Nikolay Achasov, Alexey Kiselev

Sobolev Institute for Mathematics, Novosibirsk

# Light scalar mesons and the data on two-kaon correlation functions

N.N. Achasov and A.V. Kiselev,
Phys. Rev. **D 97**, 036015 (2018),
"The $a_0(980)$ physics in semileptonic $D^0$ and $D^+$ decays" , arXiv:1805.10145

## A brief reminder on light scalar mesons

- Nonet of light scalar mesons: $a_0(980)$, $f_0(980)$, $\sigma(600), \kappa(800)$

- Were discovered $\sim 50$ years ago and became hard problem for the naive quark model from the outset

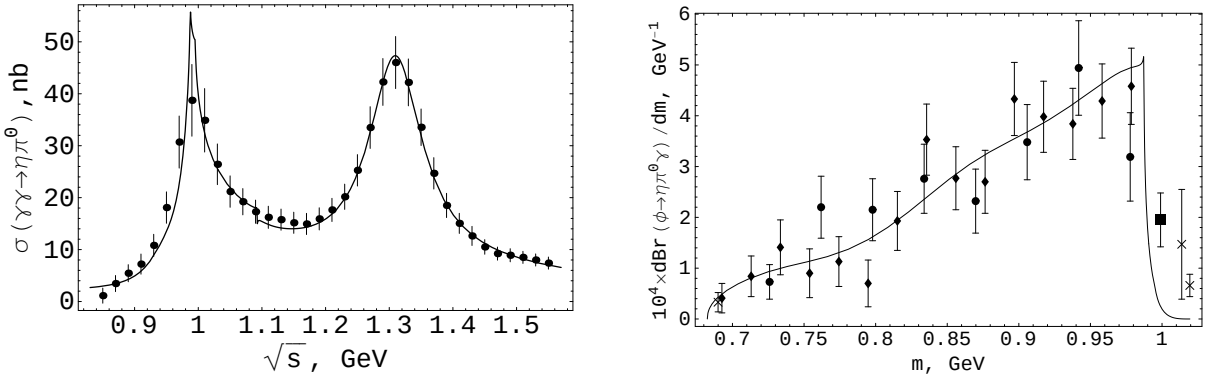
- Elucidation of their nature can shed light on confinement and the chiral symmetry realization way in the low energy region

- Perturbation theory and sum rules don't work

- The $\sigma(600)$, $a_0(980)$, and $f_0(980)$ are studied in $\phi \to S\gamma$ decays, $\pi\pi$ scattering, $\gamma\gamma \to \pi\pi$, $\eta\pi^0$ and other processes

# Light scalars in $\gamma\gamma \to \eta\pi^0$ and $\phi \to \eta\pi^0\gamma$ decay

**2015: N.N. Achasov, A.V. Kiselev, and G.N. Shestakov, simultaneous description the Belle data on $\gamma\gamma \to \eta\pi^0$ and the KLOE data on $\phi \to \eta\pi^0\gamma$, signal reactions are $\gamma\gamma \to a_0^0(980) + a_0'^0 \to \eta\pi^0$ and $\phi \to [a_0^0(980) + a_0'^0]\gamma \to \eta\pi^0\gamma$. Consideration of $\gamma^*(Q^2)\gamma \to \eta\pi^0$ reaction.**




(a) (b)

Results of the fit-2016: a) the Belle data on $\gamma\gamma \to \eta\pi^0$ cross-section; b) the KLOE data on $\phi \to \eta\pi^0\gamma$ decay, cross points are omitted in fitting, $m$ is the invariant $\eta\pi^0$ mass.

## Two-particle correlation

$$C(Q) = \frac{A(Q)}{B(Q)}\,.$$

Here $A(Q)$ represents the distribution of the invariant relative momentum $Q = \sqrt{-q^\mu q_\mu}$, $q^\mu = p_1^\mu - p_2^\mu$, for a pair of particles from the same event. $B(Q)$ is a reference distribution of the pairs of particles taken from the different events.

## $K^0_S K^\pm$ correlation in Pb-Pb interactions

2017: ALICE Collaboration measured $K^0_S K^\pm$ correlations in Pb-Pb interactions.

The approach is based on R. Lednicky and V. L. Lyuboshits, Yad. Fiz. 35, 1316 (1982). The correlation $C(k^*)$ is

$$C(k^*) = 1+\frac{\lambda}{2}(\frac{1}{2}|\frac{f(k^*)}{R}|^2+2\frac{Ref(k^*)}{\sqrt{\pi}R}F_1(2k^*R)-\frac{Imf(k^*)}{R}F_2(2k^*R)), \quad (1)$$

where $k^*$ is the kaon momentum in the kaon pair rest frame, $k_{\pi\eta}$ is the corresponding $\pi\eta$ momentum, $R$ is the radius parameter from the spherical Gaussian source distribution, $\lambda$ is the correlation strength, and

$$F_1(z) = \frac{e^{-z^2}}{z}\int_0^z e^{x^2}dx, \quad F_2(z) = \frac{1-e^{-z^2}}{z}.$$

**The scattering amplitude used by experimenters is**

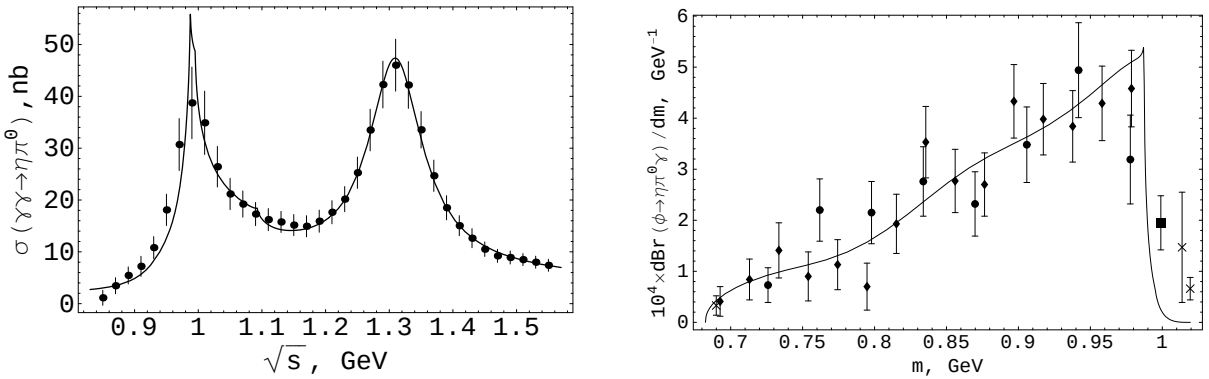
$$f(k^*) = \frac{\gamma_{a_0 \to K\bar{K}}}{m_{a_0}^2 - s - i(\gamma_{a_0 \to K\bar{K}} k^* + \gamma_{a_0 \to \pi\eta} k_{\pi\eta})}. \tag{2}$$

**We use**

$$f(k^*) = \frac{2}{\sqrt{s}} \sum_{S,S'} \frac{g_{SK_S^0K^+} G^{-1}_{SS'} g_{S'K_S^0K^+}}{16\pi}. \tag{3}$$

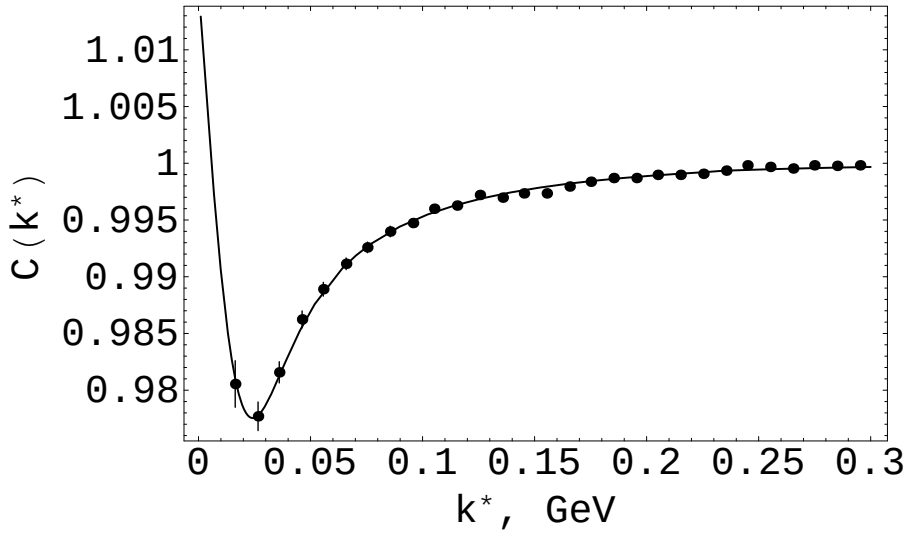
**where** $S, S' = a_0^+, a_0'^+$**, and the constants** $g_{SK_S^0K^+} = -g_{SK_L^0K^+} = g_{SK^+K^-}$**. The matrix of the inverse propagators is**

$$G_{SS'} \equiv G_{SS'}(m) = \begin{pmatrix} D_{a_0'}(m) & -\Pi_{a_0'a_0}(m) \\ -\Pi_{a_0'a_0}(m) & D_{a_0}(m) \end{pmatrix}, \tag{4}$$




(a) (b)

(a) The $\gamma\gamma \to \eta\pi^0$ cross section. (b) The $\phi \to \eta\pi^0\gamma$ decay.




$K^0_S K^+$ correlation: the solid line represents our fit, and the points are ALICE experimental data.

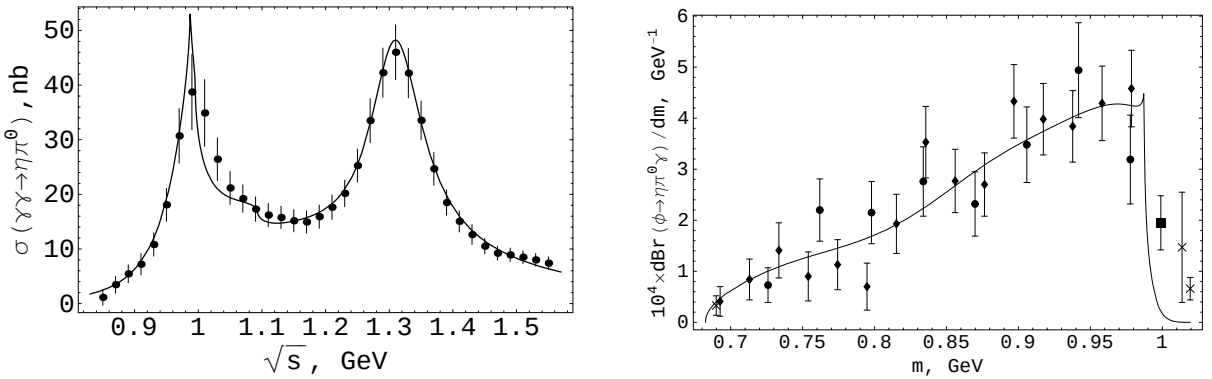
## New data description

**Recently BES Collaboration measured the decays $D^0 \to d\bar{u}\, e^+\nu \to a_0^- e^+\nu \to \pi^-\eta e^+\nu$ and $D^+ \to d\bar{d}\, e^+\nu \to a_0^0 e^+\nu \to \pi^0\eta e^+\nu$ for the first time.**

**In arXiv:1805.10145 we present a simultaneous description of $\gamma\gamma \to \eta\pi^0$, $\phi \to \eta\pi^0\gamma$ and $K_S^0 K^+$ correlation in agreement with BESIII current results. $\lambda = 1$, $a_0(980)$ has no $q\bar{q}$ component at all ($g^{(0)}_{a_0\gamma\gamma} = 0$, $g_{d\bar{u}a_0^-} = g_{d\bar{d}a_0^0} = 0$).**

## Properties of the resonances and the description quality

| | | | |
|---|---|---|---|
| $m_{a_0}$, MeV | 999.5 | $m_{a_0'}$, MeV | 1439.4 |
| $g_{a_0^0 K^+K^-}$, GeV | 3.50 | $g_{a_0'^0 K^+K^-}$, GeV | 4.45 |
| $g_{a_0\eta\pi}$, GeV | 3.42 | $g_{a_0'\eta\pi}$, GeV | $-0.20$ |
| $g_{a_0\eta'\pi}$, GeV | $-3.64$ | $g_{a_0'\eta'\pi}$, GeV | 0.41 |
| $g^{(0)}_{a_0^0\gamma\gamma}$ | 0 | $g^{(0)}_{a_0'^0\gamma\gamma}$, $10^{-3}\,\mathrm{GeV}^{-1}$ | $-14.62$ |
| $\lambda$ | 1 | $R$, fm | 6.3 |
| $\chi^2_{sp}$ / 24 points | 25.3 | $\chi^2_{corr}$ / 29 points | 17.2 |
| $\chi^2_{\gamma\gamma}$ / 36 points | 10.9 | $(\chi^2_{\gamma\gamma}+\chi^2_{sp}+\chi^2_{corr})$/n.d.f. | 55.5/75 |

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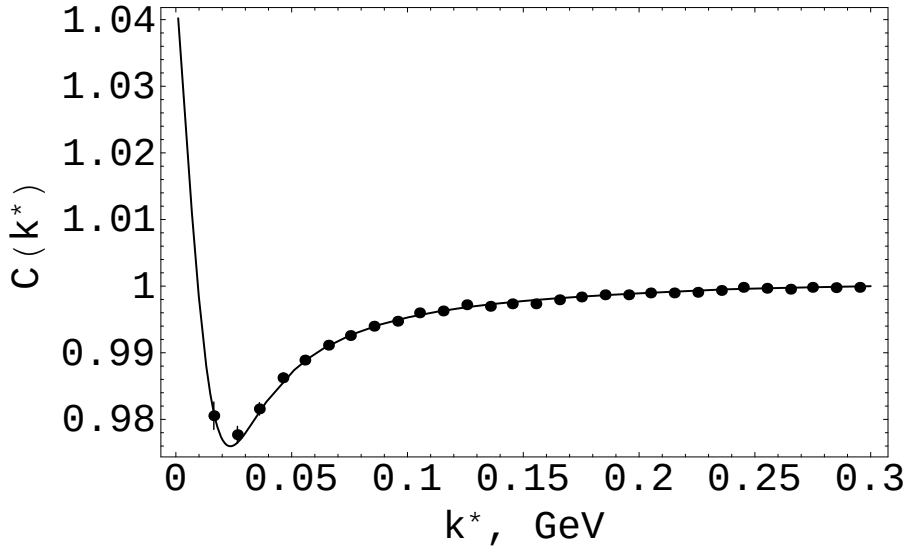


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