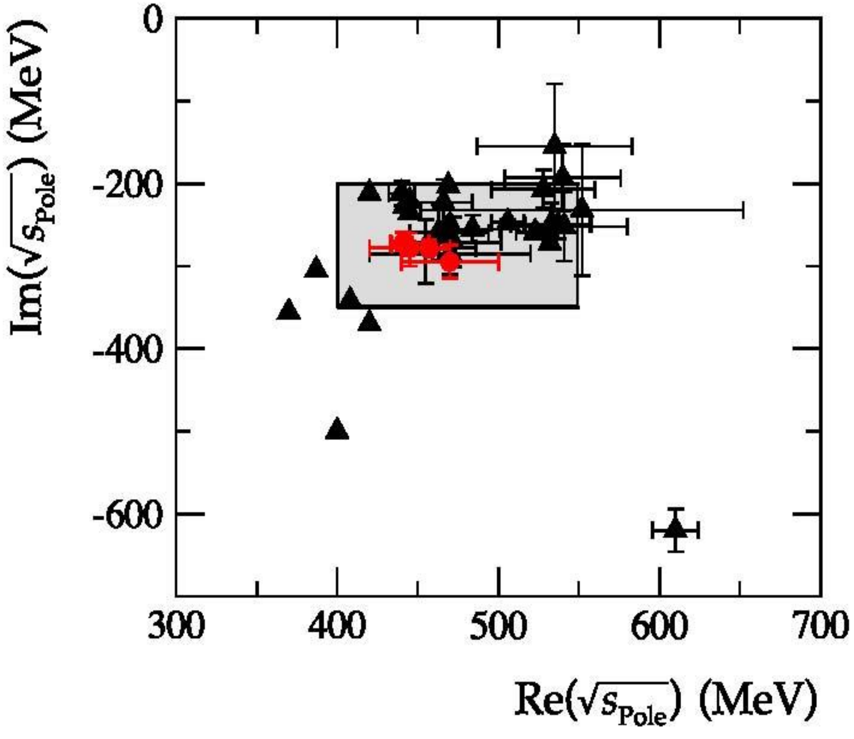


To my view…
still **too conservative,**
but quite a good improvement

Actually, in PDG 2012: “Note on scalars”

One might also take the more radical point of view and just average the most advanced dispersive analyses, Refs. [8–11], shown as solid dots in Fig. 1, for they provide a determination of the pole positions with minimal bias. This procedure leads to the much more restricted range of $f_0(500)$ parameters

$$\sqrt{s^{\sigma}_{\rm Pole}} = (446 \pm 6) - i(276 \pm 5)\ {\rm MeV}\ .$$



For a FANTASTIC review
by a very recomendable author

From controversy to precision on the sigma meson: a review on the status of the non-ordinary f0(500) resonance.
J.R.P. arXiv:1510.00653. Phys.Rept. in press

8. G. Colangelo, J. Gasser, and H. Leutwyler, NPB603, 125 (2001).
9. I. Caprini, G. Colangelo, and H. Leutwyler, PRL 96, 132001 (2006).
10. R. Garcia-Martin , R. Kaminski, JRP, J. Ruiz de Elvira, PRL107, 072001(2011).
11. B. Moussallam, Eur. Phys. J. C71, 1814 (2011).

But why not the kappa??

Comments on the minor additions to the $K_0^*(800)$ @PDG12

- "omittted from the summary table" since, "needs confirmation"

But, all descriptions of data respecting unitarity and chiral symmetry find a pole at M=650-770 MeV and Γ~550 MeV or larger.

As for the σ, the best determination comes from a SOLUTION of a Roy-Steiner dispersive formalism, consistent with UChPT Decotes Genon et al 2006

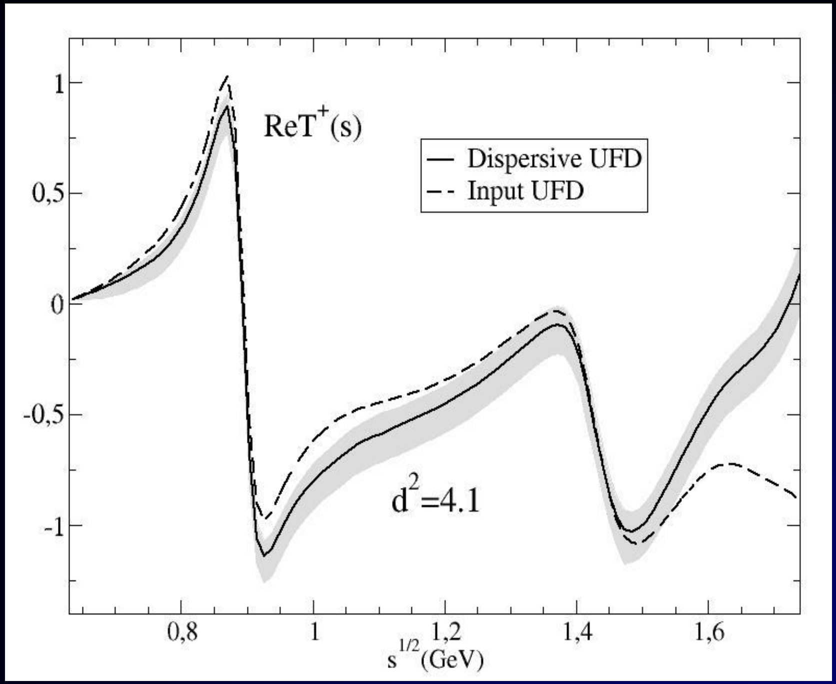
PDG dominated by such a SOLUTION

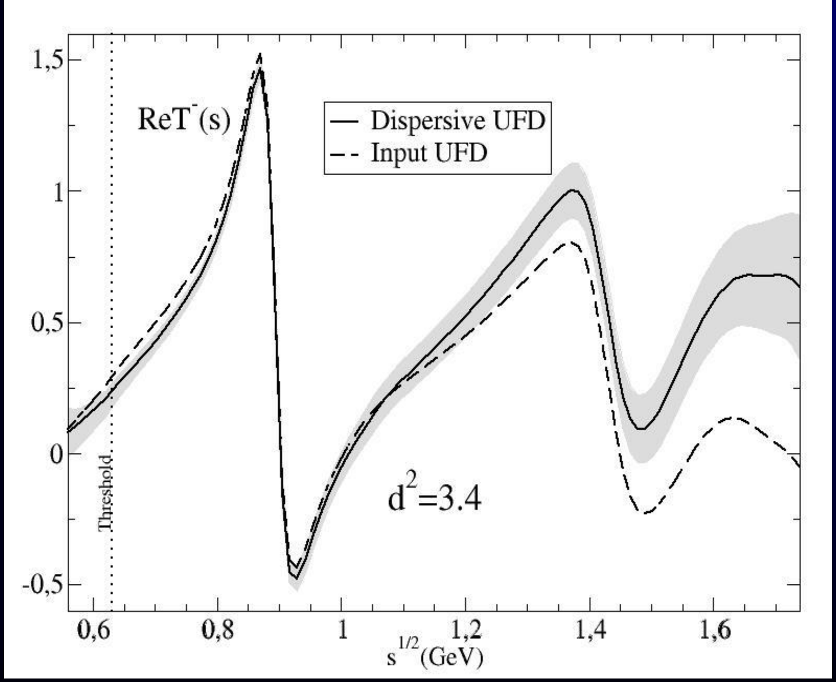
$M-i\,\Gamma/2=(682\pm29)-i(273\pm i12)$ MeV @PDG2015

$K_0^*(800)$ Situation similar to the sigma before the 2012 revision

PDG willing to consider it confirmed.. if additional independent dispersive DATA analysis.

We have been encouraged by PDG members to do it.





We (A.Rodas & JRP) are working on a

Dispersive analysis of πK scattering DATA

(**not a solution** of dispersión relations, but a constrained fit)

First observation:
Forward Dispersion relations
Not well satisfied by data
Particularly at high energies

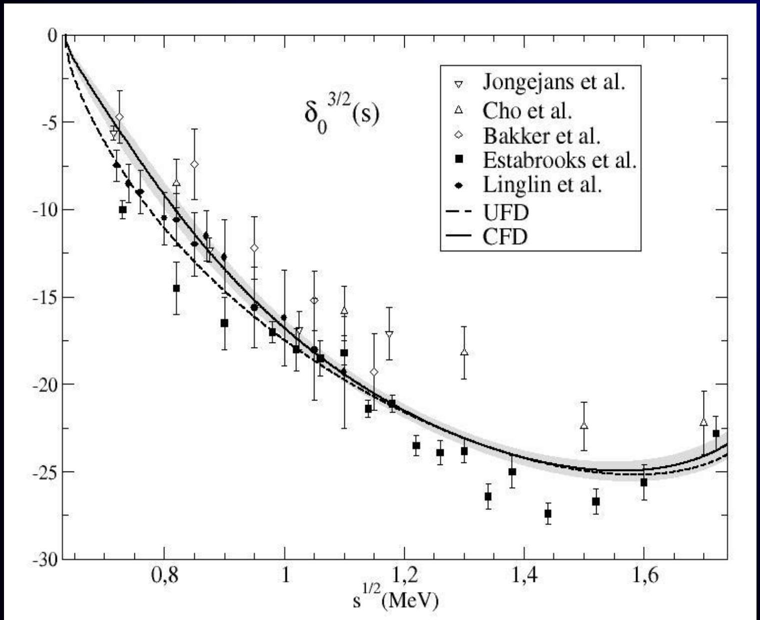
So we use
Forward Dispersion Relations
as CONSTRAINTS on fits

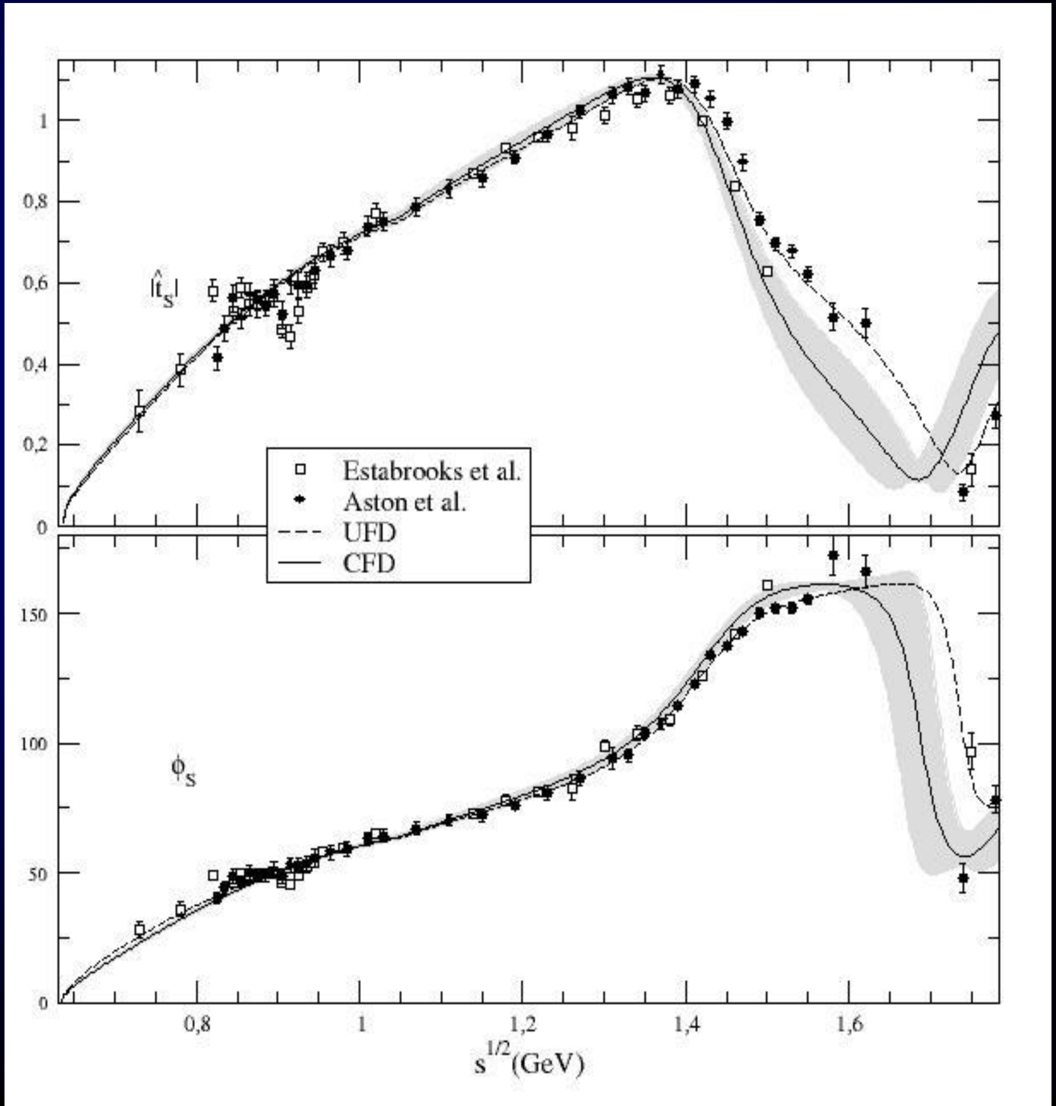
From Unconstrained (UFD) to Constrained Fits to data (CFD)

S-waves. The most interesting for the kappa

Largest changes from UFD to CFD

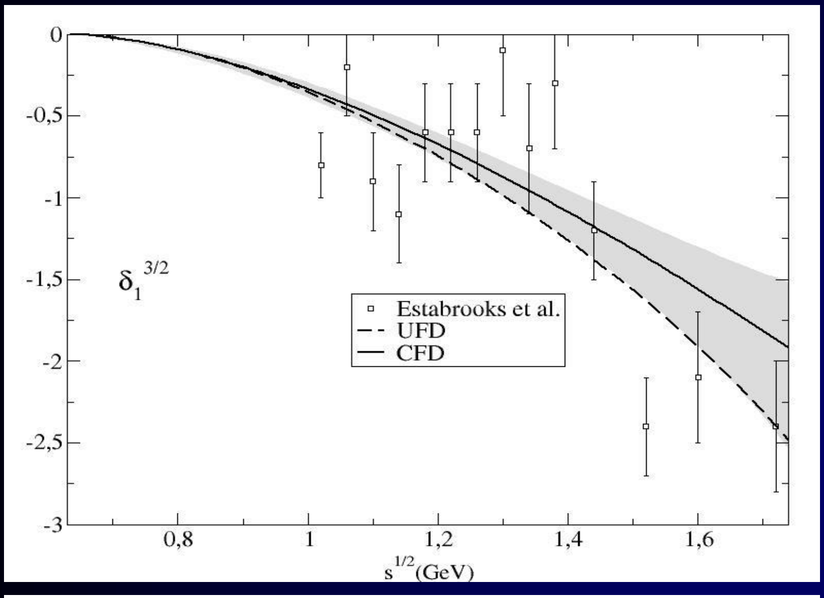
at higher energies

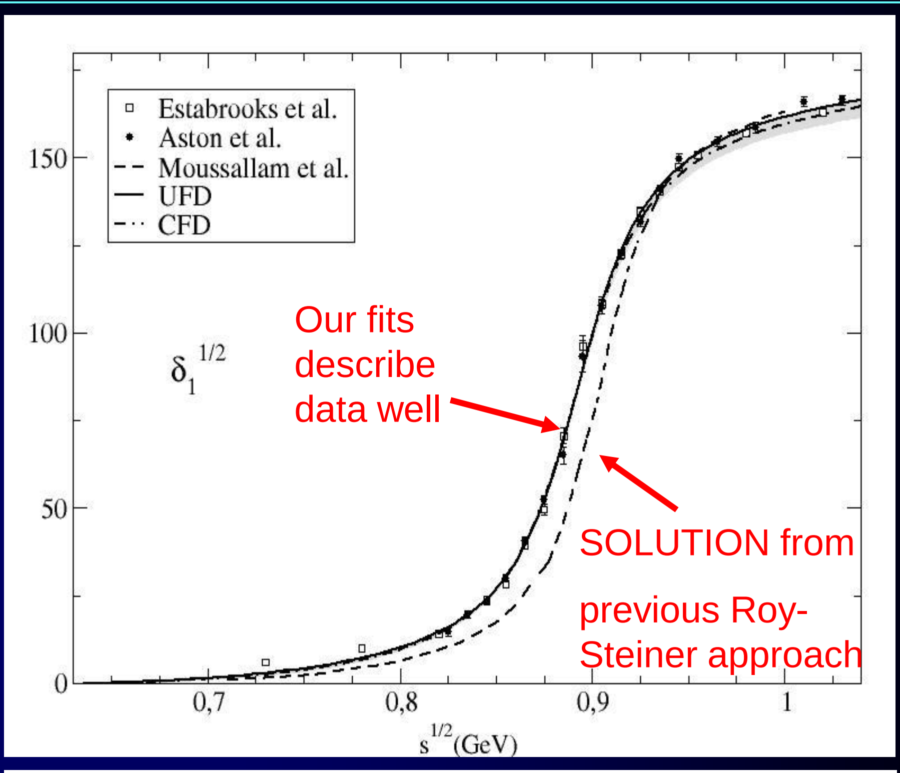


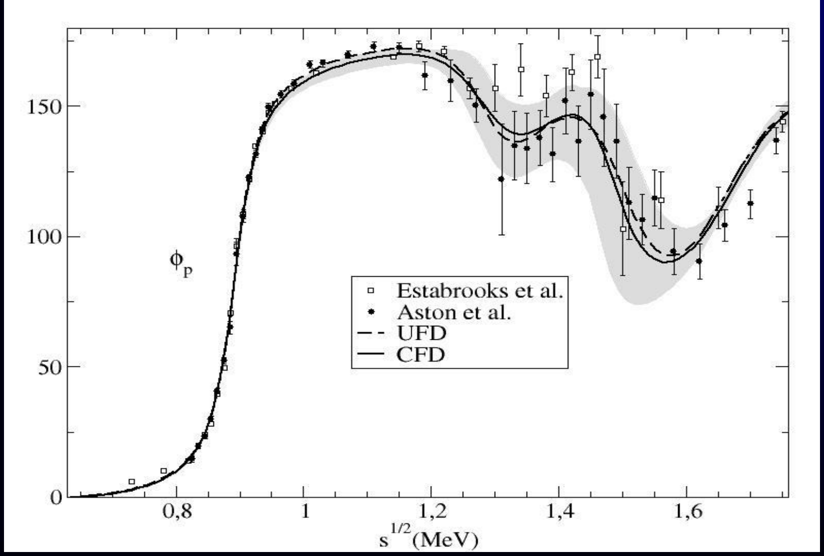


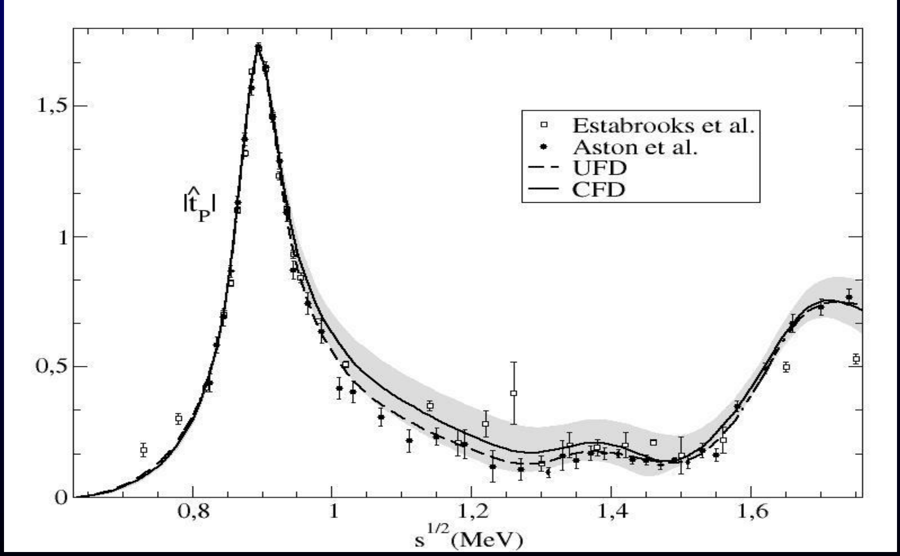
From Unconstrained (UFD) to Constrained Fits to data (CFD)

P-waves: Small changes



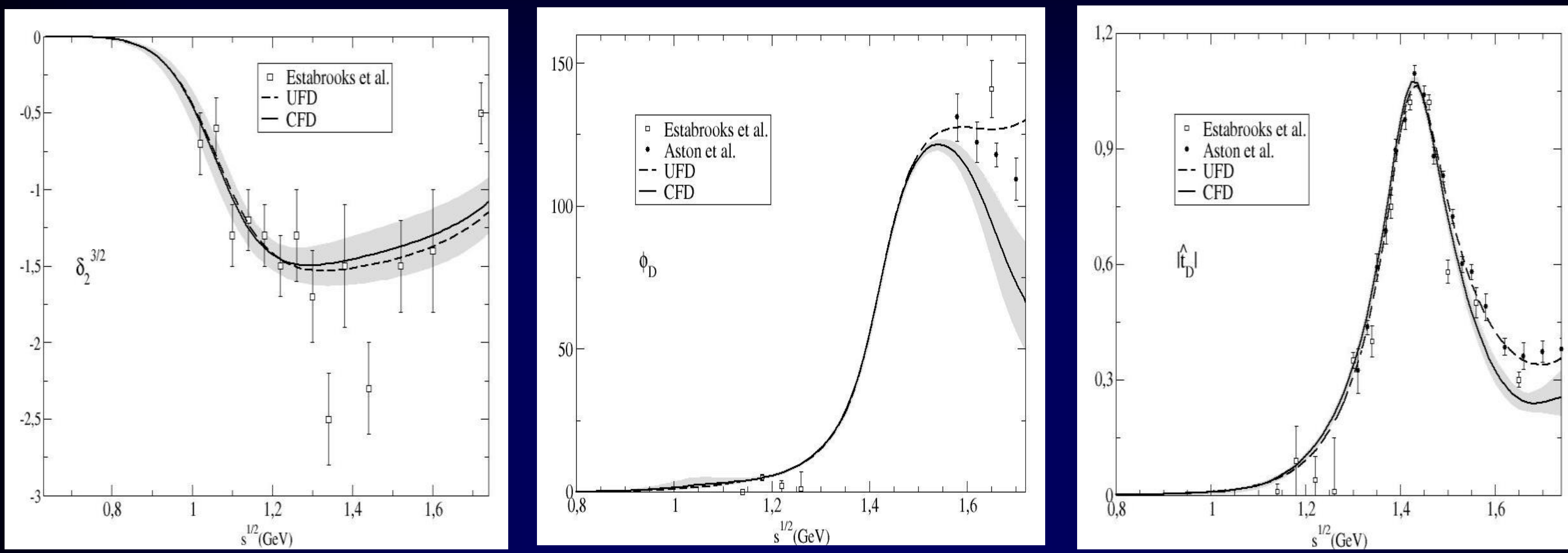






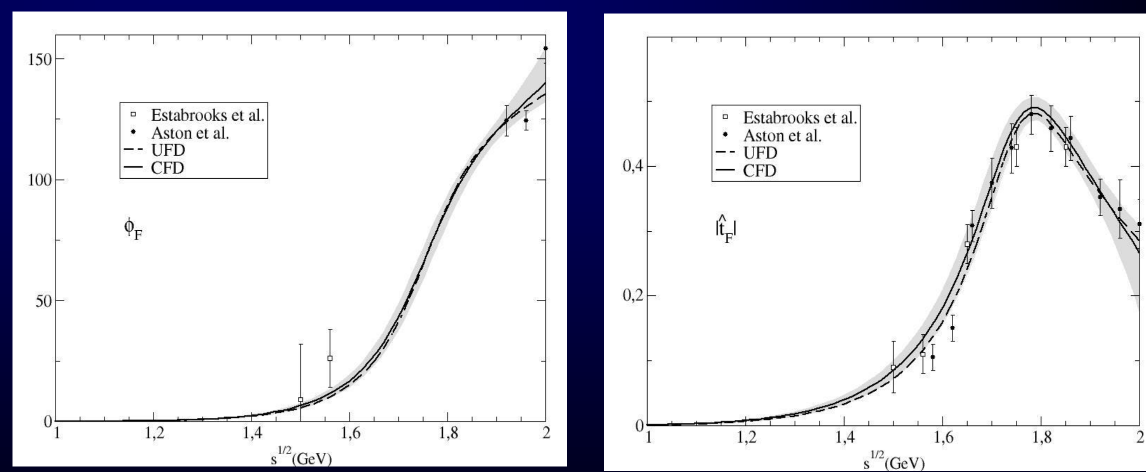
From Unconstrained (UFD) to Constrained Fits to data (CFD)

D-waves: Largest changes of all, but at very high energies

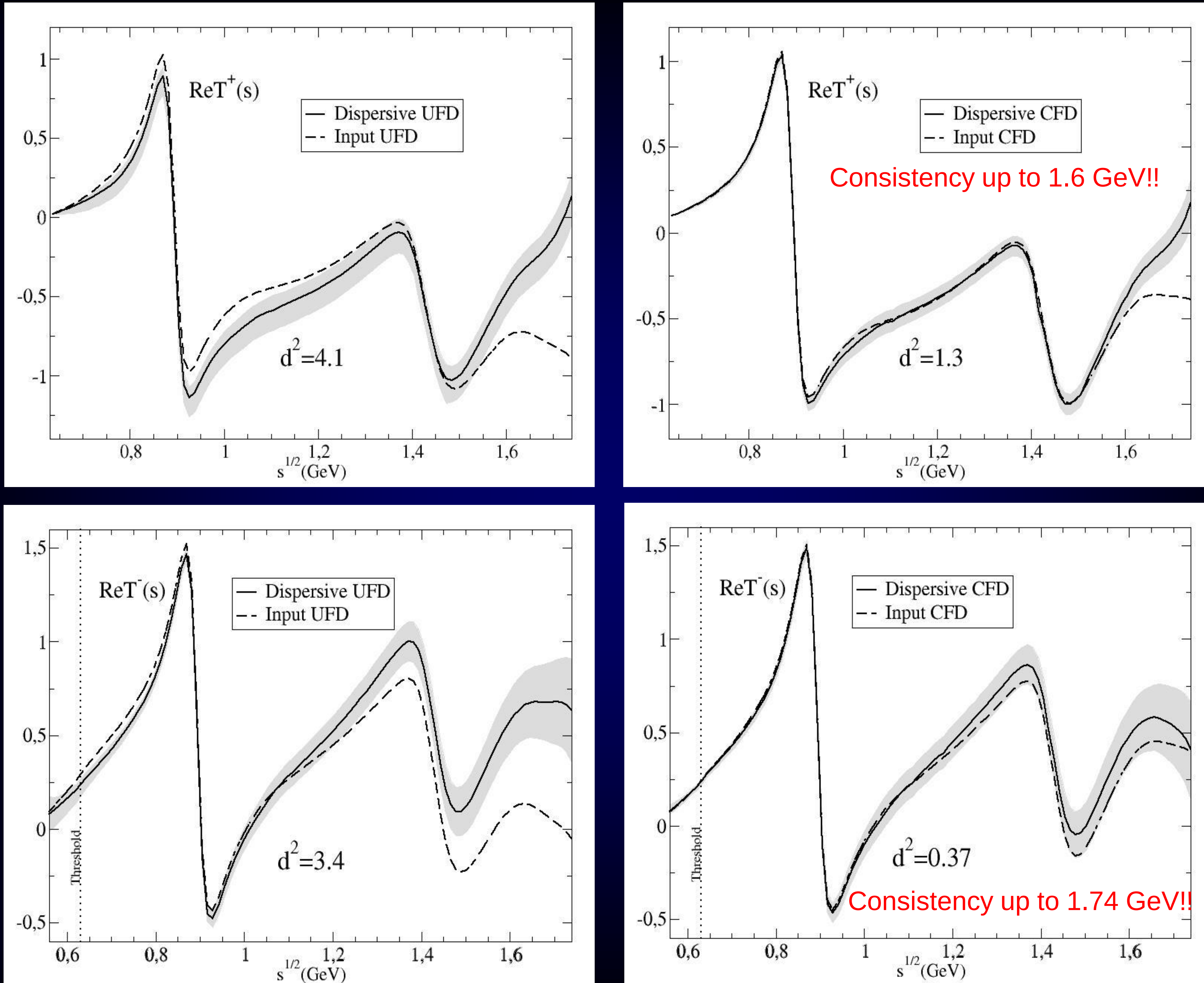


F-waves:

Imperceptible changes



Regge parameterizations allowed to vary: Only πK-ρ residue changes by 1.4 deviations



ReT+(s)
Dispersive UFD
Input UFD
d2=4.1
s1/2(GeV)
ReT+(s)
Dispersive CFD
Input CFD
Consistency up to 1.6 GeV!!
d2=1.3
s1/2(GeV)
ReT-(s)
Dispersive UFD
Input UFD
Threshold
d2=3.4
s1/2(GeV)
ReT-(s)
Dispersive CFD
Input CFD
Threshold
d2=0.37
Consistency up to 1.74 GeV!!
s1/2(GeV)

Kappa pole from CFD

We have amplitudes that describe data and satisfy dispersion relations up to 1.6 GeV

THERE IS A KAPPA POLE
Extracted from conformal parameterization
Preliminary and STILL MODEL DEPENDENT

$$M-i\,\Gamma/2=(680\pm15)-i(334\pm i15)\ \text{MeV}$$

Compare to PDG:
$M-i\,\Gamma/2=(682\pm29)-i(273\pm i12)$ MeV

Still in progress:

We are planning to extract it in a model Independent way with rigorous analytic methods and also imposing Roy-Steiner dispersion relations, as done for the sigma. IN PROGRESS

We expect this second dispersive determination will finally settle the $\kappa/K_0^*(800)$ issue at the PDG.

Now, about the kappa non-ordinary nature

1) Non linear Regge trajectory

2) Large Nc from UChPT

Already discussed 4 years ago at this meeting

Regge Theory and Chew-Frautschi Plots

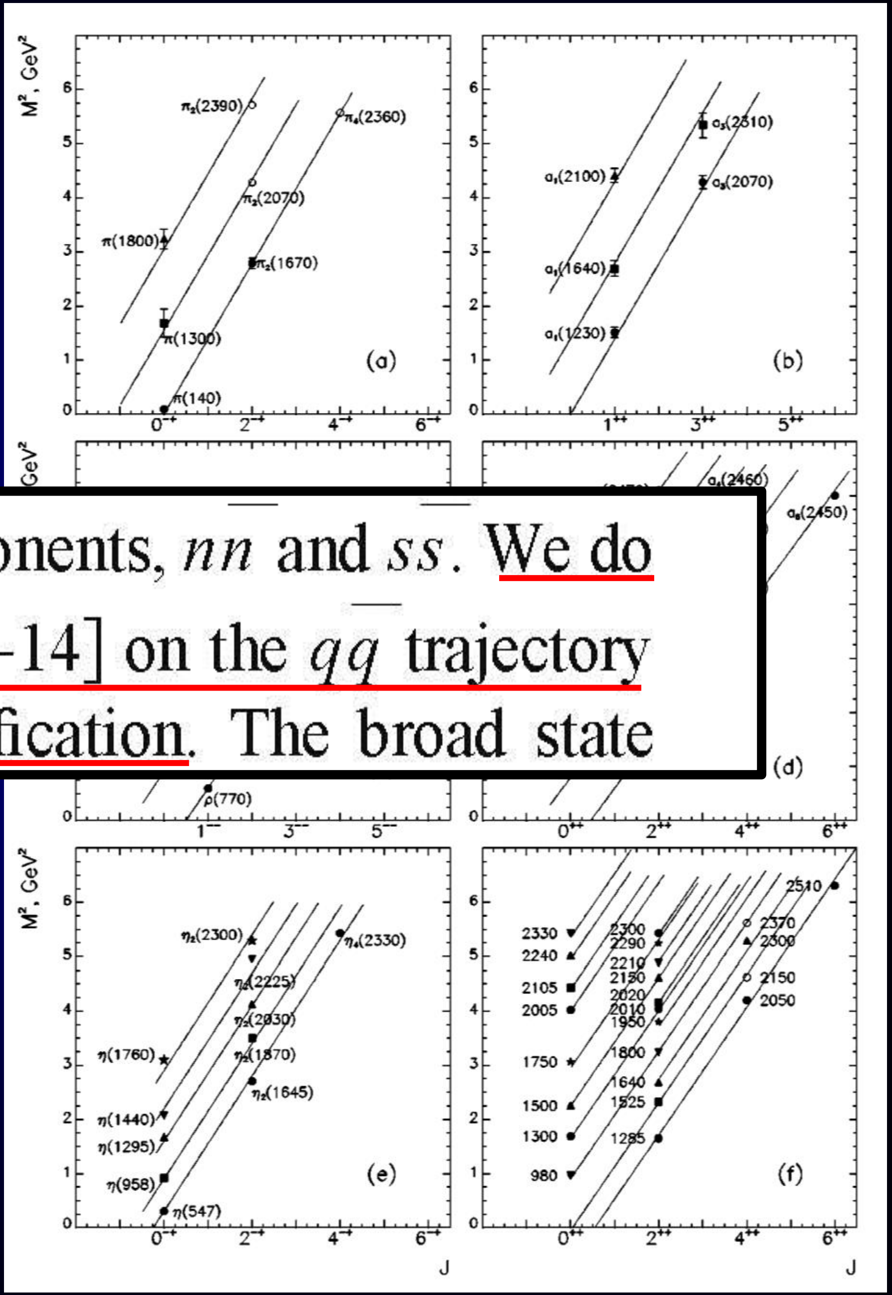
All hadrons are classified in almost linear (J,M^2) trajectories

Intuitively like a quark-antiquark pair confined at the ends of a string-like/flux-tube configuration.

ALL OF THEM? Not quite…

are doubled due to two flavor components, $n\bar{n}$ and $s\bar{s}$. We do not put the enigmatic σ meson [11–14] on the $q\bar{q}$ trajectory supposing σ is alien to this classification. The broad state

And the $K_0^*(800)$ is NOT EVEN MENTIONED

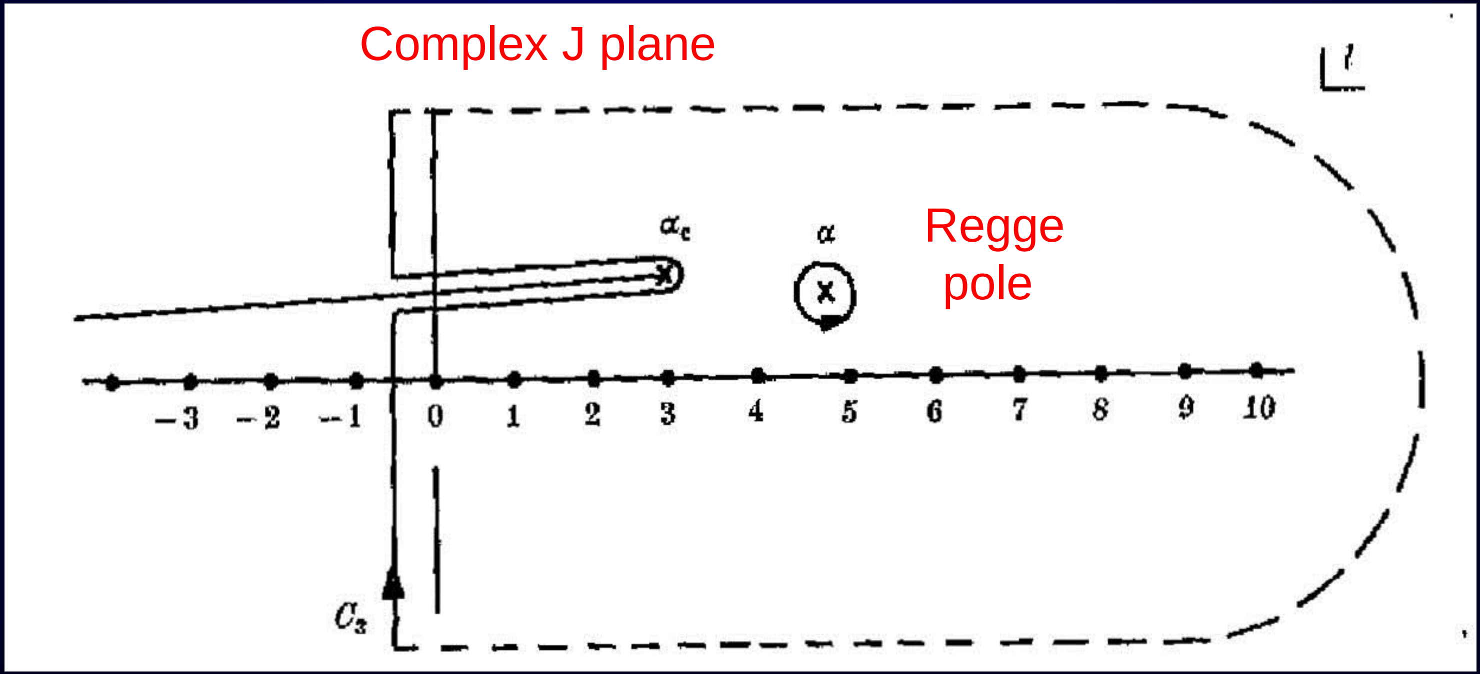


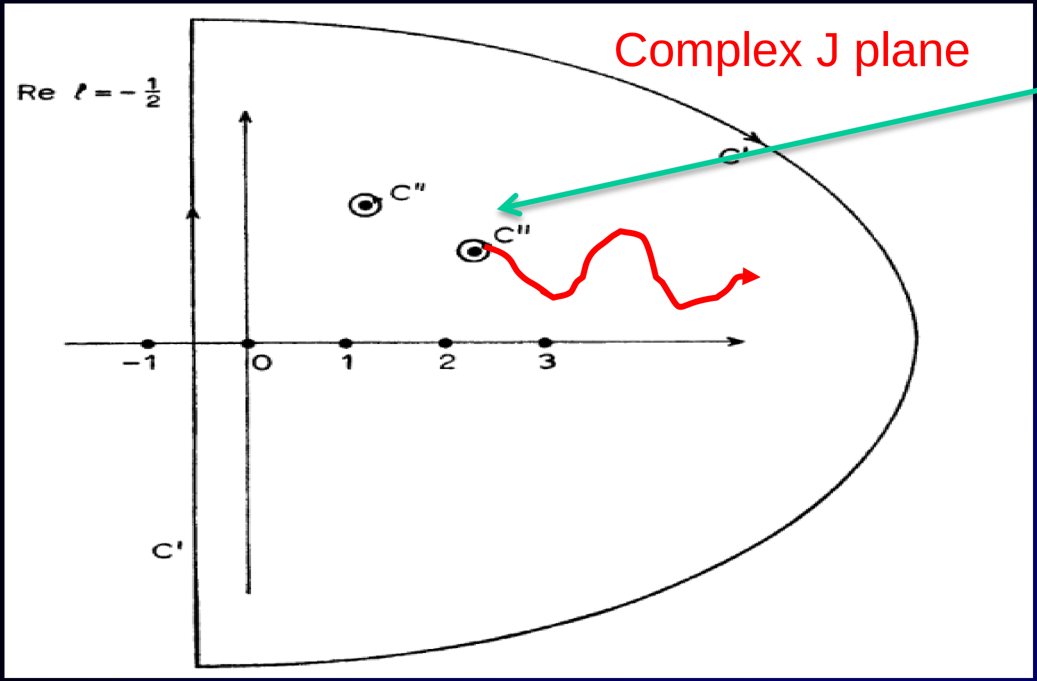
Anisovich-Anisovich-Sarantsev-Phys.Rev.D62.051502-4

Linear trajectories due to of some specific dynamics
OTHER DYNAMICS MAY LEAD TO OTHER TRJECTORIES

The Regge trajectories can be understood from the analytic extension to the complex angular momentum plane of the partial wave expansion through the Sommerfeld-Watson transform:

$$T(s,t) = \sum_{J=0}^{\infty} (2\,J+1) f_J(s)\, P_J(z) \quad \longrightarrow \quad T(s,t) = -\frac{1}{2\,i}\int_C \frac{(2\,J+1) f(J,s)\, P_J(-z)}{\sin \pi\, J}\mathrm{d}J$$





Regge poles

Position $\alpha(s)$

Residue $\beta(s)$

For different s poles move in the complex J plane along **Regge Trajectories**

The contribution of a single Regge pole to a partial wave, is shown to be

$$f(J,s) = \hat{f} + \frac{\beta(s)}{J - \alpha(s)}$$

"background" regular function.

Assumption: WE WILL AVOID IT in our cases by going to the pole

Parametrization of amplitudes dominated by Regge pole

Chu, Epstein, Kaus, Slansky, Zachariasen, PR175, 2098 (1968).

Moreover, for meson-meson scattering:

- Unitarity condition on the real axis implies

$$\mathrm{Im}\ \alpha(s) = \rho(s)\beta(s)$$

$$\rho(s) = \sqrt{1 - 4m_\pi^2/s}$$

- Further properties of β*(s)*

threshold behavior

$$\beta(s) = \frac{\hat{s}^{\alpha(s)}}{\Gamma(\alpha(s) + \frac{3}{2})}\gamma(s)$$

$$\hat{s} = \frac{s - 4m^2}{\tilde{s}}$$

suppress poles
of full amplitude

$$(2\alpha + 1)P_\alpha(z_s) \sim \Gamma(\alpha + \frac{3}{2})$$

analytic function:
β*(s)* real on real axis
⇒ phase of *Y(s)* known
⇒ Omnès-type disp. relation

Parametrization of Regge pole dominated amplitudes

(Already presented in the 2014 edition of this meeting)

The trajectory and residue should satisfy these integral equations:

$$\mathrm{Re}\,\alpha(s) = \alpha_0 + \alpha' s + \frac{s}{\pi} PV \int_{4m_\pi^2}^{\infty} ds' \frac{\mathrm{Im}\,\alpha(s')}{s'(s'-s)},$$

$$\mathrm{Im}\,\alpha(s) = \rho(s) b_0 \frac{\hat{s}^{\alpha_0+\alpha' s}}{|\Gamma(\alpha(s)+\frac{3}{2})|} \exp\Big(-\alpha' s[1-\log(\alpha'\tilde{s})] + \frac{s}{\pi} PV \int_{4m_\pi^2}^{\infty} ds' \frac{\mathrm{Im}\,\alpha(s') \log\frac{\hat{s}}{\hat{s}'} + \arg\Gamma\left(\alpha(s')+\frac{3}{2}\right)}{s'(s'-s)}\Big)$$

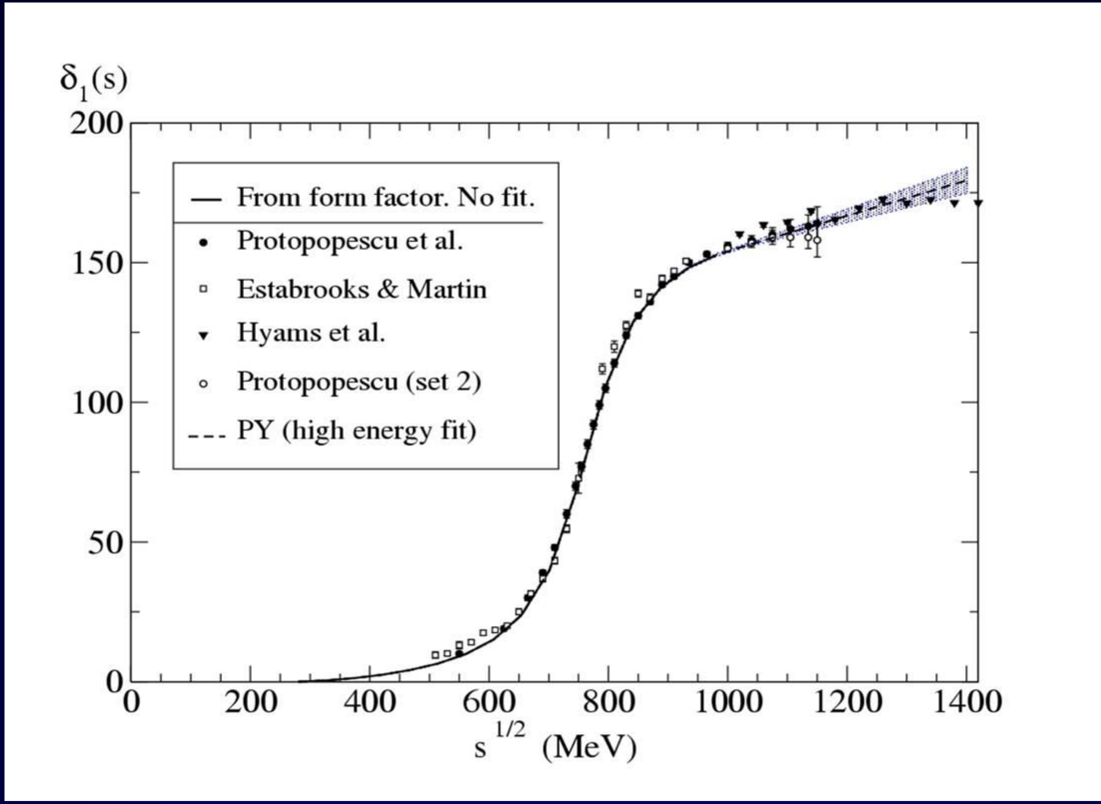
Different interactions have different constants

In the scalar case a slight modification is introduced (Adler zero)

Constants fixed by forcing the amplitude to have

THE POLE AND RESIDUE OF THE DESIRED RESONANCE

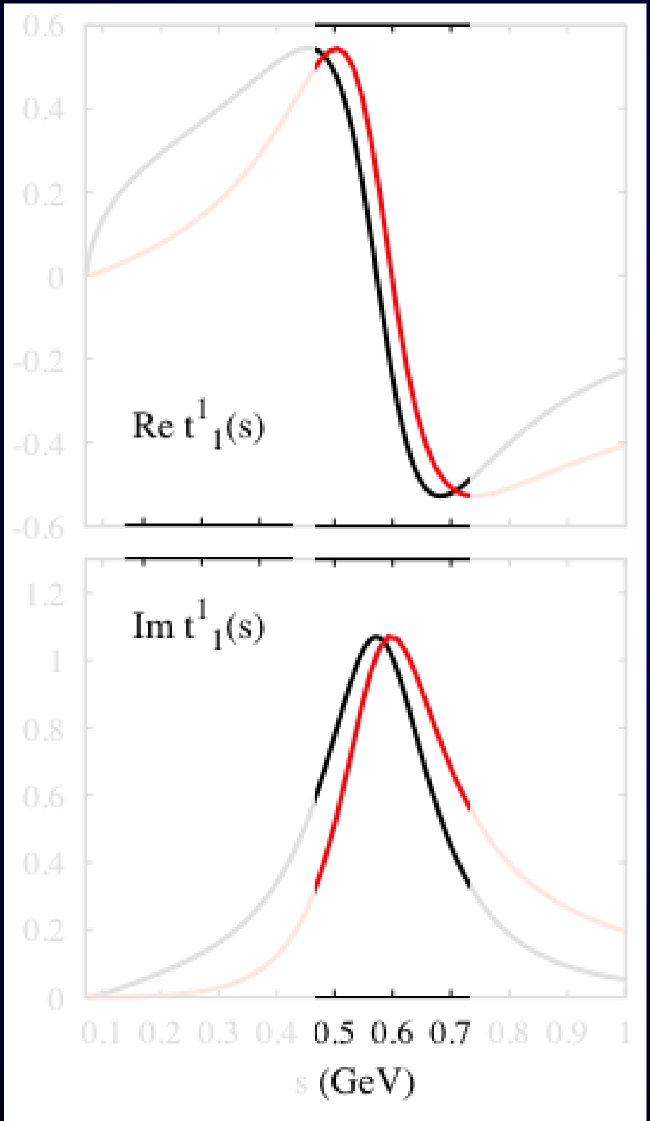
INPUT:Analytic continuation to the complex plane of a dispersive analysis of data



- INPUT for our purposes: **The ρ pole:**

$$\rho_{pole} \approx 763^{+1.7}_{-1.5} - i73.2^{+1.0}_{-1.1}\,\text{MeV} \qquad |g| = 6.01^{+0.04}_{-0.07}$$

Results: ***ρ case (I = 1, J = 1)***



We (black) recover a fair representation of the partial wave, in agreement with the GKPY amplitude (red)

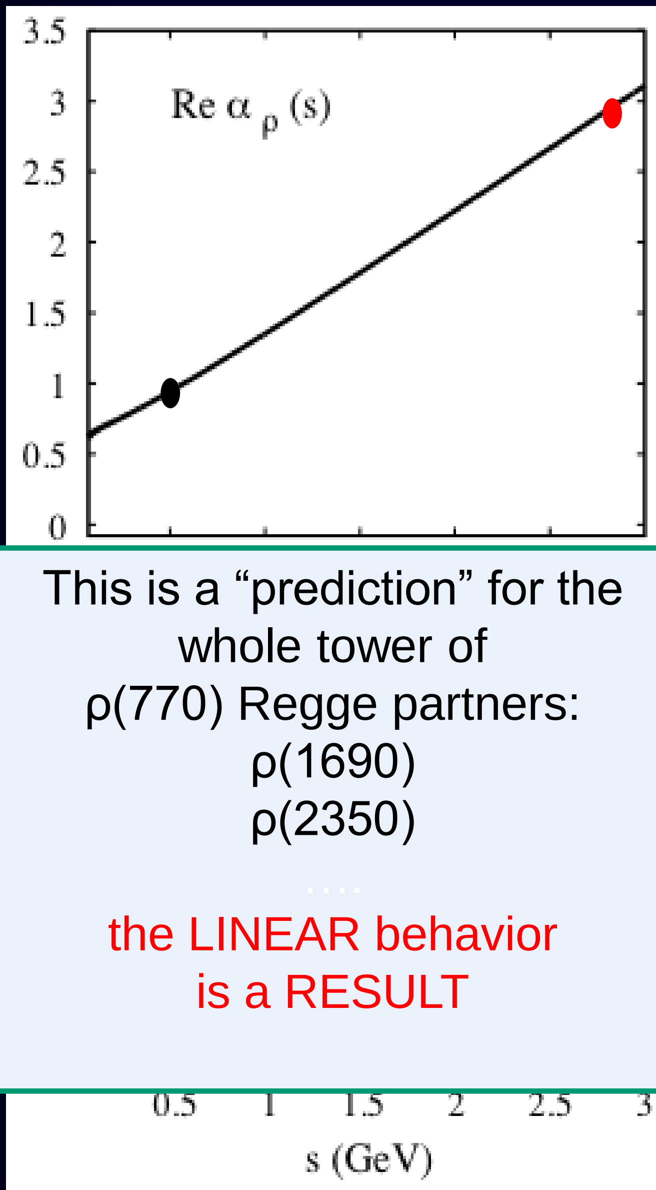
Neglecting the “background” vs. Regge pole gives a 10-15% error.

Particularly in the resonance region

Fair enough to look for the Regge trajectory

Results: ***ρ case (I = 1, J = 1)***

We get a prediction for the ρ Regge trajectory, which is almost real



This is a “prediction” for the whole tower of $\rho(770)$ Regge partners:

$\rho(1690)$

$\rho(2350)$

….

the LINEAR behavior is a RESULT

Almost LINEAR $\alpha(s) \sim \alpha_0 + \alpha' s$

intercept $\alpha_0 = 0.520 \pm 0.002$

slope $\alpha' = 0.902 \pm 0.004$ GeV^{-2}

Previous studies from FITS:

[1] $\alpha_0 = 0.5$

[2] $\alpha_0 = 0.52 \pm 0.02$

[3] $\alpha_0 = 0.450 \pm 0.005$

[1] $\alpha' = 0.83$ GeV^{-2}

[2] $\alpha' = 0.9$ GeV^{-2}

[4] $\alpha' = 0.87 \pm 0.06$ GeV^{-2}

Remarkably consistent with the literature!!, (taking into account our approximations)

[1] A. V. Anisovich et al., Phys. Rev. D 62, 051502 (2000)
[2] J. R. Pelaez and F. J. Yndurain, Phys. Rev. D 69, 114001 (2004)
[3] J. Beringer et al. (PDG), Phys. Rev. D86, 010001 (2012)
[4] P. Masjuan et al., Phys. Rev. D 85, 094006 (2012)

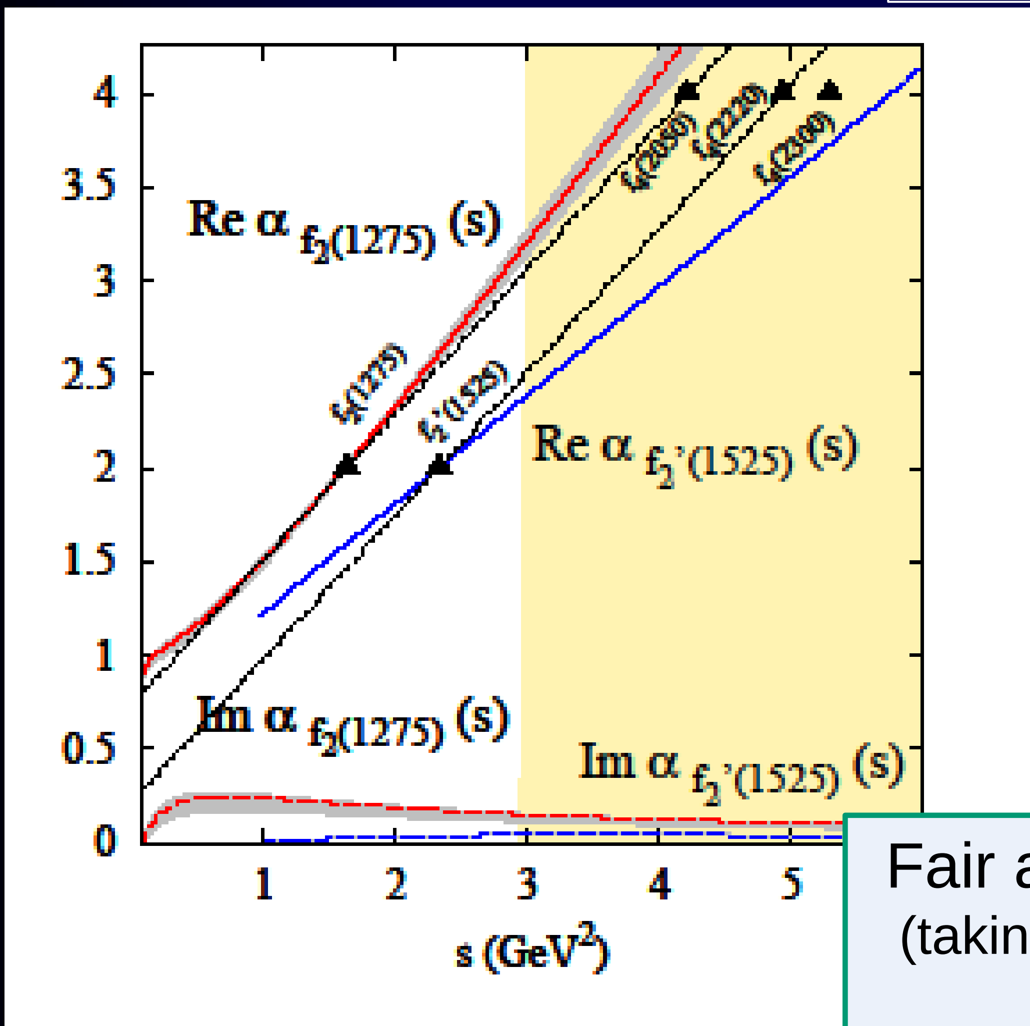
$f_2(1275)$ and $f_2'(1525)$ cases ($I = 0, J = 2$)

J.A.. Carrasco J.Nebreda, JRP, A. Szczepaniak,
Phys.Lett. B749 (2015) 399

Almost elastic: $f_2(1275)$ BR ($\pi\pi$) = 85% and $f_2'(1525)$ BR(KK)=90%.

Solving the integral equations we "predict" again:

Almost real and LINEAR $\alpha(s) \sim \alpha_0 + \alpha' s$



For the $f_2(1275)$

$\alpha_0 = 0.9^{+0.2}_{-0.3}$

$\alpha' = 0.7^{+0.3}_{-0.2}$ GeV^{-2}

For the $f'_2(1525)$

$\alpha_0 = 0.53^{+0.10}_{-0.44}$

$\alpha' = 0.63^{+0.20}_{-0.06}$ GeV^{-2}

Fair agreement with the literature!!

(taking into account our approximations)

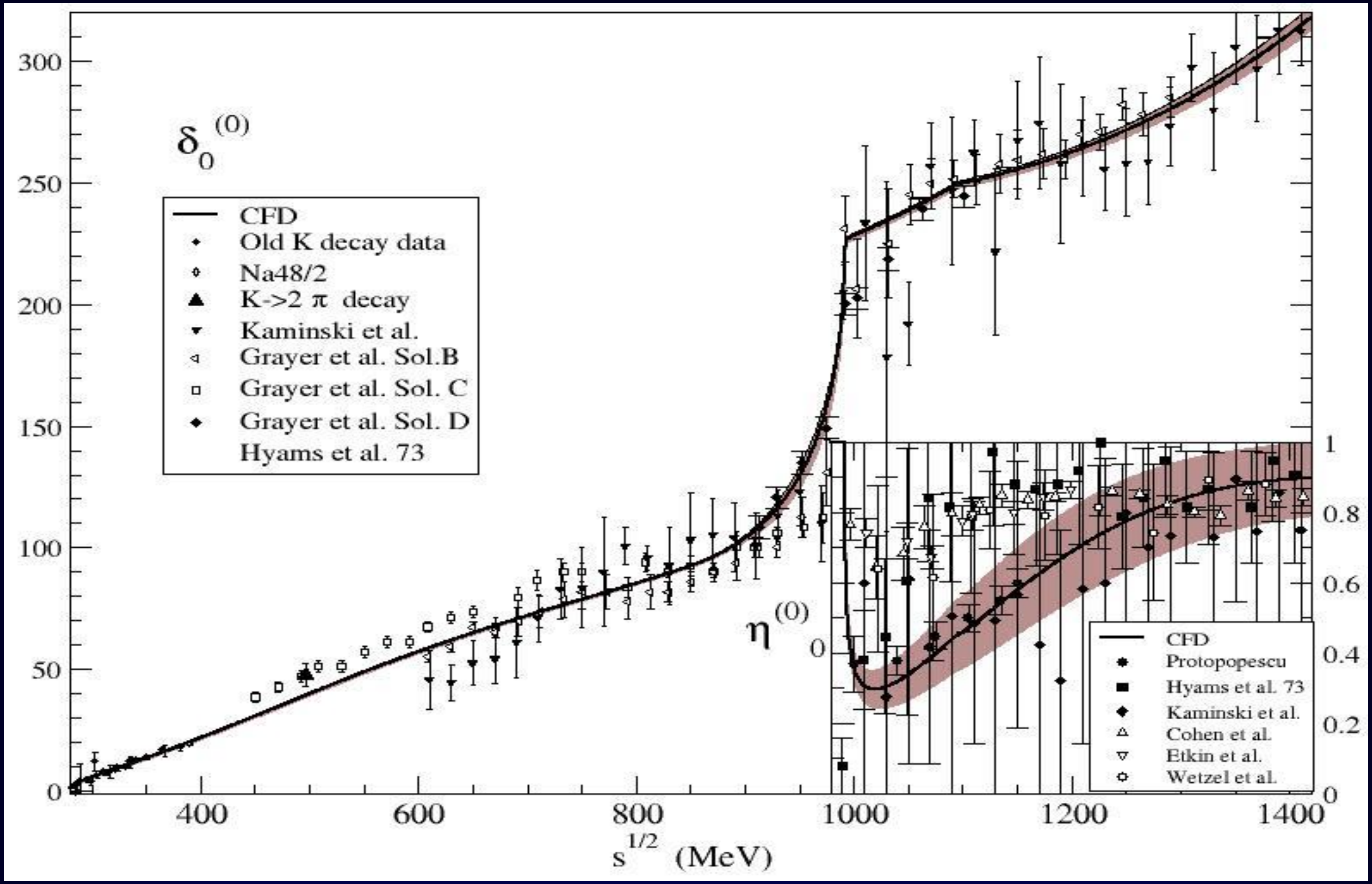
Remember this is NOT a fit!!

The “prediction” for the rho trajectory
was known since the 70’s, we have just updated it
and obtained new “predictions” for the f_2 and f_2’

So, once we have checked that our approach
predicts the established Regge trajectories just from the pole
position and residue…

What about the $\sigma/f_0(500)$ and $K^*_0(800)$?

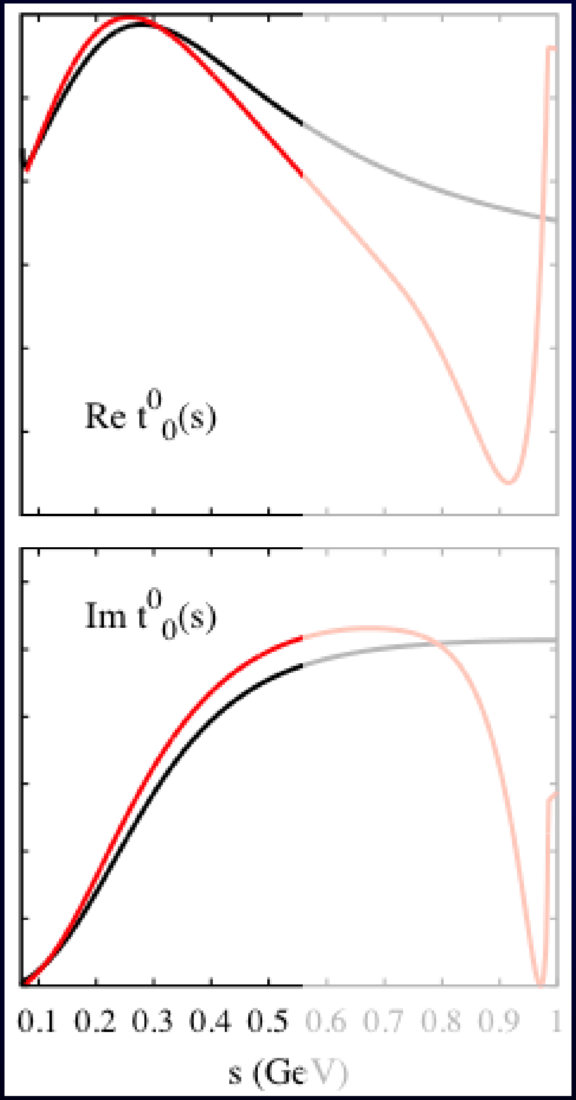
INPUT:Analytic continuation to the complex plane of a dispersive analysis of data



- INPUT for our purposes: **The σ pole:**

$$(457^{+14}_{-15}) - i(279^{+11}_{-7})\text{MeV} \qquad |g| = 3.59^{+0.11}_{-0.13}\ \text{GeV}$$

Results: ***σ case (I = 0, J = 0)***

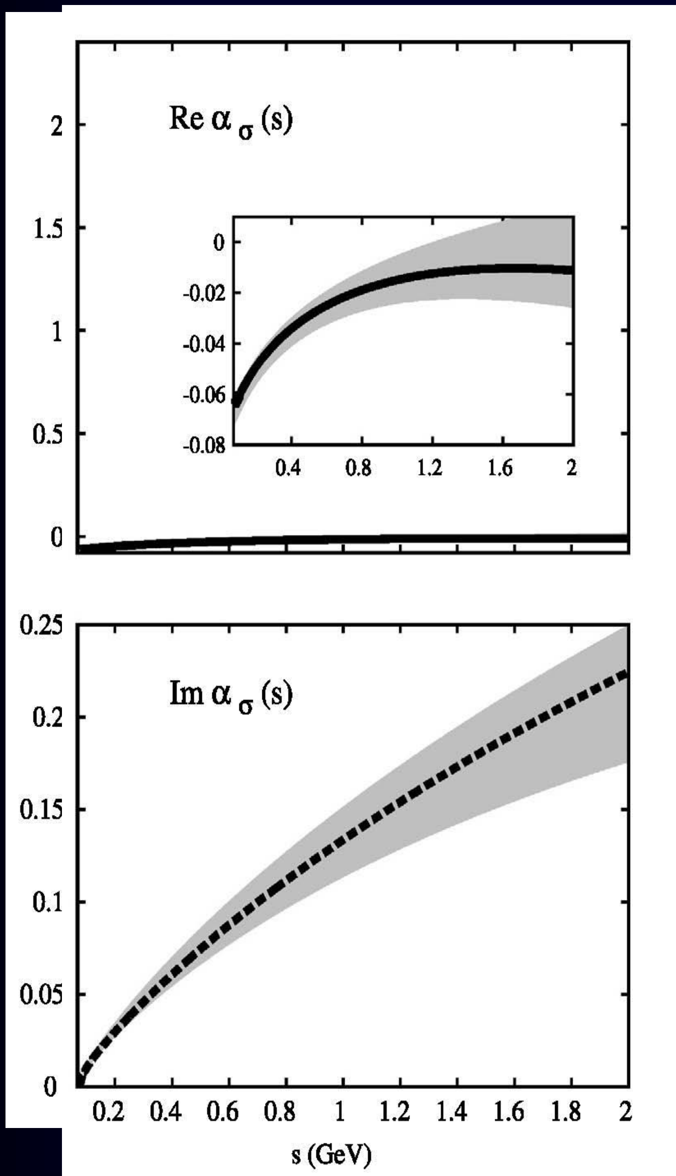


Somewhat better agreement in the resonance region of the Regge pole dominated amplitude with the dispersive amplitude.

So, we apply a similar procedure but now for the $f_0(500)$

Results: ***σ case (I = 0, J = 0)***

The prediction for the *σ* Regge trajectory, is:



- NOT approximately real
- NOT linear

intercept

$$\alpha_\sigma(0) = -0.090^{+0.004}_{-0.012},$$

slope

$$\alpha'_\sigma \simeq 0.002^{+0.050}_{-0.001}\ \mathrm{GeV}^{-2}$$

Compare with the rho result…

α_0= 0.52

α' = 0.913 GeV^{-2}

The sigma does **NOT** fit the ordinary meson trajectory

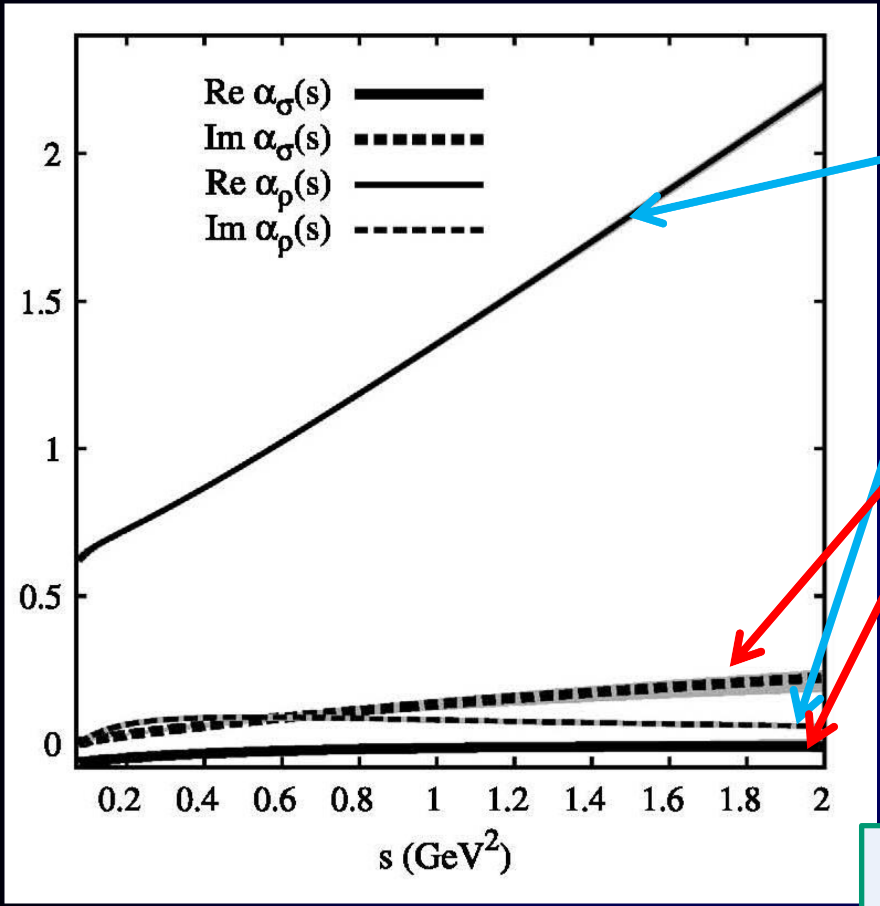
Two orders of magnitude flatter than other hadrons

Typical of meson physics?

F_π , m_π ?

We CALCULATE the $\sigma/f_0(500)$ trajectory

Londergan, Nebreda, JRP, Szczepaniak PLB 729 (2014) 99



Ordinary ρ(770) trajectory

$\alpha_0 = 0.52$ $\alpha' = 0.913\ GeV^{-2}$

The $\sigma/f_0(500)$ trajectory is **not real** and much smaller

$$\alpha_\sigma(0) = -0.090^{+0.004}_{-0.012},$$

$$\alpha'_\sigma \simeq 0.002^{+0.050}_{-0.001}\ GeV^{-2},$$

The σ trajectory is **NOT** ordinary

No evident Regge partners

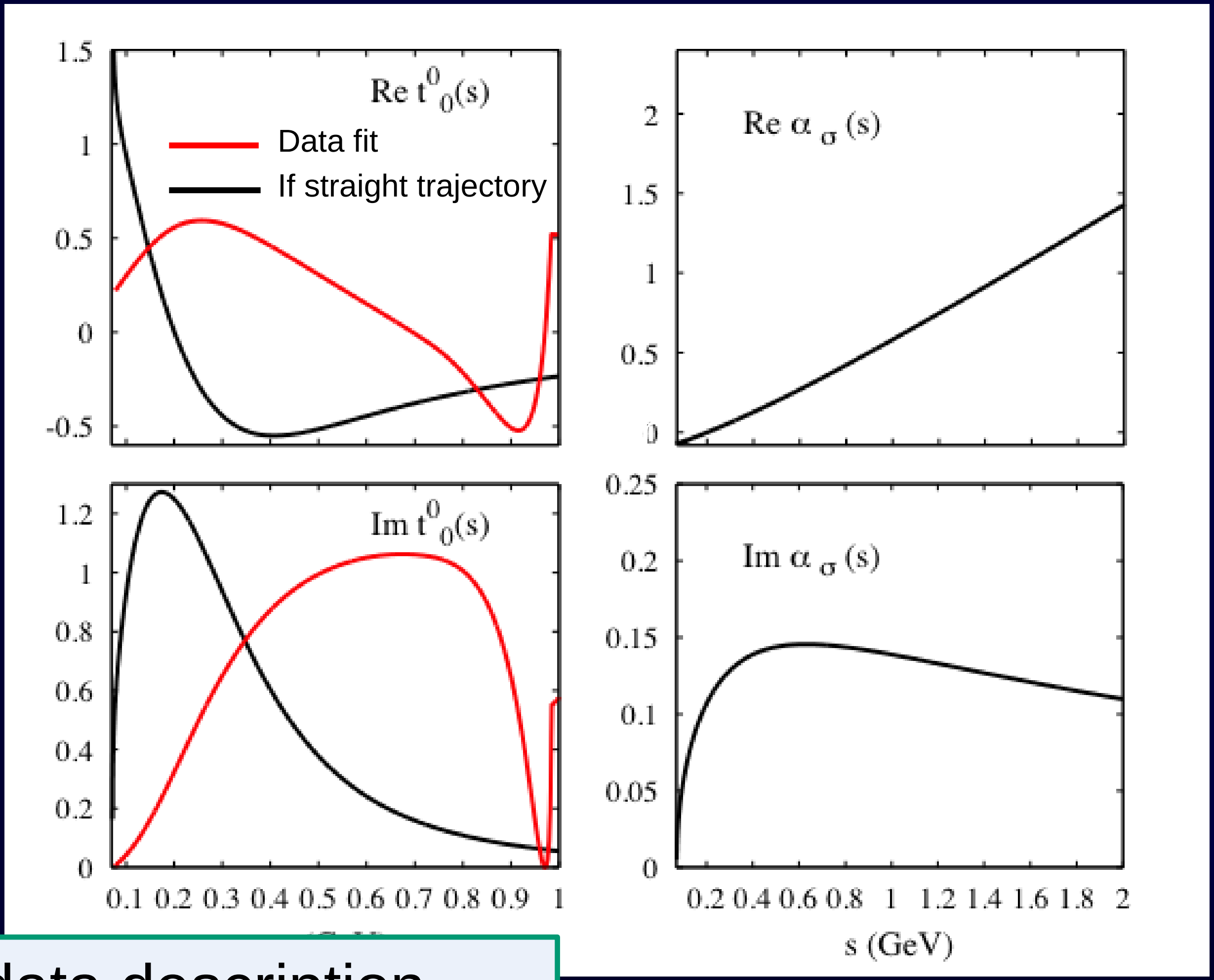
Much flatter than other hadrons.

Another scale at play.

Meson physics involved? F_π , m_π ?

Results: ***σ case (I = 0, J = 0)***

IF WE INSISTED in fixing the *α’* to an “ordinary” value ~ 1 GeV^{-2} and the trajectory to a straight line…



The data description would be severely spoilt

And now the trajectories with strangeness

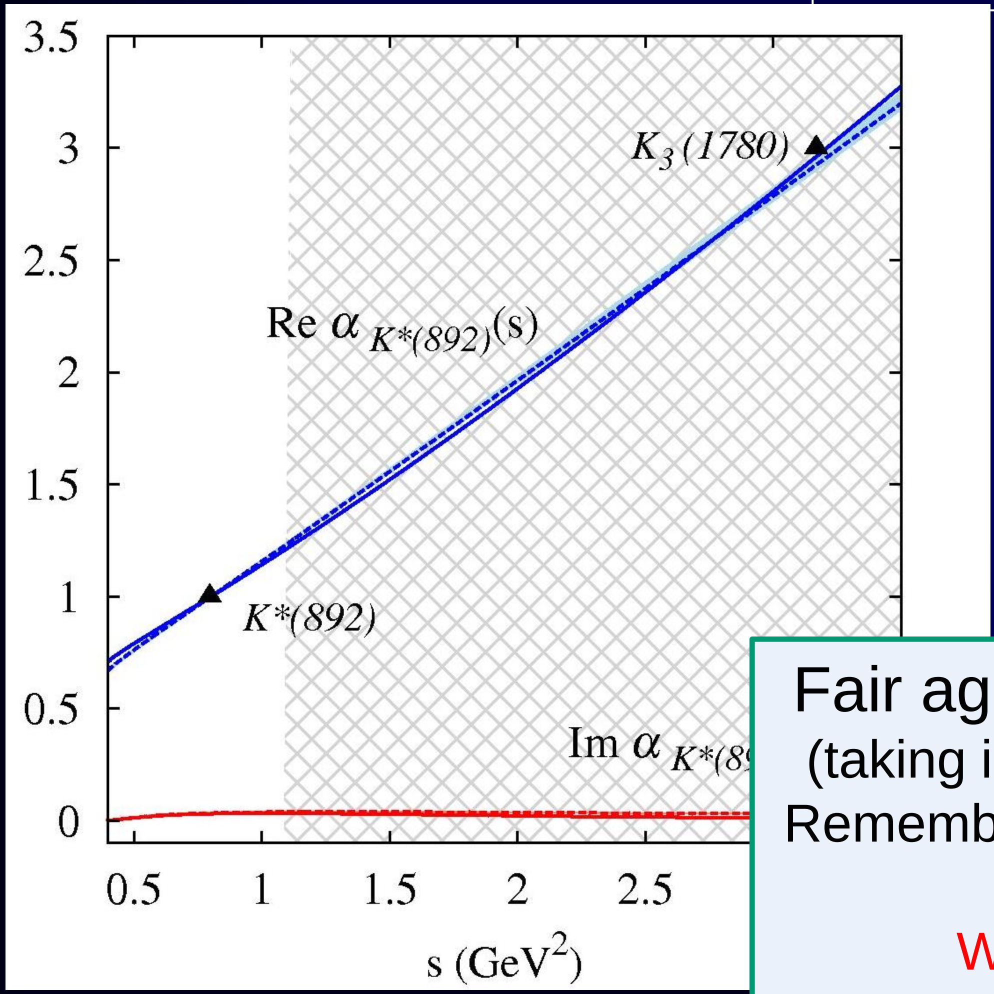
The K(892) case (I = 1/2, J = 1)*

J.A.. Carrasco J.Nebreda, JRP, A. Szczepaniak, Phys.Lett. B749 (2015) 399

Very elastic to Kπ. Different masses now. Slight modification

Solving the integral equations we "predict" again:

Almost real and LINEAR $\alpha(s) \sim \alpha_0 + \alpha' s$



For the ***K*(892)***

$\alpha_0 = 0.32 \pm 0.01 GeV^{-2}$

$\alpha' = 0.83 \pm 0.01$

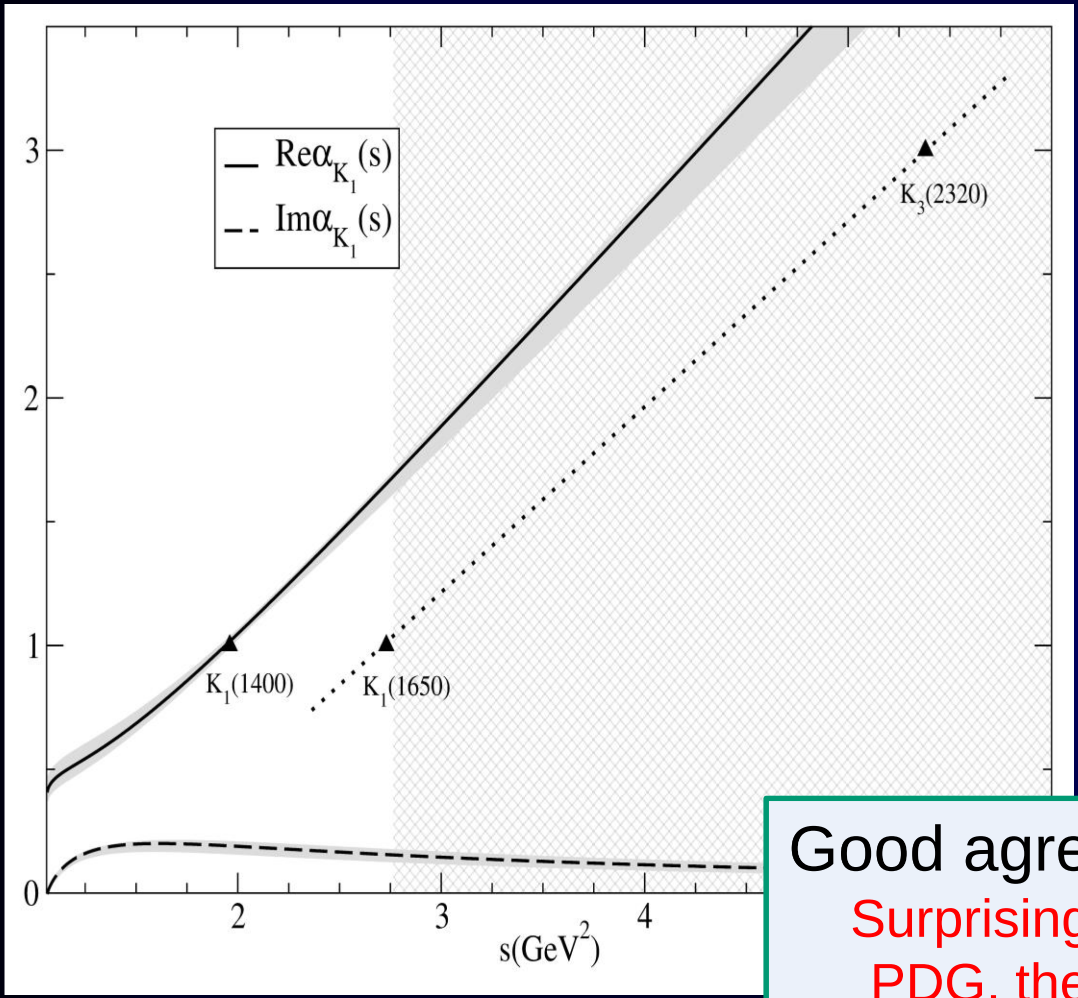
Fair agreement with the literature!!
(taking into account our approximations)
Remember this is NOT a fit to the tower of resonances!!
We only fit the K*(892) pole
Impressive prediction of $K_3^*(1780)$

The $K^*_1(1400)$ case (I = 1/2, J = 1)

JRP, A.Rodas in preparation

Very elastic to K*π, BR=94±6%. Decays to a resonance+pion

Solving the integral equations we "predict" again:



Almost real and LINEAR

$\alpha(s) \sim \alpha_0 + \alpha' s$

For the $K^*_1(1400)$

$\alpha_0 = -0.72 + 0.13 - 0.03$

$\alpha' = 0.90 \pm 0.01 \text{GeV}^{-2}$

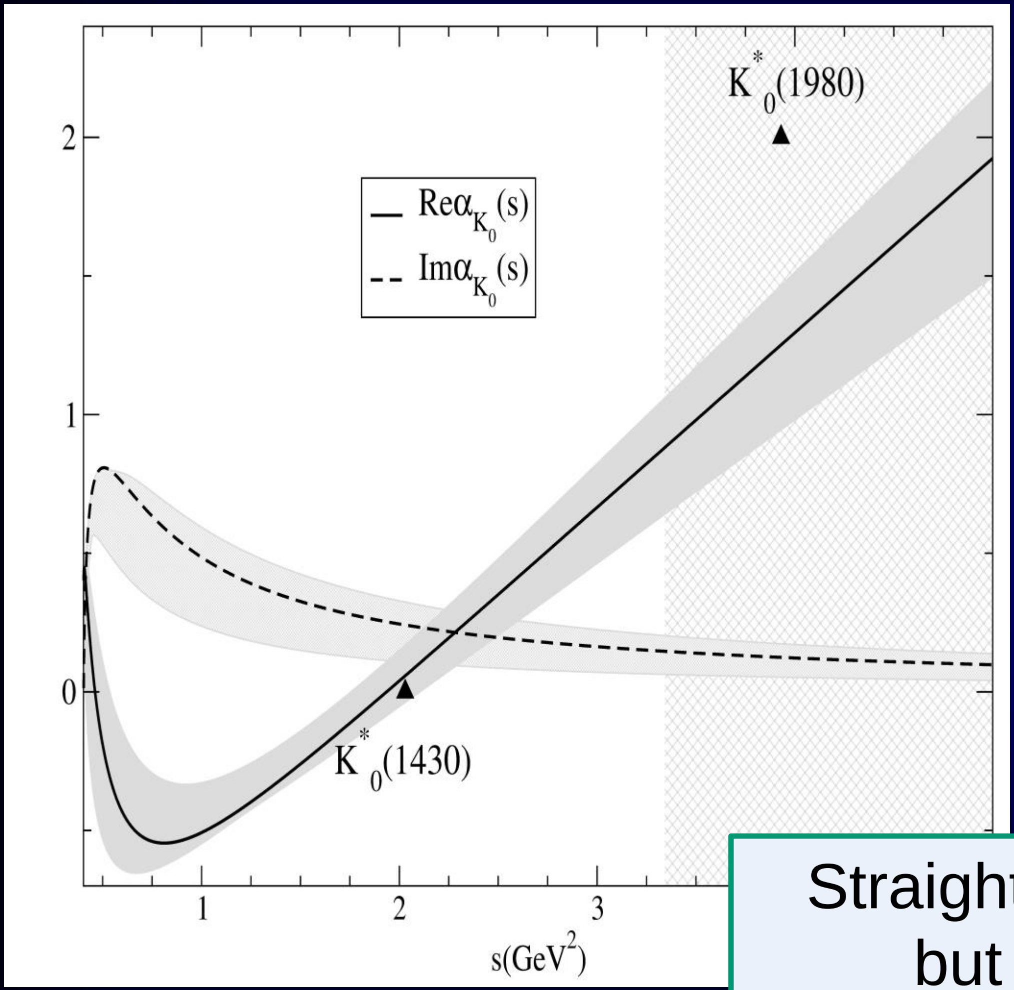
Good agreement with universal slope

Surprisingly there is no candidate in the PDG, the nearest one fits better in the $K_1^*(1650)$ trajectory

The $K_0^*(1430)$ case ($I = 1/2$, $J = 0$)

JRP, A.Rodas in preparation

Quite elastic to Kπ, BR=93±10%. Many models predict quark-antiquark with sizable mixing to Kπ. Solving the integral equations we "predict" again:



LINEAR real part around resonance

$\alpha(s) \sim \alpha_0 + \alpha' s$

For the $K_0^*(1400)$

$\alpha_0 = -0.76+0.21-0.10$

$\alpha' = 0.62 \pm 0.10\,GeV^{-2}$

Straight line in applicability región but slope somewhat small

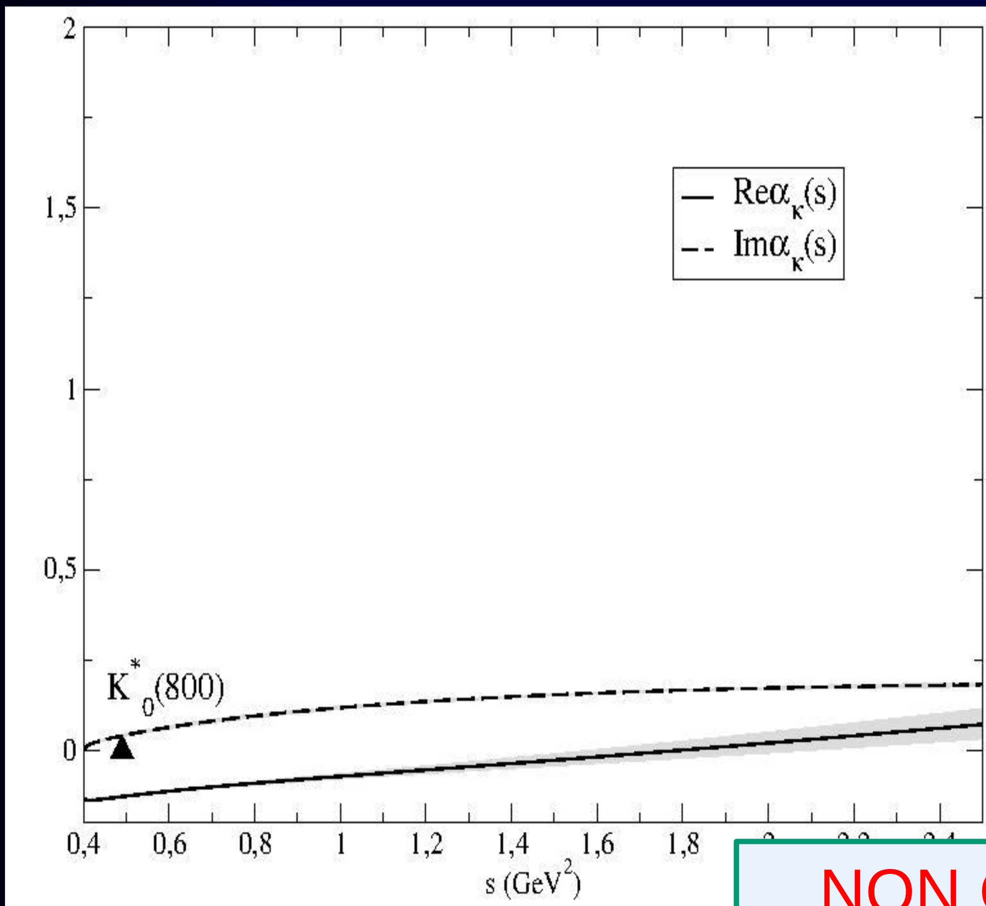
(mixing?)

The kappa case (I = 1/2, J = 0)

JRP, A.Rodas in preparation

Elastic to Kπ. Cryptoexotic candidate

Solving the integral equations we “predict”:



Trajectory far from real,
Very small
Real part NON-linear

For the $K_0^*(800)$

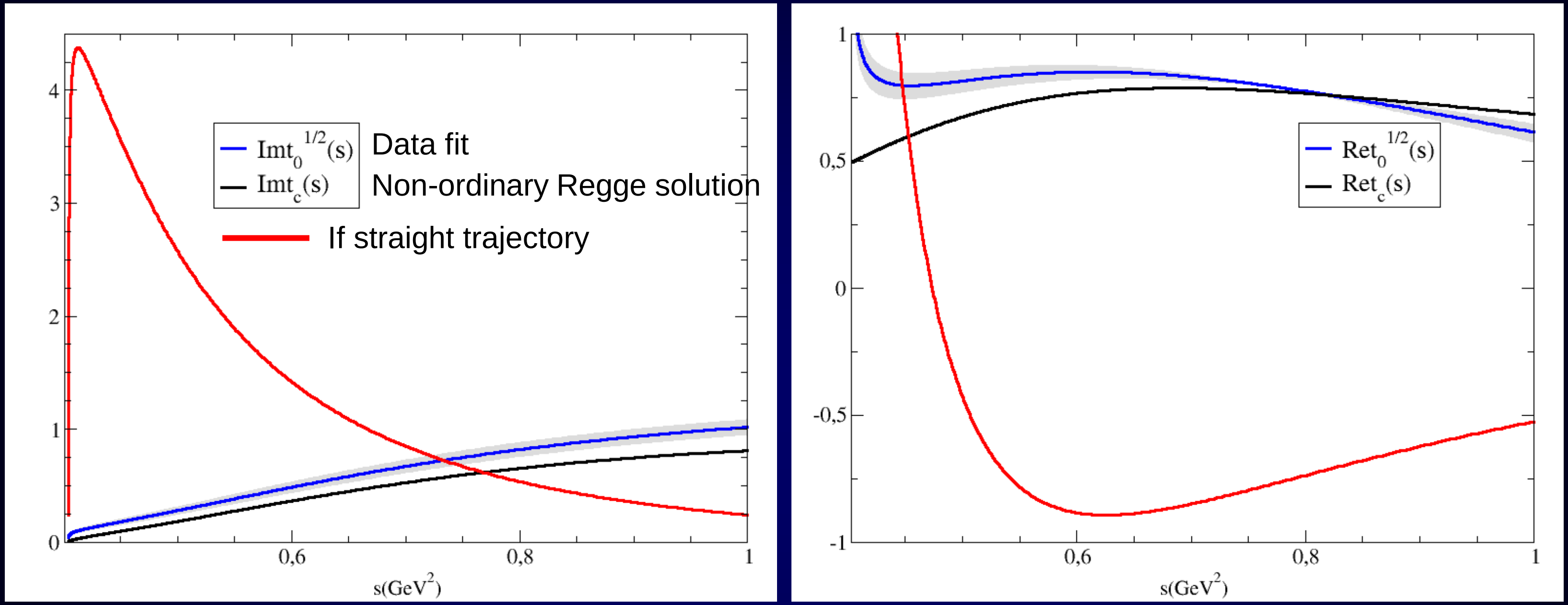
$\alpha_0 = -0.28+0.02$

$\alpha' = 0.16 \pm 0.03\ GeV^{-2}$

NON ORDINARY TRAJECTORY
Not real,not linear
Scales smaller tan usual

Results: ***κ case (I = 1/2, J = 0)***

IF WE INSISTED in fixing the *α'* to an "ordinary" value ~ 1 GeV^{-2} and the trajectory to a straight line…



The data description would be severely spoilt

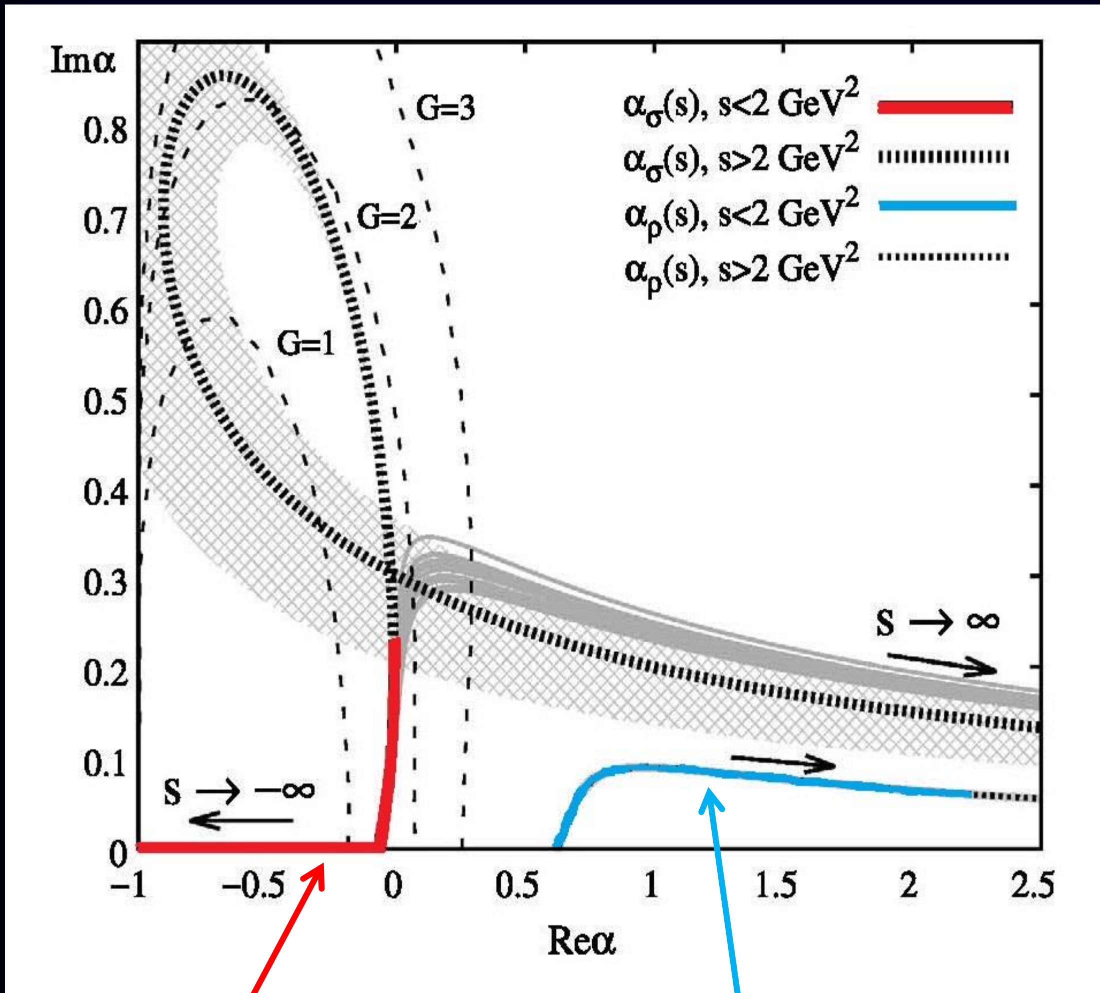
If not-ordinary…

What then?

Can we identify the dynamics of the σ and κ trajectories?

Not quite yet… but…

Ploting the trajectories in the complex J plane…



Striking similarity with Yukawa potentials at low energy:

$V(r) = -Ga\exp(-r/a)/r$

Our result is mimicked with $a = 0.5\ \mathrm{GeV}^{-1}$

to compare with S-wave ππ scattering length $1.6\ \mathrm{GeV}^{-1}$

"a" rather small !!!

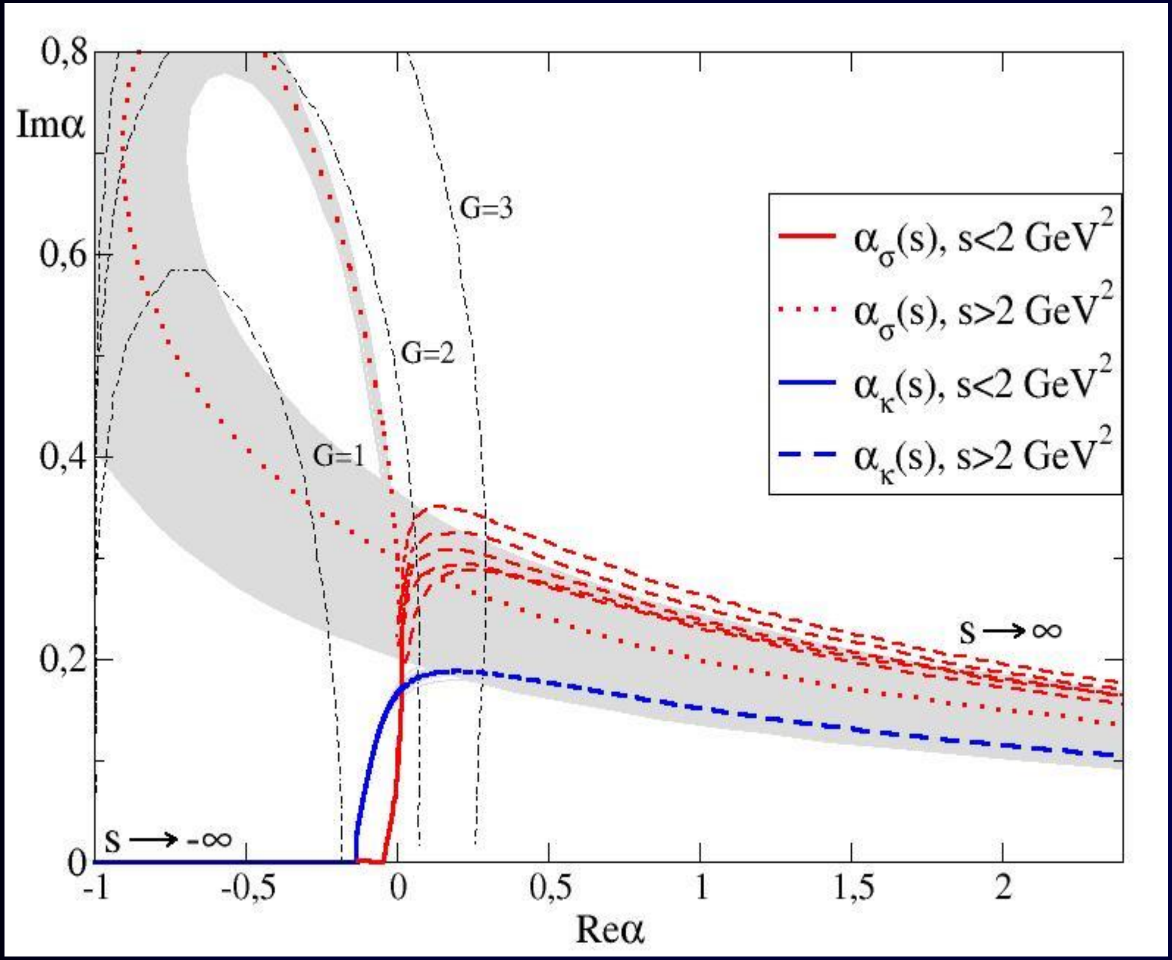
Non-ordinary σ trajectory

Ordinary ρ trajectory

The extrapolation of our trajectory also follows a Yukawa but deviates at very high

Results: ***κ case (I = 1/2, J = 0)***

For the kappa we find a very similar behavior to the sigma:



Compared to:
V(r)=−Ga exp(−r/a)/r

Similar order of magnitude for range

$a_{\pi\pi}$=0.5 GeV^{-1}

$a_{\pi K}$=0.33 GeV^{-1}

$a_{\pi\pi}$/ $a_{\pi K}$ ~1.52

Maybe a_{MM} scales as inverse of reduced mass

$\mu_{\pi K}$ / $\mu_{\pi\pi}$ =1.57

Summary

Part 1

The use of good data and MODEL INDEPENDENT DISPERSIVE methods were essential to establish the **σ/f_0(500)** parameters

The **κ/K_0^*(800)** is now in a similar situation as the σ/f_0(500) in 2010. We are working to have an additional DISPERSIVE DETERMINATION that will confirm its parameters.

For the moment we have Kπ amplitudes consistent with Forward Dispersion Relations and data up to 1.6GeV. Naive extrapolation gives consistent kappa pole. Rigorous pole extraction coming. Expect changes @PDG soon.

Part 2

Using dispersive approach we can CALCULATE the Regge trajectories of elastic resonances. The ρ, K*, f2, f2' and K_1 result in the usual linear trajectories.

But the **σ/f_0(500)** and **κ/K_0^*(800) do not fit into conventional linear Regge trajectories.** They behave similarly and have scales typical of meson physics