Study of light scalar mesons at BES

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Introduction

Scalars below 1GeV

$f_0(980)$ $a_0(980)$

$K^*_0(800)$ (κ)

$f_0(600)$ (σ)

Do they exist?

What is their nature?

- **Observation of the charged κ in $J/\psi \to K^{*\pm}K\pi$, using 5.8 X 10^7 J/ψ @ BESII.**

- **Direct measurements of a_0-f_0 mixing via $J/\psi \to \phi f_0 \to \phi a_0$ and $\chi_{c1} \to \pi^0 a_0 \to \pi^0 f_0$, using 2.26X$10^8$ J/ψ & 1.06X10^8 ψ'@ BESIII.**

Observation of charged κ at BESII

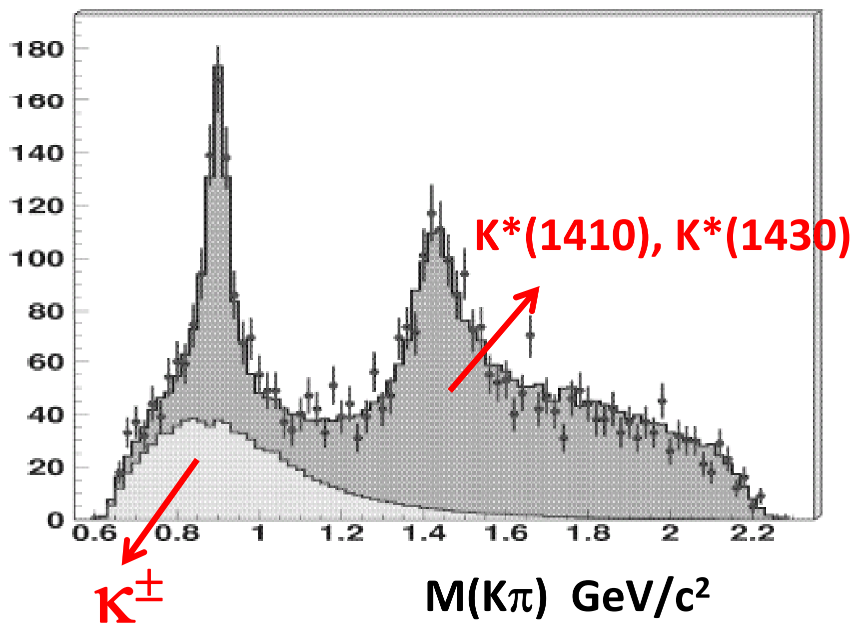
κ was first found in $K\pi$ scattering data. However, there have been hot debates on its existence.

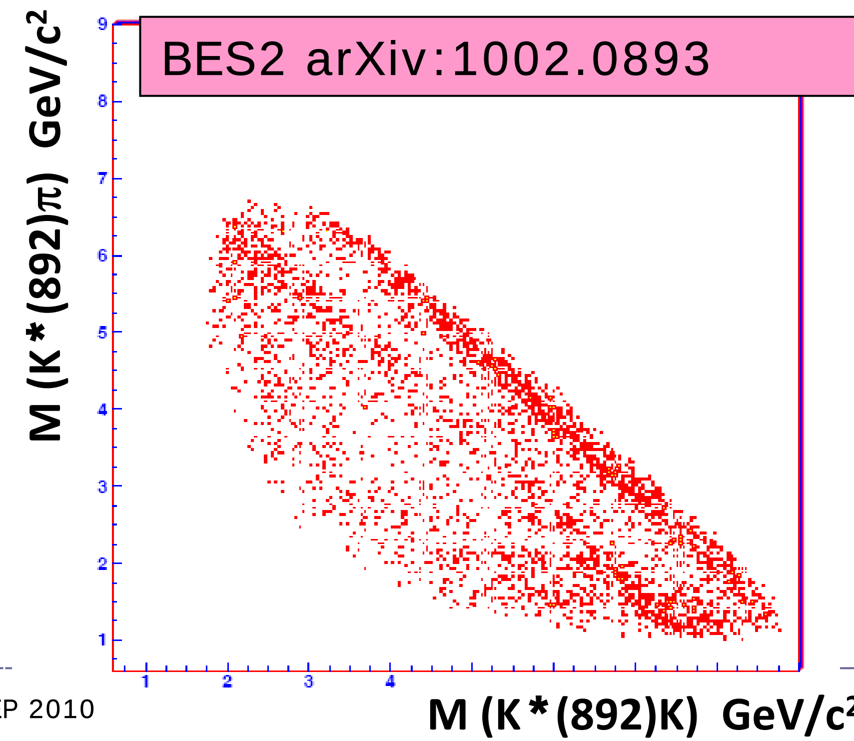
In recent years:

- **Evidence for κ found in**
  - $D^+ \to K^-\pi^+\pi^+$ [E791 PRL 89(2002) 121801]
  - $D^+ \to K^-\pi^+\mu^+\nu_\mu$ [FOCUS PL B535(2002) 430]
  - $J/\psi \to \underline{K^*}(892)^0 K^+\pi^-$ [BESII PL B633(2006) 681]
- **$K\pi$ s-wave component found in**
  - $D^+ \to K^-\pi^+e^+\nu_e$. [CLEO PR D74(2006) 052001]
  - $\tau^- \to K^0_S\pi^-\nu_\tau$, [BELLE PL B654(2007) 65]
- **No evidence of κ found in**
  - $D^0 \to K^-\pi^+\pi^0$ [CLEO PR D63(2001) 090001]

The existence of charged κ is expected !

- **CLEO reported the necessity of** $\kappa^{\pm} \rightarrow K^{\pm}\pi^{0}$ **in** $D^{0} \rightarrow K^{+}K^{-}\pi^{0}$
[CLEO PRD 74 031108R] .
- **However, no charged κ is needed in BABAR** $D^{0} \rightarrow K^{+}K^{-}\pi^{0}$ **data**
[BABAR PRD 76 011102R] .
- **BESII studied charged κ in** $J/\psi \rightarrow K^{*\pm}\kappa^{\mp} \rightarrow K_{s}\pi^{\pm}K^{\mp}\pi^{0}$





BES2
arXiv:1002.0893

Observation of charged κ at BESII

Resonance parameters of charged κ

(BW with constant width)

$$(849 \pm 77^{+18}_{-14}) - i(256 \pm 40^{+46}_{-22})\ \mathrm{MeV/c^2}$$

For reference, resonance parameters of neutral κ

$$(841 \pm 30^{+81}_{-73}) - i(309 \pm 45^{+48}_{-72})\ \mathrm{MeV/c^2}$$ **[BESII PL B633(2006) 681]**

- **Different parameterizations of κ give consistent results on the pole of charged κ .**

- **The pole position for charged κ is consistent with that for neutral κ within the error.**

$a_0(980) - f_0(980)$ mixing

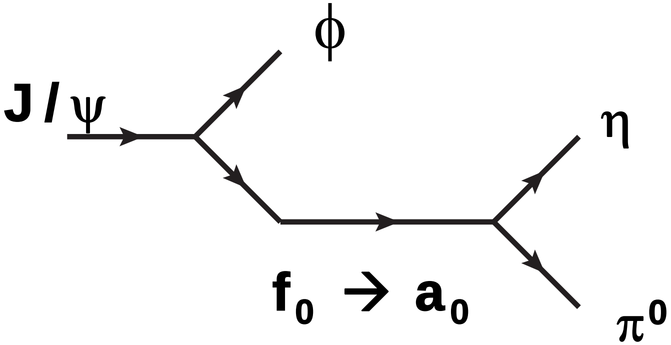
- a_0 / f_0 : $q\bar{q}$, four quarks, $K\bar{K}$ molecule, hybrids,…
- Study of the mixing of a_0 and f_0 will shed new light on the enigmatic light scalars. No firm experimental determination.
- A narrow peak (8MeV) between the charged and neutral kaon thresholds (987~995 MeV).

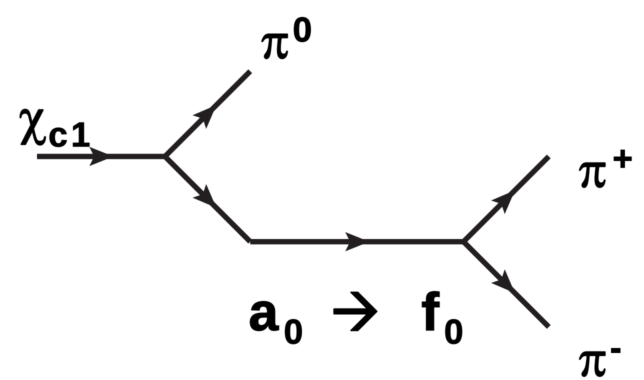
J.Wu, Q.Zhao, B.Zou PRD75 114012,

C. Hanhart etc. PRD76 074028,

etc.

J.Wu, B.Zou PRD78 074017

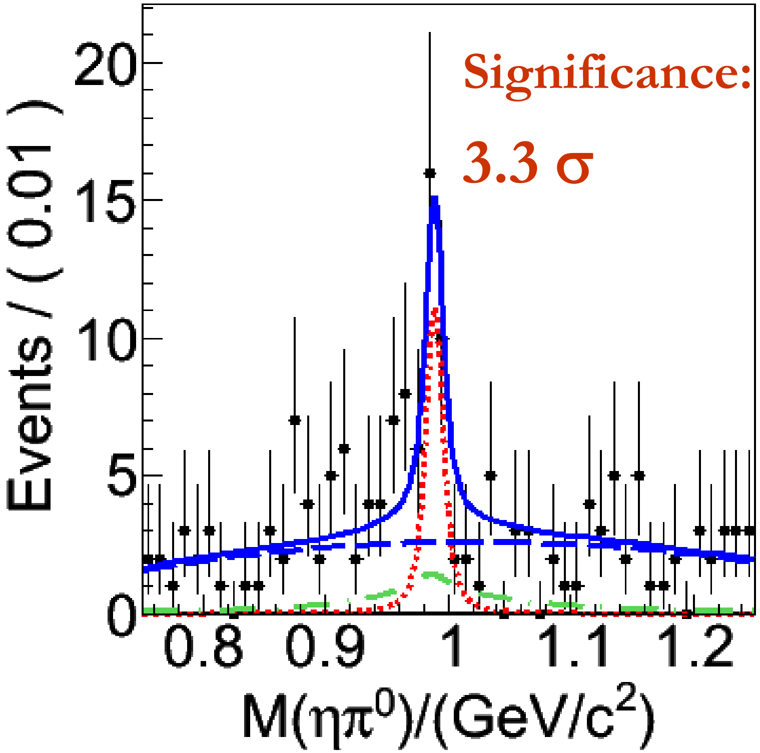




$a_0(980)-f_0(980)$ mixing: $f_0 \to a_0$ transition

$J/\psi \to \phi f_0 \to \phi a_0 \to \phi\eta\pi^0$

BESIII Preliminary



.... Mixing signal

--- $a_0(980)$ contribution from $J/\psi \to \gamma^* / K^*K \to \phi a_0(980)$

--- Background polynomial

N(mixing)=24.7 ± 8.6 (<36.7 @90% C.L)

$$\mathrm{Br}(J/\psi \to \phi f_0 \to \phi a_0 \to \phi\eta\pi^0) = (3.1 \pm 1.1 \pm 0.8)\times 10^{-6}$$

(<5.5×10⁻⁶ @ 90% C.L.)

Mixing intensity:

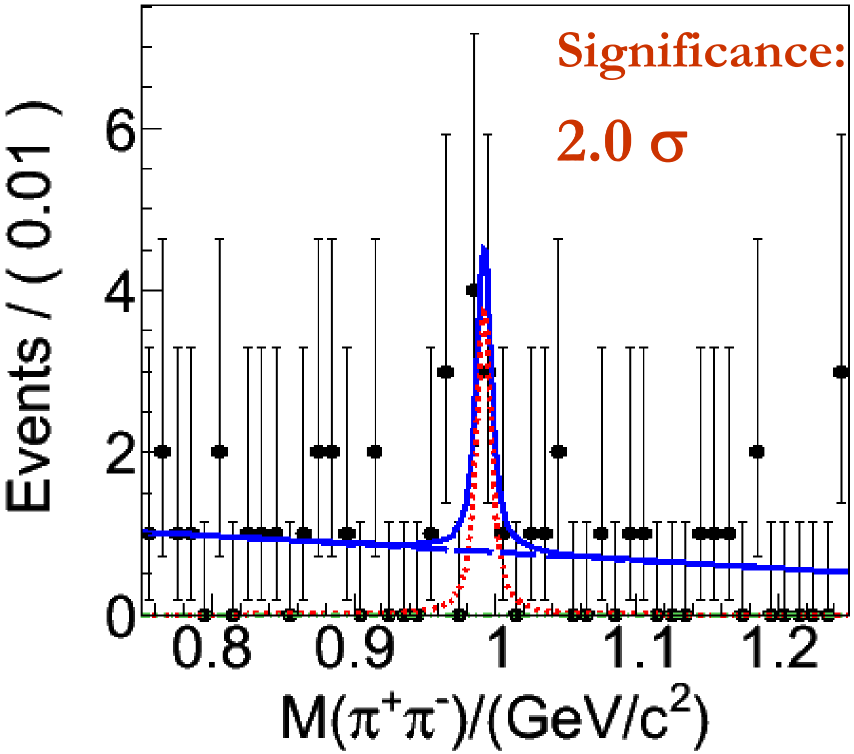
$$\xi_{fa} = \frac{\mathrm{Br}(J/\psi \to \phi f_0 \to \phi a_0 \to \phi\eta\pi^0)}{\mathrm{Br}(J/\psi \to \phi f_0 \to \phi\pi\pi)^{[BESII]}} = (0.6 \pm 0.2 \pm 0.2)\%$$

(<1.1% @ 90% C.L.)

$a_0(980) - f_0(980)$ mixing: $a_0 \to f_0$ transition

$\psi' \to \gamma\chi_{c1}$, $\chi_{c1} \to a_0\pi^0 \to f_0\pi^0 \to \pi^+\pi^-\pi^0$

BESIII Preliminary



.... Mixing signal

--- $f_0(980)$ contribution from other processes

--- Background polynomial

N(mixing)=6.5±3.2

(<12.1 @90% C.L)

$$Br(\psi' \to \gamma\chi_{c1})Br(\chi_{c1} \to a_0\pi^0 \to f_0\pi^0 \to \pi^+\pi^-\pi^0)$$

$$=(2.8\pm1.4\pm0.5)\times10^{-7}$$

$$(<5.5\times10^{-7} \text{ @ 90\% C.L.})$$

Mixing intensity:

$$\xi_{af} = \frac{Br(\chi_{c1} \to a_0\pi^0 \to f_0\pi^0 \to \pi^+\pi^-\pi^0)}{Br(\chi_{c1} \to \pi^0 a_0 \to \eta\pi^0\pi^0)^{[PDG]}}$$

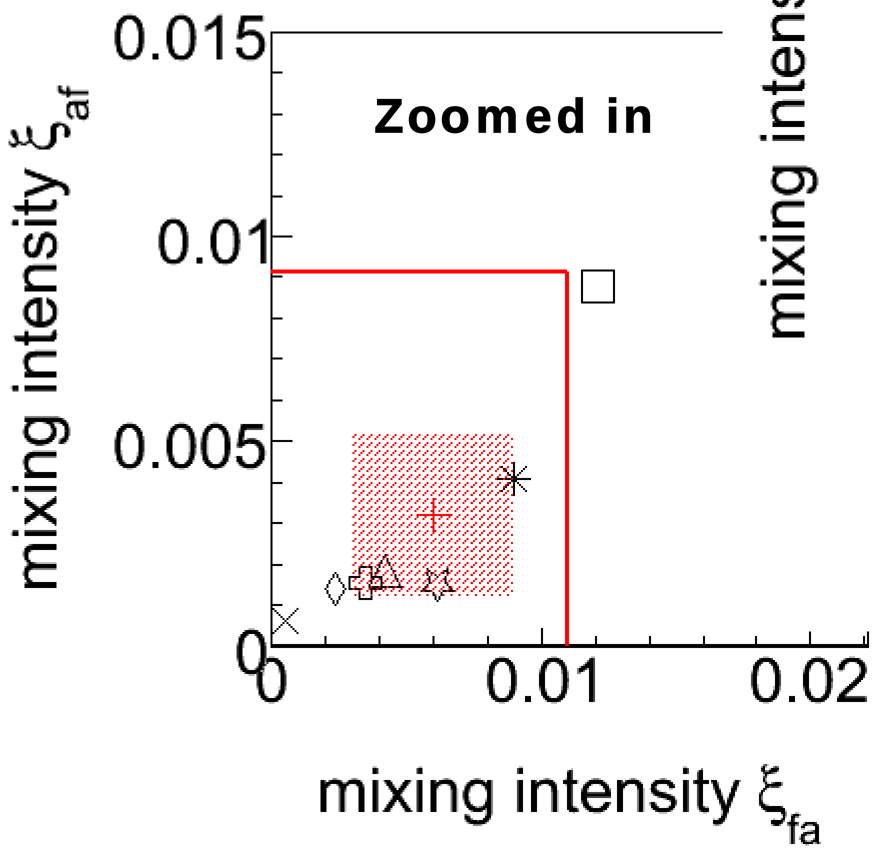
$$= (0.3\pm0.2\pm0.1)\%$$

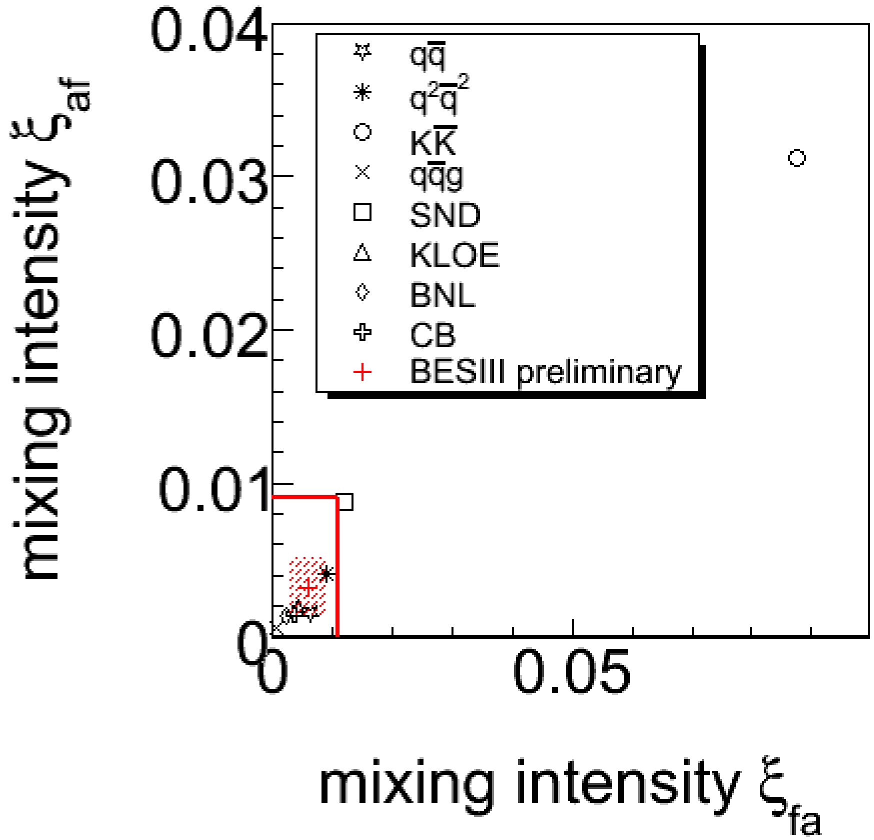
$$(<0.9\% \text{ @ 90\% C.L.})$$

Models of a_0 / f_0 give different resonance parameters Comparison with ξ_{fa} / ξ_{af} from those parameters

a_0–f_0 mixing:

a sensitive probe





BESIII Preliminary

shaded region: BES3 measurements

red line: BES3 upper limit

dots: various predictions

Summary

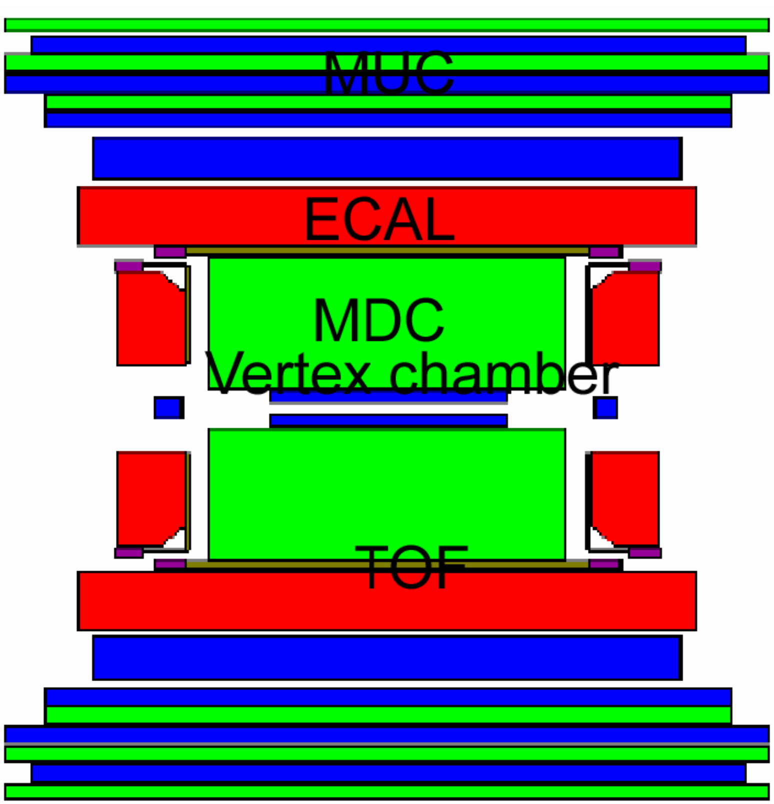
- The charged κ particle is found in $J/\psi \rightarrow K^{*\pm}K\pi$. The pole position of the charged κ is consistent with that of neutral κ.

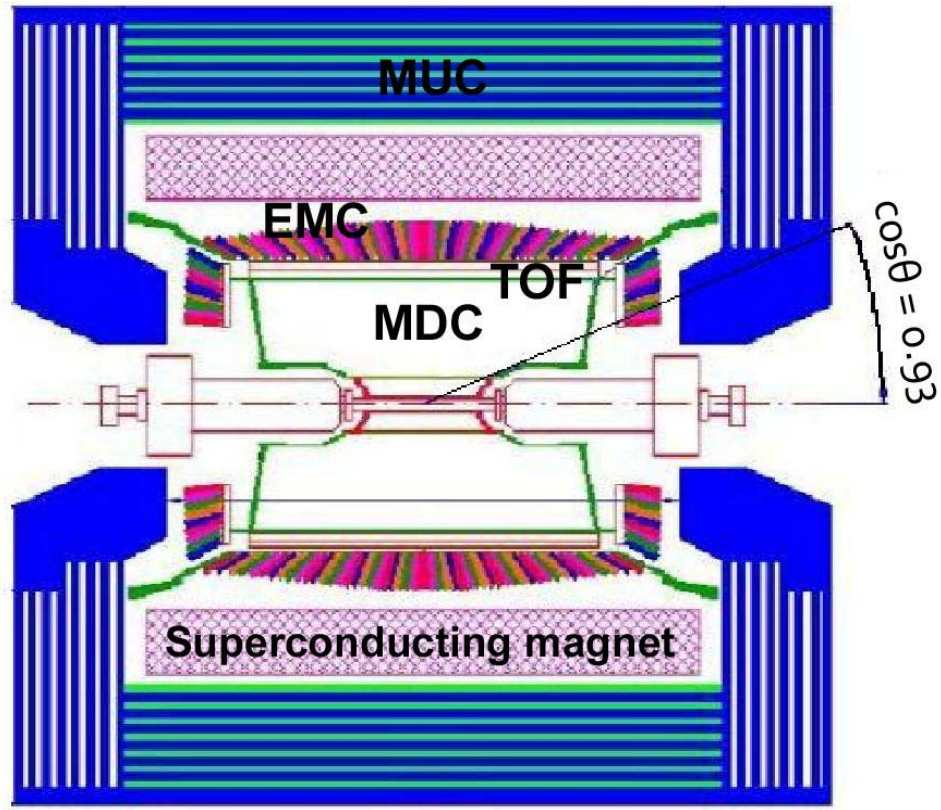
- Study the $f_0 \rightarrow a_0$ transition in $J/\psi \rightarrow \phi\, f_0 \rightarrow \phi\, a_0$ and the $a_0 \rightarrow f_0$ transition in $\chi_{c1} \rightarrow a_0\pi^0 \rightarrow f_0\pi^0$. The mixing intensities are extracted from experiment, which will be very useful for pinning down the resonance parameters of $a_0(980)$ and $f_0(980)$.

Thank you

Backups

BES II @ BEPC   BES III @ BEPC II

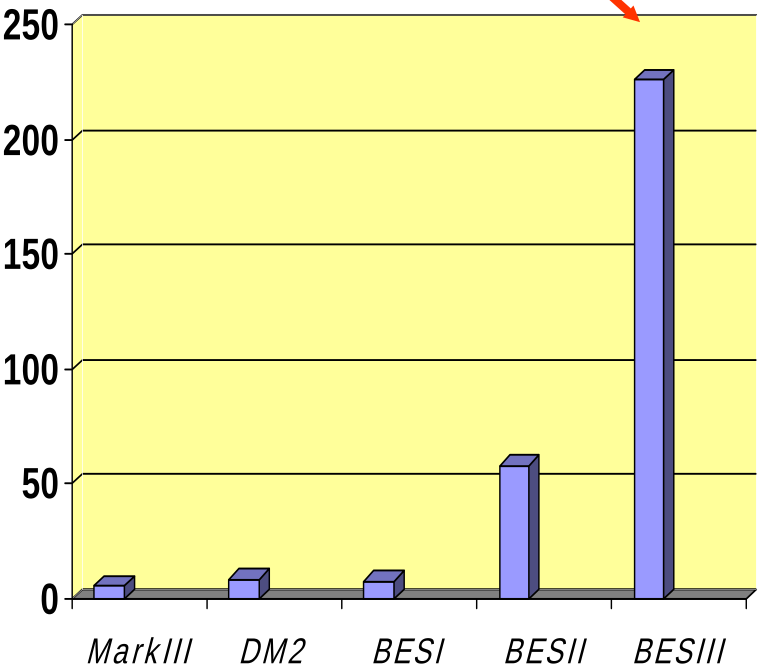


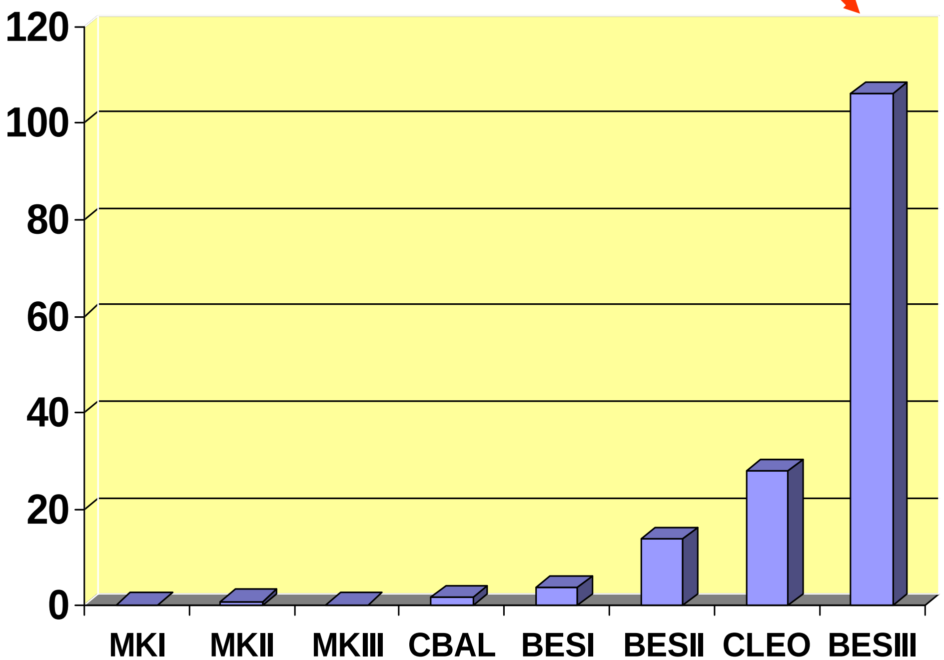


	BESII	BESIII
MDC	$\sigma(p)/p = 1.78\,\% \cdot \sqrt{1+p^2}$ $dE/dx_{reso} = 8\,\%$	$\sigma(p_t)/p_t = 0.32\,\% \cdot p_t$ $dE/dx_{reso} < 6\,\%$
TOF	180 ps (for bhabha)	90 ps (for bhabha)
EMC	$\sigma(E)/E = 22\% \cdot \sqrt{E}$	$\sigma(E)/E = 2.3\,\% \cdot \sqrt{E}$
MUC	3 layers for barrel	9 layers for barrel, 8 for endcap

World J/ψ and ψ(2S) Samples ($\times 10^6$)

BESIII: J/ψ 2009 – ~226M ψ(2S) 2009 – 106M

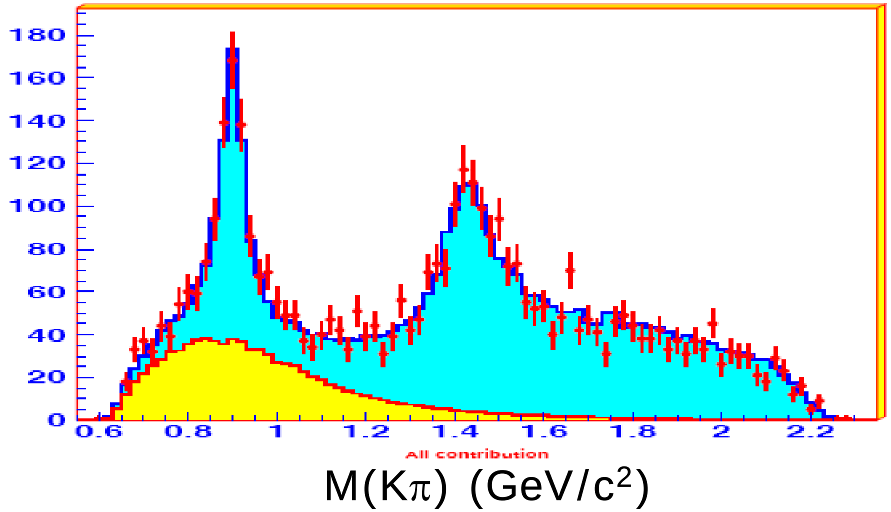


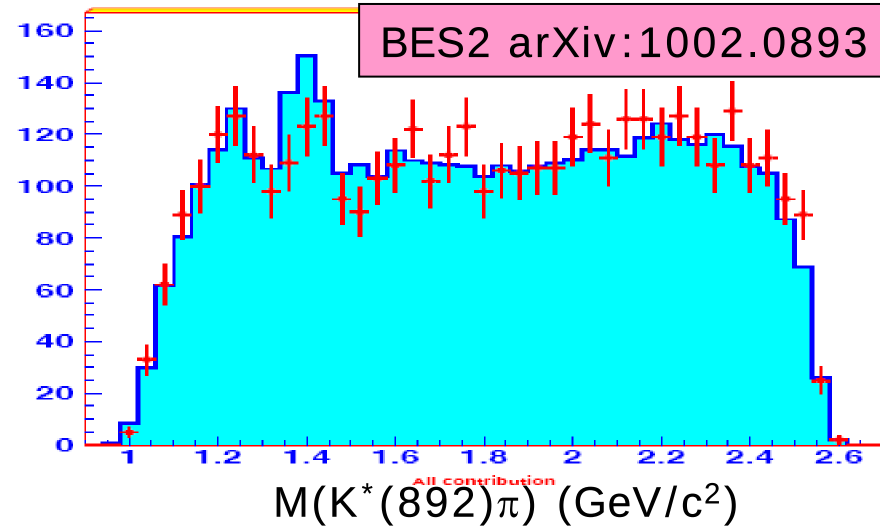


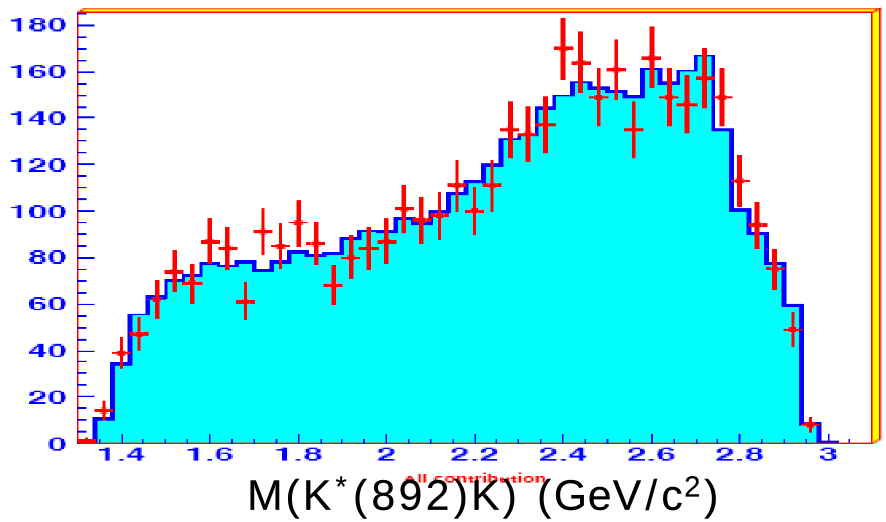
BESII: J/ψ 58M ψ(2S) 14M

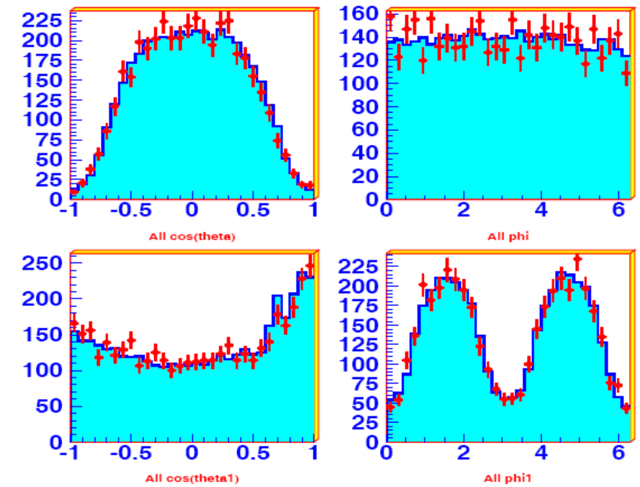
Partial wave analysis results

BES2 arXiv:1002.0893









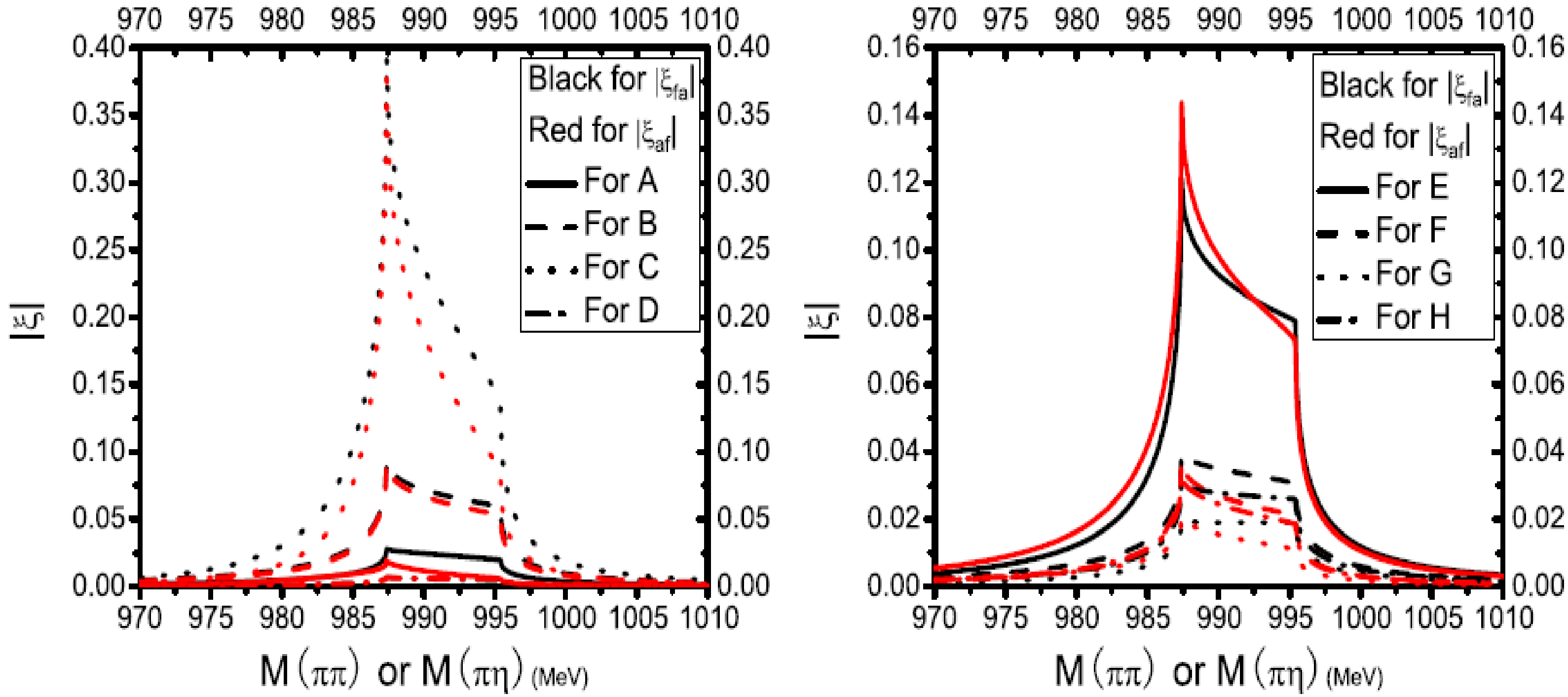


TABLE I. $m_{a_0^0(980)}$ (MeV), $m_{f_0(980)}$ (MeV), and coupling constants $g_{a_0\pi\eta}$ (GeV), $g_{a_0K^+K^-}$ (GeV), $g_{f_0K^+K^-}$ (GeV), and $g_{f_0\pi^0\pi^0}$ (GeV) from various models (A–D) and experimental measurements (E–H), and calculated values of $|\xi_{af}|$ and $|\xi_{fa}|$ at $\sqrt{s} = 991.4$ MeV by Eqs. (17) and (18).

No.	Model or experiment	m_a	$g_{a_0\pi\eta}$	$g_{a_0K^+K^-}$	m_f	$g_{f_0\pi^0\pi^0}$	$g_{f_0K^+K^-}$	$\lvert\xi_{fa}\rvert$	$\lvert\xi_{af}\rvert$
A	$q\bar{q}$ model [14]	983	2.03	1.27	975	0.64	1.80	0.023	0.010
B	$q^2\bar{q}^2$ model [14]	983	4.57	5.37	975	1.90	5.37	0.068	0.062
C	$K\bar{K}$ model [18,19,21]	980	1.74	2.74	980	0.65	2.74	0.21	0.15
D	$q\bar{q}g$ model [20]	980	2.52	1.97	975	1.54	1.70	0.005	0.006
E	SND [22,23]	995	3.11	4.20	969.8	1.84	5.57	0.088	0.089
F	KLOE [24,25]	984.8	3.02	2.24	973	2.09	5.92	0.034	0.025
G	BNL [26]	1001	2.47	1.67	953.5 [27]	1.36 [27]	3.26 [27]	0.019	0.014
H	CB [28]	999	3.33	2.54	965 [29]	1.66 [29]	4.18 [29]	0.027	0.023

Complementary study of a_0-f_0 mixing

$$\xi_{fa}(s) = \frac{|D_{af}|^2 \Gamma^a_{\pi\eta}}{|D_a|^2 \Gamma^f_{\pi\pi}} \tag{8}$$

$$= \left| \frac{g_{a_0^0 K^+K^-} g_{f_0 K^+K^-}}{g_{a_0^0 \pi^0 \eta} g_{f_0 \pi^0 \pi^0}} \right|^2 \frac{|\rho_{K^+K^-}(s) - \rho_{K^0\bar{K}^0}(s)|^2}{3\rho_{\pi\pi}(s)\rho_{\pi\eta}(s)}$$

$$\times \frac{1}{|\frac{m_a^2 - s}{\Gamma^a_{\pi\eta}\sqrt{s}} - i[|\frac{g_{a_0^0 K^+K^-}}{g_{a_0^0 \pi^0 \eta}}|^2 (\frac{\rho_{K^+K^-(s)}}{\rho_{\pi\eta(s)}} + \frac{\rho_{K^0\bar{K}^0}}{\rho_{\pi\eta}}) + 1]|^2}. \tag{9}$$

$$\xi_{af}(s) = \frac{d\Gamma_{X \to Y a_0^0(980) \to Y f_0(980) \to Y \pi\pi(s)}}{d\Gamma_{X \to Y a_0^0(980) \to Y \pi^0 \eta(s)}}, \tag{10}$$

$$= \left| \frac{g_{a_0^0 K^+K^-} g_{f_0 K^+K^-}}{g_{a_0^0 \pi^0 \eta} g_{f_0 \pi^0 \pi^0}} \right|^2 \frac{|\rho_{K^+K^-}(s) - \rho_{K^0\bar{K}^0}(s)|^2}{3\rho_{\pi\pi}(s)\rho_{\pi\eta}(s)}$$

$$\times \frac{1}{|\frac{m_f^2 - s}{\Gamma^f_{\pi\pi}\sqrt{s}} - i[|\frac{g_{f_0 K^+K^-}}{g_{f_0 \pi^0 \pi^0}}|^2 (\frac{\rho_{K^+K^-(s)}}{3\rho_{\pi\pi(s)}} + \frac{\rho_{K^0\bar{K}^0(s)}}{3\rho_{\pi\pi(s)}}) + 1]|^2}. \tag{11}$$