Why is the $K_0^*(800)$ omitted from the summary table?

prepared for the

Meeting of the Spectroscopy Group of EURIDICE

September, 16-18 (2004)

Residencia d'Investigadors, Barcelona (Spain)

Eef van Beveren
George Rupp

Miss QCD
and her little fellow Electroweak
Barcelona, September 16th, 2004

Miss QCD, now in her early thirties, embarrassed by the very thought that from the not-exactly-faithful candidates, soon she should select a partner for life.

$K_0^*(800)$ or κ

$I(J^P) = \frac{1}{2}(0^+)$

OMITTED FROM SUMMARY TABLE

The existence of this state is controversial.

$K_0^*(800)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
722±60		[1] BUGG	03	RVUE	11 $K^- p \to K^- \pi^+ n$
797±19±43	15090	[2] AITALA	02	E791	$D^+ \to K^- \pi^+ \pi^+$
905^{+65}_{-30}		[3] ISHIDA	79B	RVUE	11 $K^- p \to K^- \pi^+ n$

1 T-matrix pole. Reanalysis of ASTON 88 data.

2 Not seen by KOPP 01 using 7070 events of $D^0 \to K^- \pi^+ \pi^0$. Possibly seen by LINK 02E in $D^+ \to K^- \pi^+ \mu^+ \nu_\mu$.

3 Reanalysis of ASTON 88 using interfering Breit-Wigner amplitudes.

$K_0^*(800)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
772±100		[4] BUGG	03	RVUE	11 $K^- p \to K^- \pi^+ n$
410±43±87	15090	[5] AITALA	02	E791	$D^+ \to K^- \pi^+ \pi^+$
545^{+235}_{-110}		[6] ISHIDA	79B	RVUE	11 $K^- p \to K^- \pi^+ n$

4 T-matrix pole. Reanalysis of ASTON 88 data.

5 Not seen by KOPP 01 using 7070 events of $D^0 \to K^- \pi^+ \pi^0$. Possibly seen by LINK 02E in $D^+ \to K^- \pi^+ \mu^+ \nu_\mu$.

6 Reanalysis of ASTON 88 using interfering Breit-Wigner amplitudes.

$K_0^*(800)$ REFERENCES

BUGG	03	PL B572 1	D.V. Bugg	
AITALA	02	PRL 89 121801	E.M. Aitala et al.	(FNAL E791 Collab.)
LINK	02E	PL B535 43	J.M. Link et al.	(FNAL FOCUS Collab.)
KOPP	01	PR D63 092001	S. Kopp et al.	(CLEO Collab.)
ISHIDA	97B	PTP 98 621	S. Ishida et al.	
ASTON	88	NP B296 493	D. Aston et al.	(SLAC, NAGO, CINC, INUS)

OTHER RELATED PAPERS

SEMENOV	03	PAN 66 526 Translated from YAF 66 553.	S.V. Semenov
BEVEREN	01B	EPJ C22 493	E. van Beveren and G. Rupp

Omitted from $K_0^*(800)$ references

$737 - i248$	N. Beisert and B. Borasoy PR D67 074007 (2003)
$450 - i480$	Long Li, et al PR D67 034025 (2003)
$905 - i273$	K. Takamatsu (Sigma and E135 Collaboration) PTP 102 E52-E57 (2001)
$797 - i205$	M. Jamin, J.A. Oller and A. Pich NP B587 331-362 (2000)
$779 - i330$	J.A. Oller and E. Oset PR D60 074023 (1999)
$911 - i158$	Black, Fariborz, Sannino and Schechter PR D58 054012 (1998)
$770 - i250$	J.A. Oller, E. Oset and J.R. Pelaez PR D59 074001 (1999) (E D60 099906 (1999))
$998 - i79$	A.V. Anisovich and A.V. Sarantsev PL B413 137-146 (1997)
$875 - i335$	T. Ishida, et al Upton 1997, Hadron spectroscopy, 385-388
$727 - i263$	E. van Beveren et al ZP C30 615-620 (1986)
$800 - i40$	M.D. Scadron PR D26 239-247 (1982)
$665 - i420$	D. Iagolnitzer, J. Zinn-Justin and J.B. Zuber NP B60 233-266 (1973)
$1100 - i190$	D.W. Mckay, J.M. Mckisic, W.W. Wada PR 184 1609-1616 (1969)
$1100 - i200$	T.G. Trippe, et al PL B28 203-207 (1968)
$725 - i14$	P. Roy PR 168 1708 (1968), (E 172 1850 (1968))

Omitted from related papers

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PTP S149 190-202 (2003); PTP 101 661-669 (1999)

Sigma and BES Collaboration, Tsukuba 2003, 29-3

BES Collaboration, Tokyo 2003, 135-14

M. Jamin, J.A. Oller and A. Pich, JHEP 0402 047 (2004)

H.Q. Zheng, et al, NP A733 235-261 (2004)

J.R. Pelaez, PRL 92 102001 (2004);
AIP CP 688 45-60 (2004); AIP CP 687 74-85 (2003)

M. Ishida and S. Ishida, Tokyo 2003, 143-15

Yuan-Ben Dai and Yue-Liang Wu, hep-ph/0304075

I. Bediaga, NP PS121 104-109 (2003)

Hai-Yang Cheng, PR D67 034024 (2003)

S. Spanier and N.A. Törnqvist, SLAC-reprint 2002-216 (2002)

V.V. Anisovich, PU 47 45-67, UFN 47 49-72 (2004)

D. Black, UMI-30-19135 (2001)

F.E. Close and N.A. Törnqvist, JP G28 R249-R267 (2002)

M. Napsuciale, Zacatecas 2001, Particles and fields, 131-13

M. Boglione and M.R. Pennington, PR D65 114010 (2002)

E791 Collaboration, AIP CP 619 63-72 (2002)

A. Gomez Nicola and J.R. Pelaez, PR D65 054009 (2002)

D. Black, A.H. Fariborz and J. Schechter, Kyoto 2000, 115-12

S.N. Cherry and M.R. Pennington, NP A688 823-841 (2001)

D. Black, A.H. Fariborz and J. Schechter,
AIP CP 549 241-244 (2002)

D. Black, A.H. Fariborz, F. Sannino and J. Schechter,
PR D59 074026 (1999)

S. Ishida, et al, PTP 98 621-629 (1997)

⋮

P. Estabrooks, et al, NP B133 490 (1978)

P. Estabrooks, PR D19 2678 (1979)

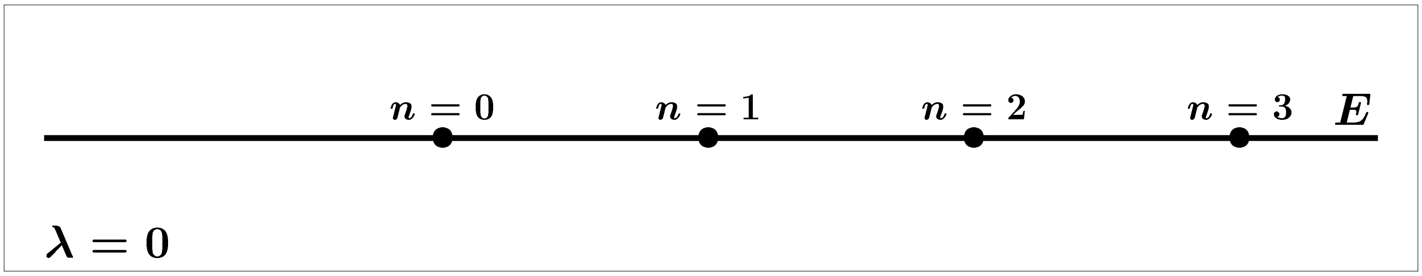
Let us here study the elastic scattering in S wave of Kaons and pions for total isospin $I = 1/2$, within a harmonic oscillator model for confinement.

Partial-wave K matrix*

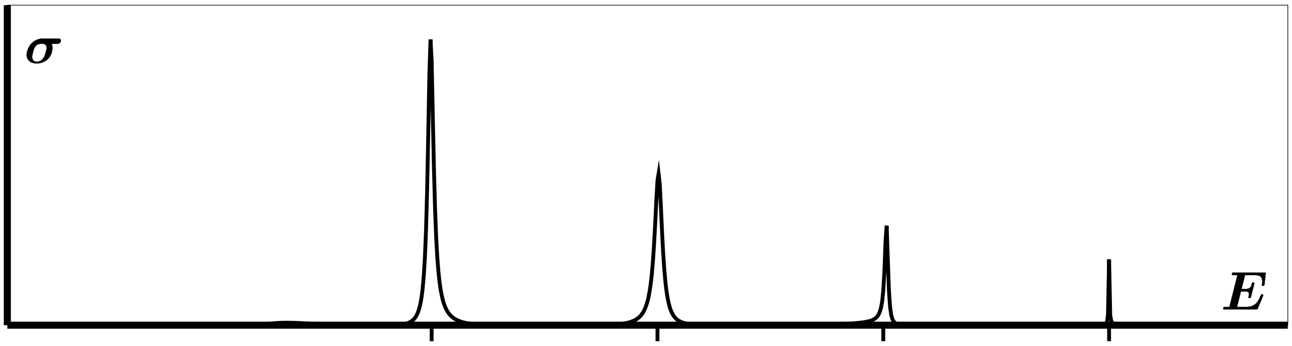
$$K_\ell(p) \;=\; \frac{\displaystyle \pi\lambda^2\mu p \sum_{n=0}^{\infty} \frac{\mathcal{J}^*_{n\ell}(p)\;\mathcal{J}_{n\ell}(p)}{E(p)-E_{n\ell_c}}}{\displaystyle \pi\lambda^2\mu p \sum_{n=0}^{\infty} \frac{\mathcal{J}^*_{n\ell}(p)\;\mathcal{N}_{n\ell}(p)}{E(p)-E_{n\ell_c}} \;-\; 1}$$

$E_{n\ell_c}$ **= radial spectrum quark-antiquark**

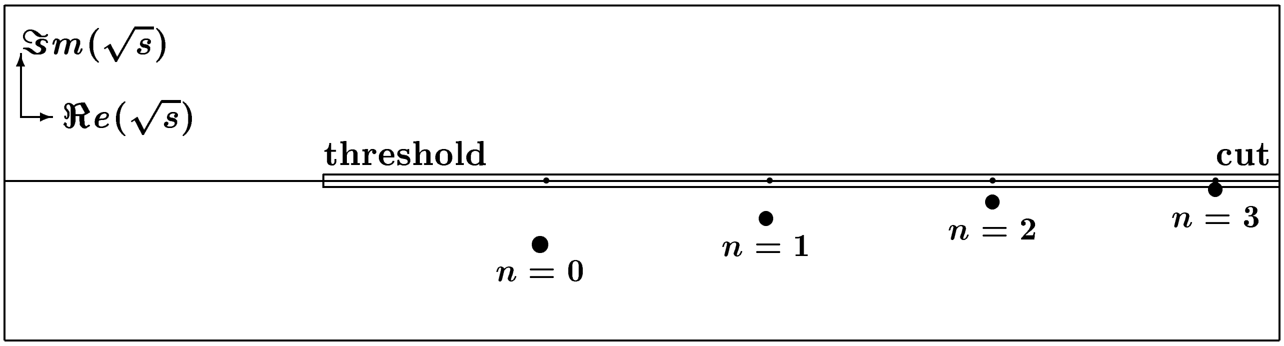
***AIP Conf. Proc. 687, 86-95 (2003) [arXiv:hep-ph/0306155].**



The spectrum of confinement for fixed ℓ_c



Elastic meson-meson scattering (λ small)

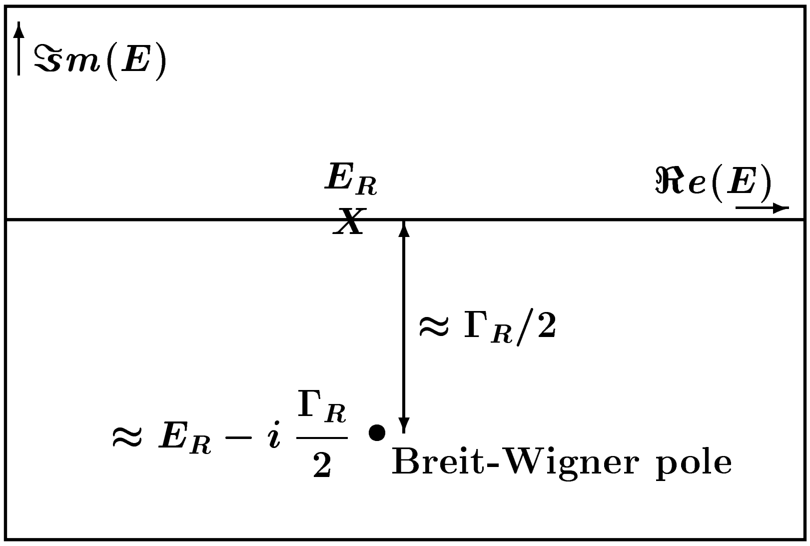


Scattering-matrix poles (λ small)

Near a Breit-Wigner Resonance (λ small)

$$K_\ell(s) \approx \frac{\Gamma_R/2}{E_R - \sqrt{s}}$$

$E_R \approx$ central resonance mass
$\Gamma_R \approx$ resonance width



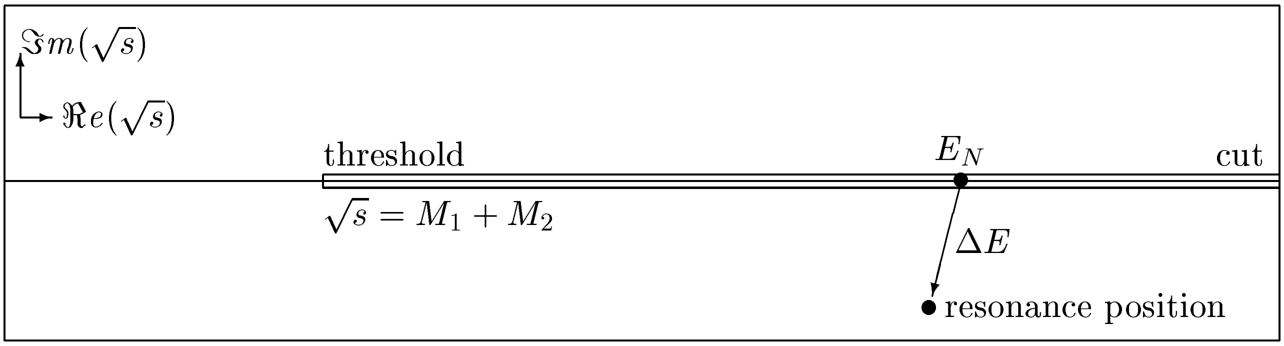
complex $E(p)$ plane

Our resonance expression:

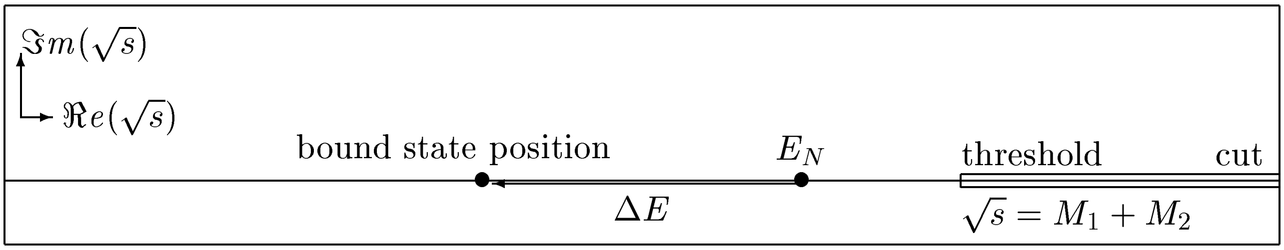
$$\boldsymbol{K_\ell(p) \;=\; \frac{\pi\lambda^2\mu p \sum\limits_{n=0}^{\infty} \dfrac{\mathcal{J}^*_{n\ell}(p)\;\mathcal{J}_{n\ell}(p)}{E(p)-E_n}}{\pi\lambda^2\mu p \sum\limits_{n=0}^{\infty} \dfrac{\mathcal{J}^*_{n\ell}(p)\;\mathcal{N}_{n\ell}(p)}{E(p)-E_n} \;-\; 1}}$$

There are two cases:

1. $\boldsymbol{E_N}$ above threshold



2. $\boldsymbol{E_N}$ below threshold



Approximation in our expression for a better contact with experiment

$$K_\ell(p) \approx \frac{2\lambda^2\ \mu\ pa\ j_\ell^2(pa) \displaystyle\sum_{n=0}^{\infty} \frac{|\mathcal{F}_n(a)|^2}{E(p)-E_n}}{2\lambda^2\ \mu\ pa\ j_\ell(pa)\ n_\ell(pa) \displaystyle\sum_{n=0}^{\infty} \frac{|\mathcal{F}_n(a)|^2}{E(p)-E_n} - 1}$$

λ = coupling constant
p = relative meson-meson linear momentum
$E(p)$ = total invariant meson-meson mass
E_n = n-th level of the confinement spectrum
μ = reduced meson-meson mass
j_ℓ = spherical Bessel function
n_ℓ = spherical Neumann function
$\mathcal{F}_n$ = quark-antiquark confinement wave function
a = $q\bar{q}$ separation distance (≈ 0.5 fm)

and a further approximation

$$\lambda^2 \sum_{n=0}^{\infty} \frac{|\mathcal{F}_n(a)|^2}{E-E_n} \approx \lambda^2 \left(\sum_{n=0}^{N} \frac{B_n}{E-E_n} - 1 \right)$$

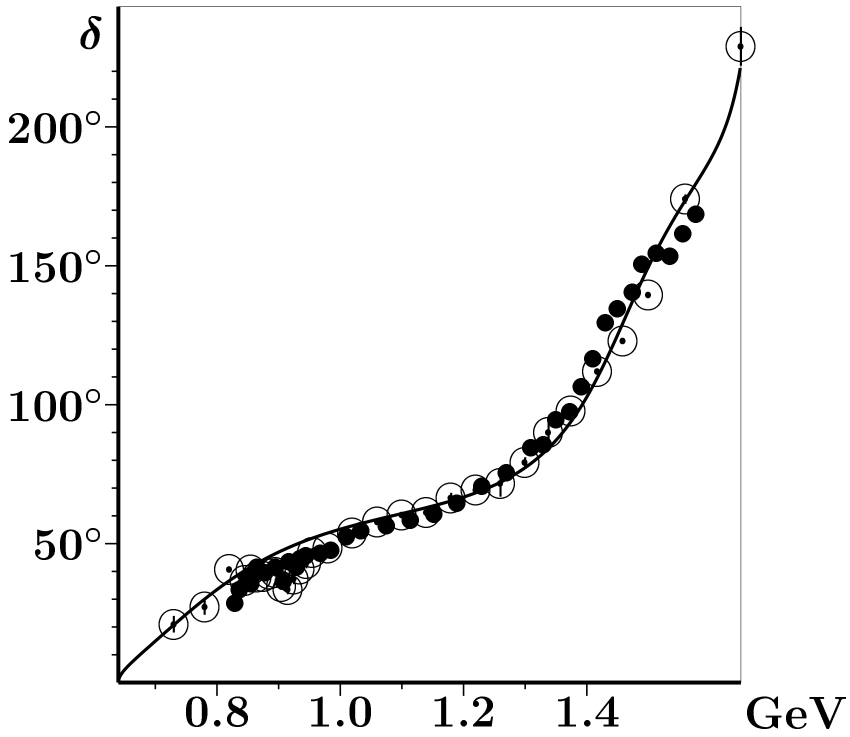
with a redefinition of λ

$K\pi$

Elastic $I = \frac{1}{2}$ S-wave scattering

$\lambda = 0.75\ \mathrm{GeV}^{-3/2}$ and $a = 3.2\ \mathrm{GeV}^{-1}$

$$\left(\frac{1.0}{E - 1.31} + \frac{0.2}{E - 1.69} - 1\right)\ \mathrm{GeV}^2$$

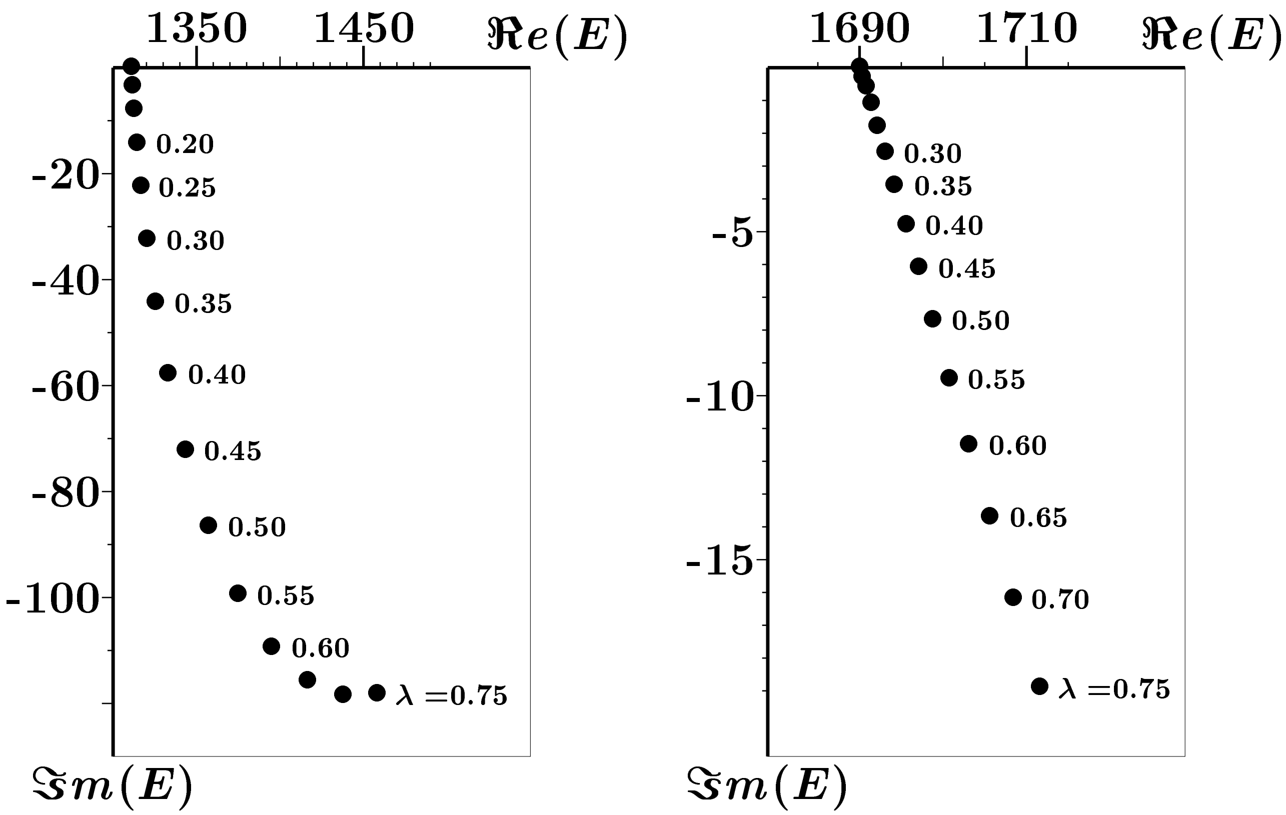


total CM energy

Complex-energy singularities of the S-matrix as function of $\boldsymbol{\lambda}$

The points on the real axis correspond to the bare states ($\boldsymbol{\lambda = 0}$)

Units are in MeV



Notice nonperturbative behaviour of lower singularity

and a singularity at

713 - 227i MeV

in

E. van Beveren, T. A. Rijken, K. Metzger,
C. Dullemond, G. Rupp, and J. E. Ribeiro
Zeitschrift für Physik C30, 615 (1986)

found at

727 - 263i MeV

many more channels

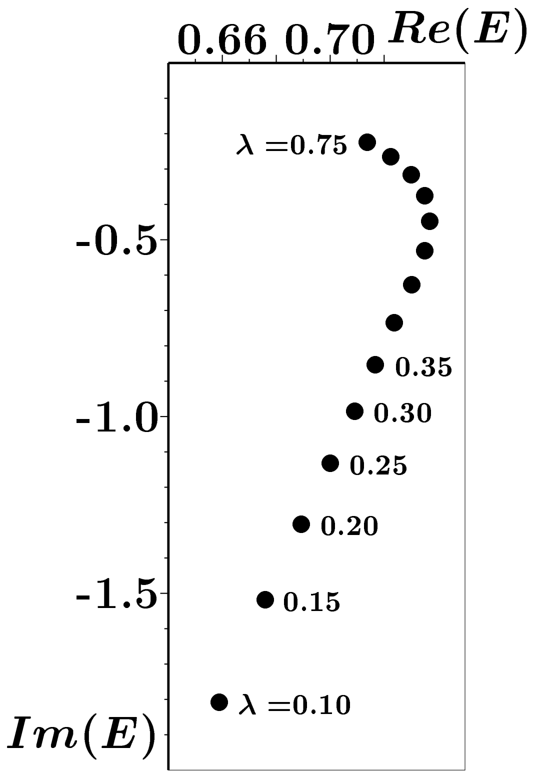
full transition potential

harmonic oscillator confinement

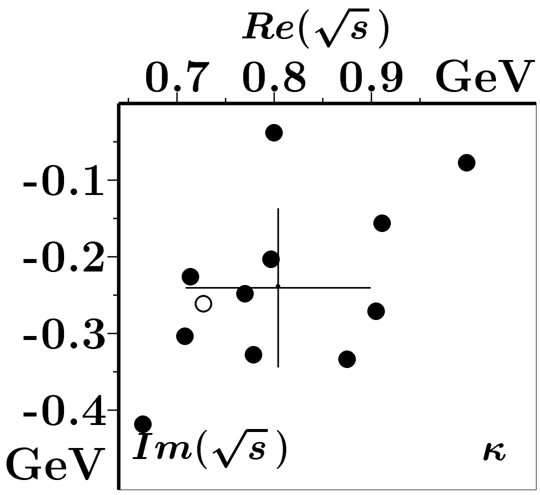
no free parameters

Complex-energy singularities of the S-matrix as function of λ

Singularity disappears in background for $\lambda = 0$



Units are in GeV



World average for kappa equals $(804 \pm 95) - i(241 \pm 104)$ MeV.

Eliminating parameters

by recombining 2 quarks and 2 antiquarks within a harmonic oscillator model for confinement.

E. van Beveren, Z. Phys. C 21, 291 (1984)

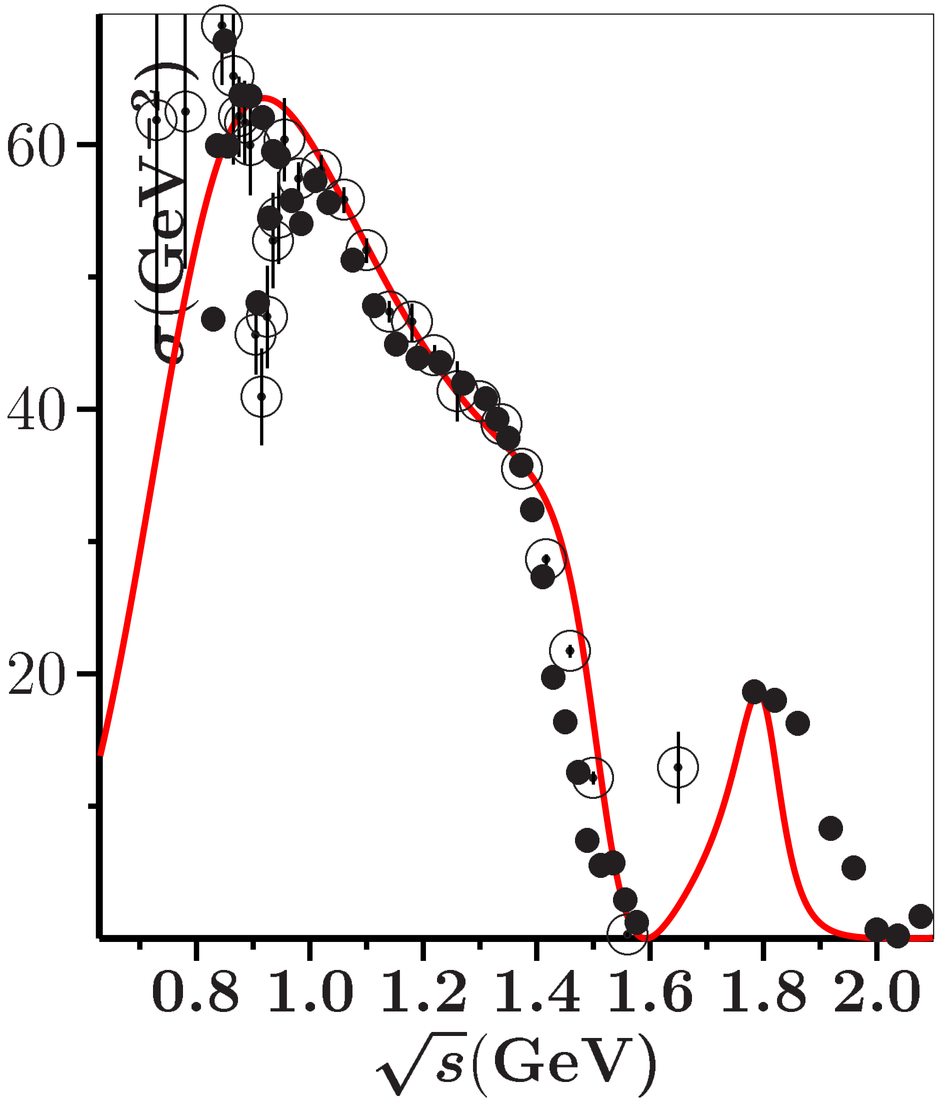
$$\left(\frac{1.0}{E - 1.31} + \frac{0.2}{E - 1.69} - 1 \right) \text{GeV}^2$$

turns into

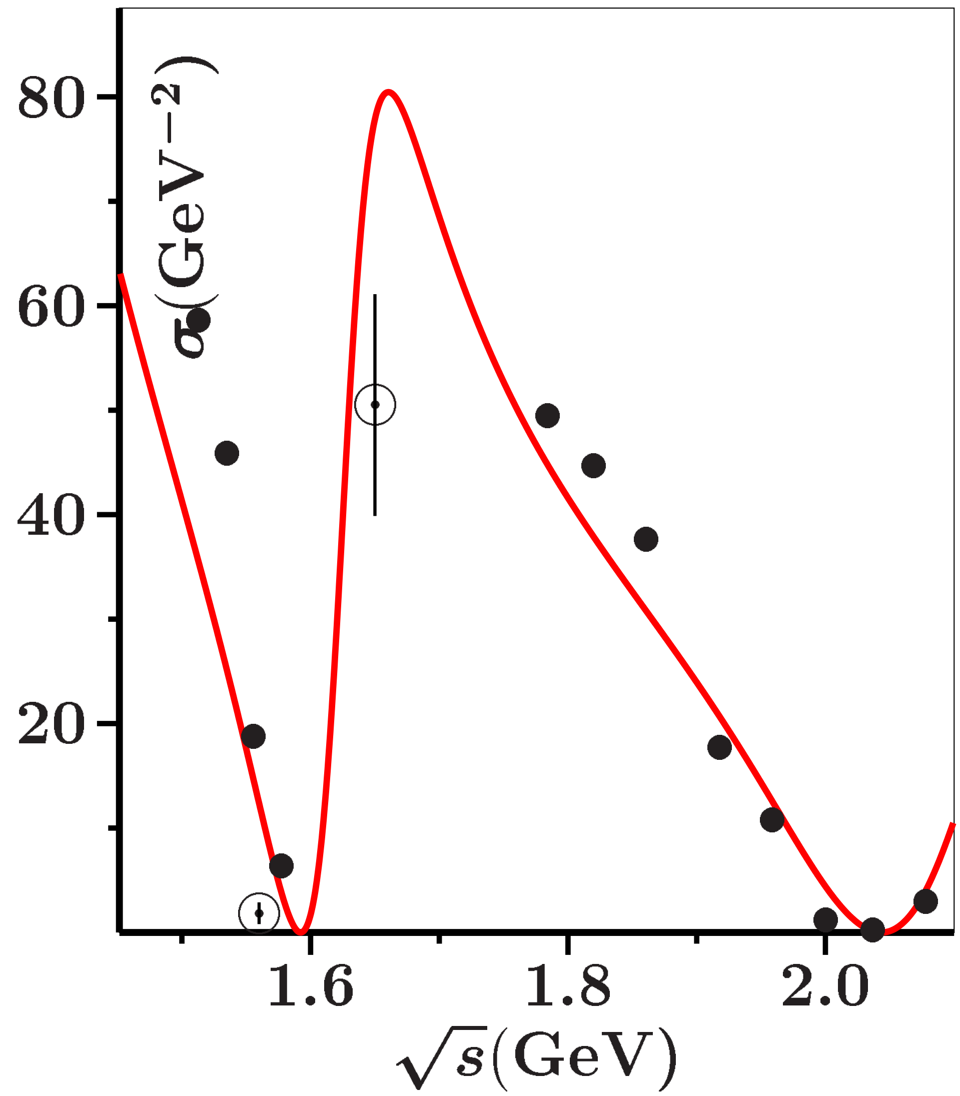
$$\sum_{n=0}^{\infty} \frac{(n+1) \times 4^{-n}}{E - (1.31 + n \times 0.38)} \quad \text{GeV}^2$$

$(n+1) \times 4^{-n}$ represents the matrix element for the coupling of an excited scalar $u\bar{s}$ pair to a $\pi^0 K^+$ pair in S wave.

The reason for this number to drop fast with n, is that the higher the radial excitation, the more the level degeneracy in the 4-particle harmonic oscillator. Hence, the smaller the coupling to a specific channel.

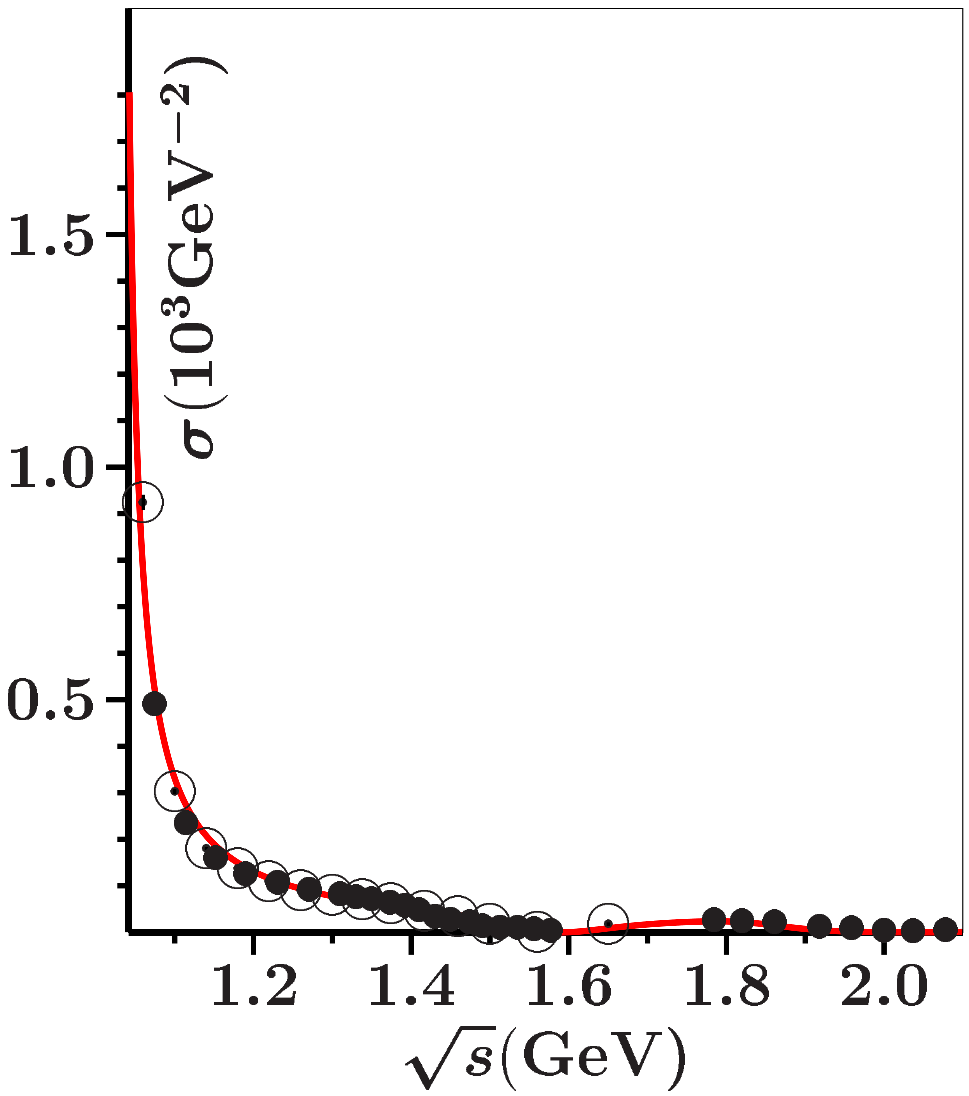


$$\pi^0 K^+ \to \pi^0 K^+$$



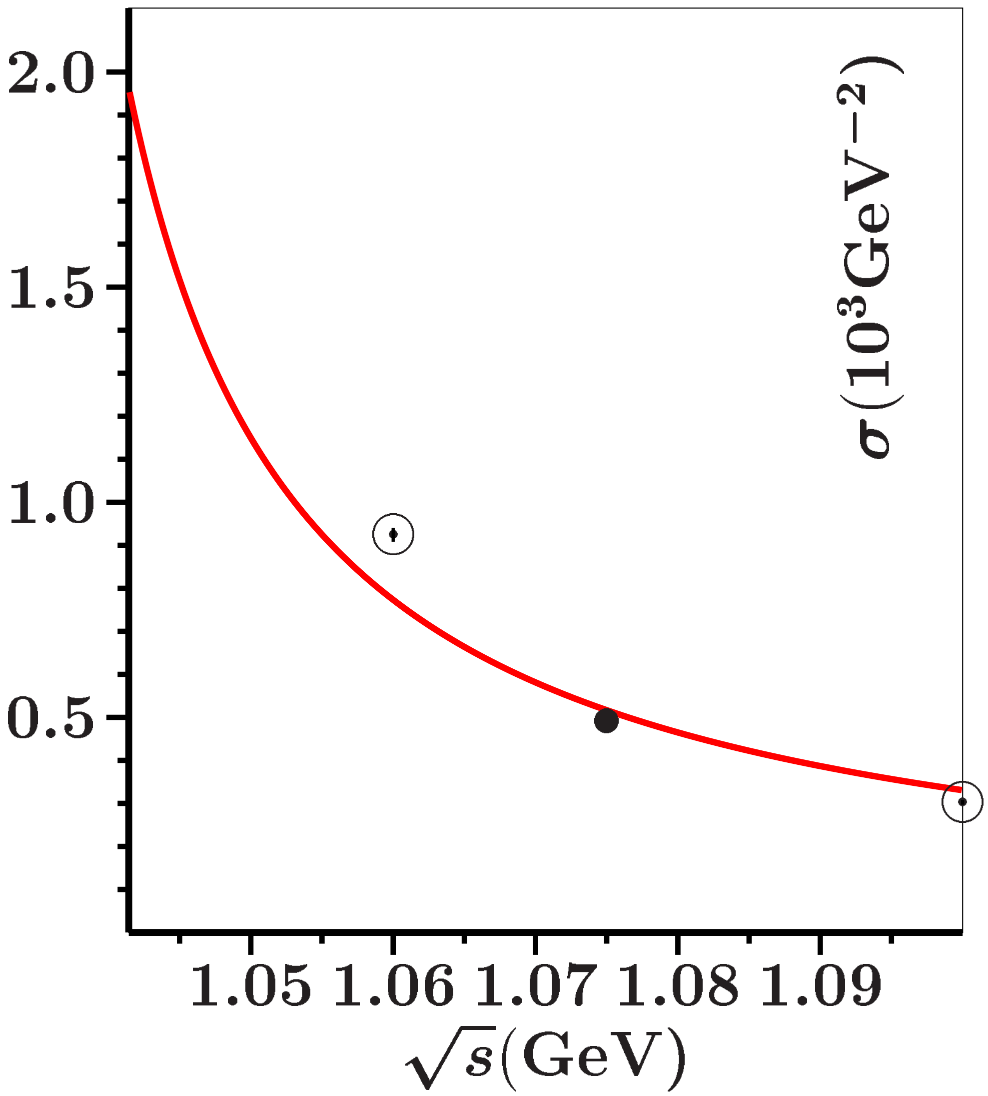
$$\eta' K^+ \rightarrow \eta' K^+$$

Data = $\pi^0 K^+$ phase shifts and $\eta' K^+$ kinematics

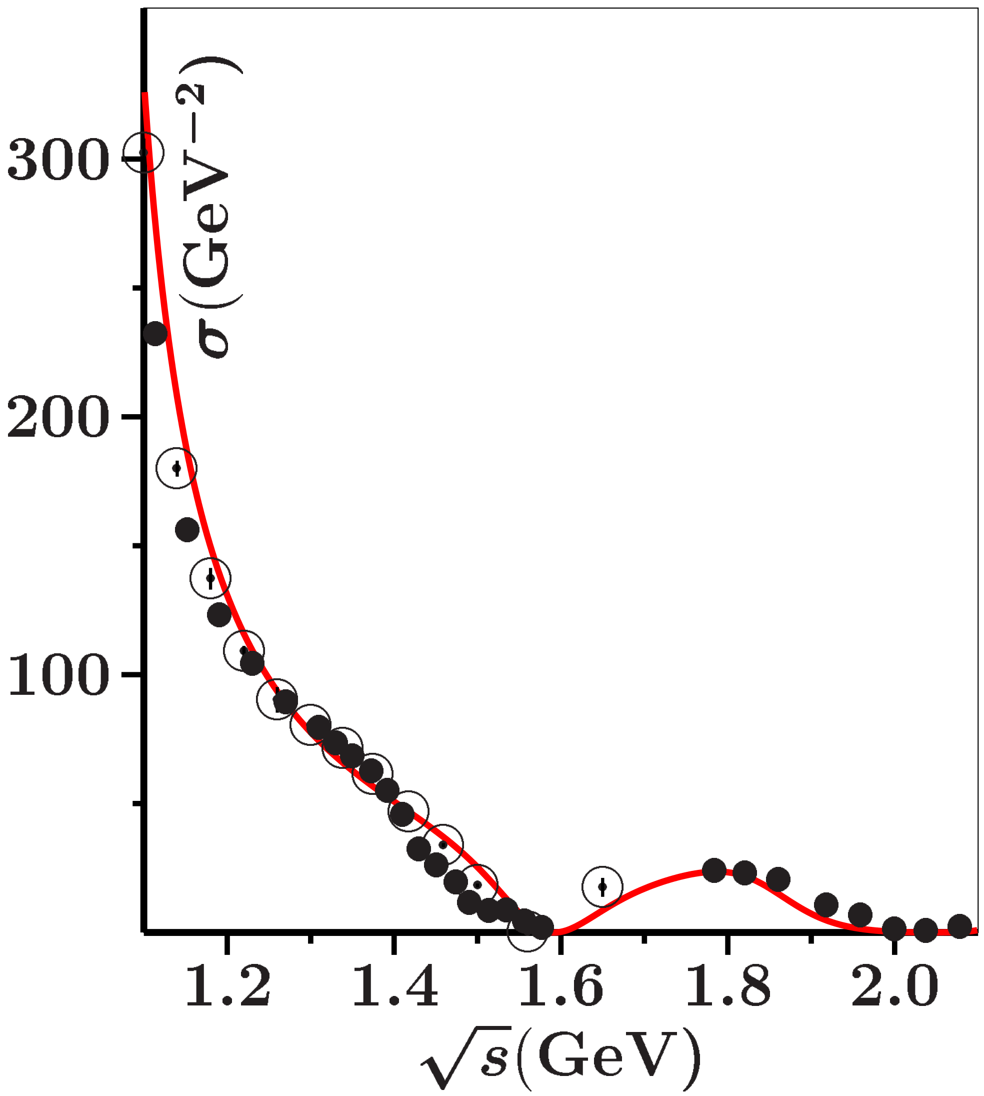


$$\eta K^+ \to \eta K^+$$

Data = $\pi^0 K^+$ **phase shifts and** ηK^+ **kinematics**



detail of $\eta K^+ \to \eta K^+$



detail of $\eta K^+ \to \eta K^+$

CONCLUSION(S)

The expression

$$K_\ell(p) \approx \frac{2\lambda^2 \mu\, pa\, j_\ell^2(pa) \sum_{n=0}^{\infty} \frac{|\mathcal{F}_n(a)|^2}{E(p)-E_n}}{2\lambda^2 \mu\, pa\, j_\ell(pa)\, n_\ell(pa) \sum_{n=0}^{\infty} \frac{|\mathcal{F}_n(a)|^2}{E(p)-E_n} - 1}$$

seems a good approximation for data analysis.

Full off-shell T matrix:

- **hep-ph/0304105 (δ-shell for V_t)**
- **hep-ph/0306155 (in the appendix, more general)**

Many-channel analysis of light scalar mesons:

- **Zeitschrift für Physik C30, 615 (1986)**
(postscript version available through Spires)