Experimental study of ϕ(2170)

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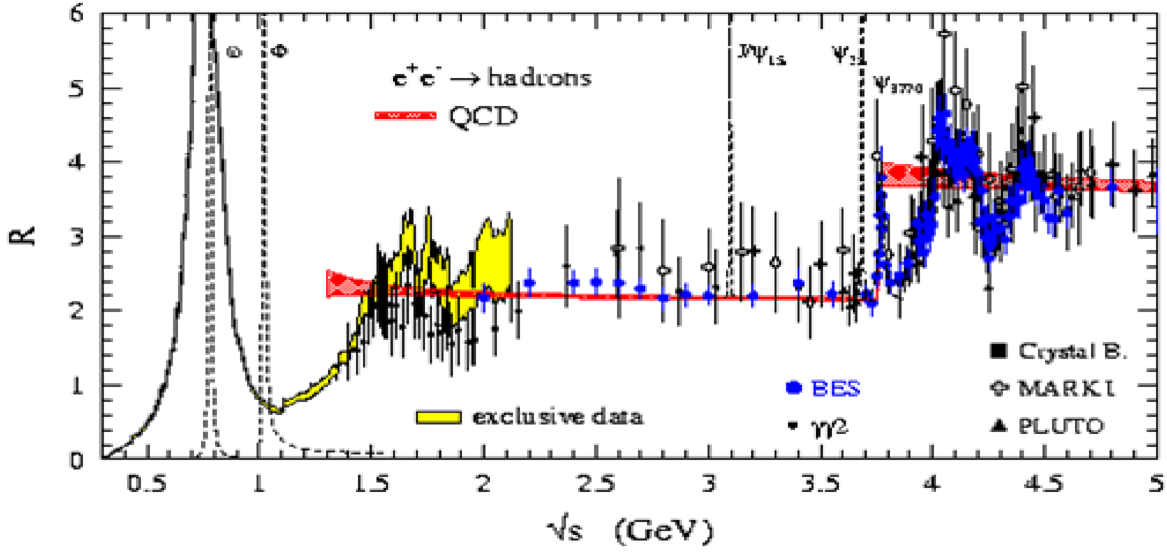
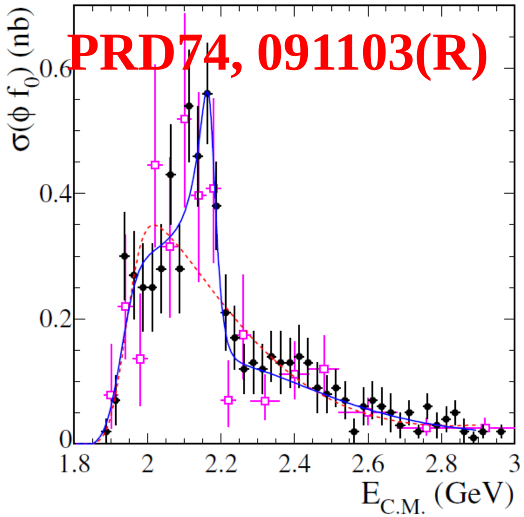


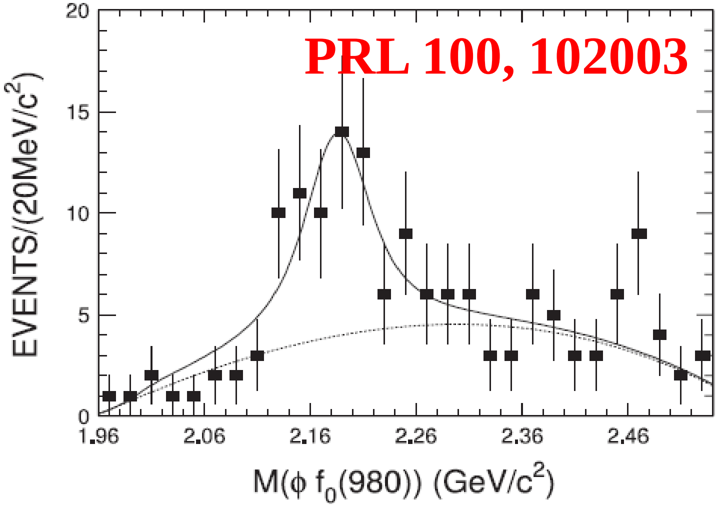
"5th workshop on the XYZ particles"，2018.10.20，郑州

ϕ(2170)/Y(2175)

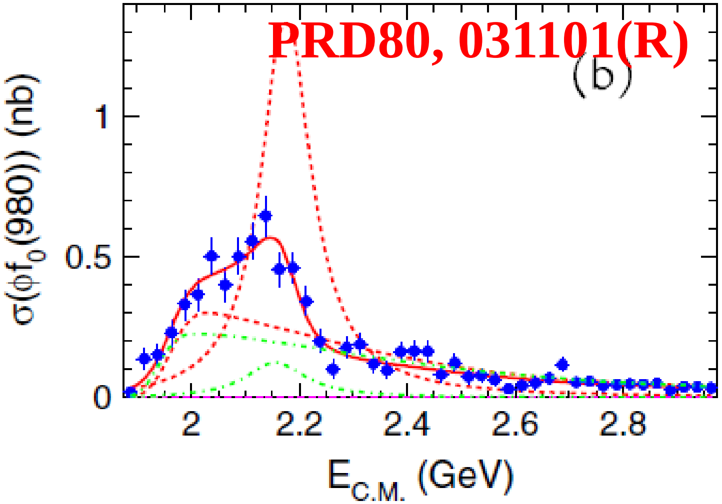
PRD74, 091103(R)



PRL 100, 102003



PRD80, 031101(R)



Eur. Phys. J. C72, 2008

$$e^+e^- \Rightarrow \begin{cases} Y(2175) \to \phi(1020)\pi^+\pi^- & \text{strange,} \\ Y(4260) \to J/\psi\pi^+\pi^- & \text{charm,} \\ \Upsilon(10860) \to \Upsilon(1S,2S)\pi^+\pi^- & \text{bottom,} \end{cases}$$

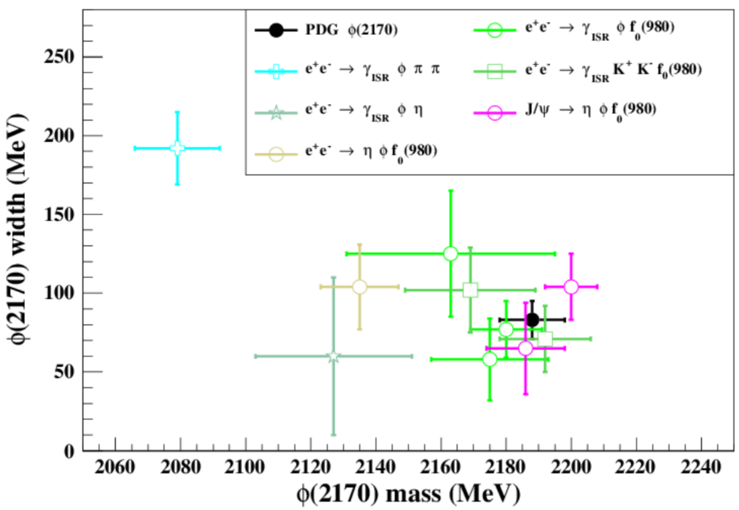
ϕ(2170) as strange analogue of Y(4220)

ϕ(2170)

PDG

$\phi(2170)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$e^+ e^-$	seen
Γ_2	$\phi\eta$	
Γ_3	$\phi\pi\pi$	
Γ_4	$\phi f_0(980)$	seen
Γ_5	$K^+ K^- \pi^+ \pi^-$	
Γ_6	$K^+ K^- f_0(980) \to K^+ K^- \pi^+ \pi^-$	seen
Γ_7	$K^+ K^- \pi^0 \pi^0$	
Γ_8	$K^+ K^- f_0(980) \to K^+ K^- \pi^0 \pi^0$	seen
Γ_9	$K^{*0} K^\pm \pi^\mp$	not seen
Γ_{10}	$K^*(892)^0 \overline{K}^*(892)^0$	not seen



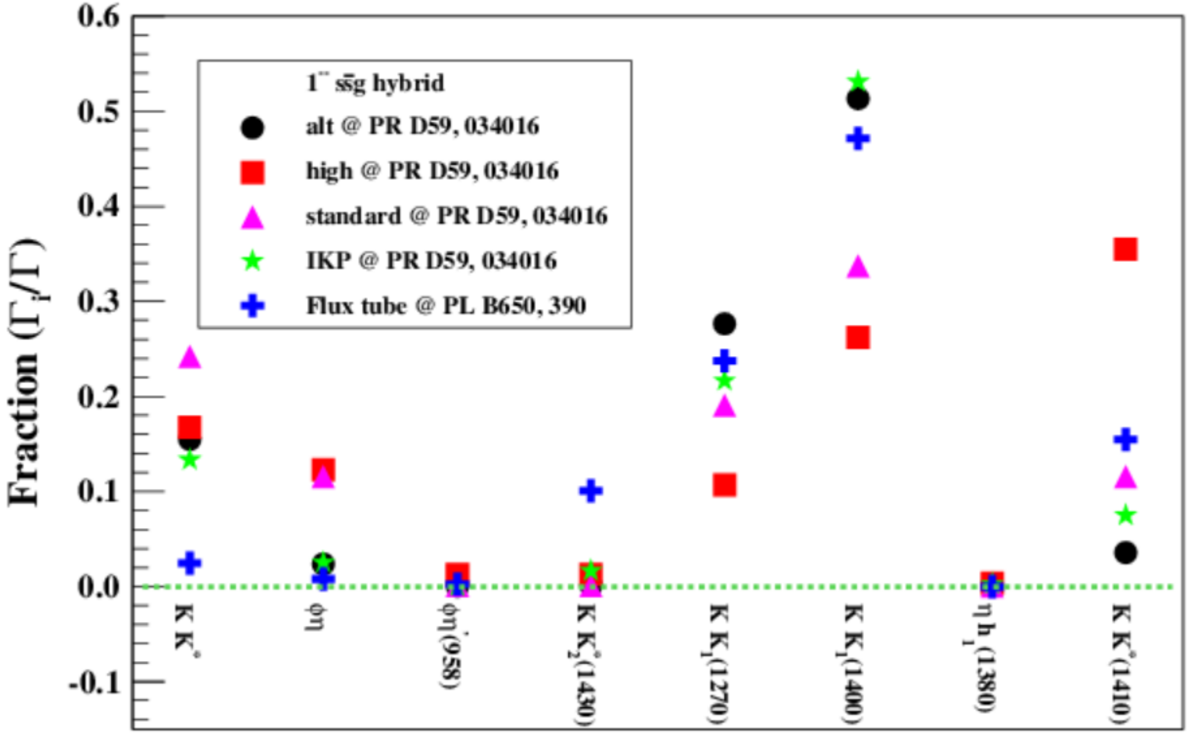
- **Published experimental information**
  - ✓ **Limited decay modes**
  - ✓ **Inconsistence on mass & width**
- **Theorists explain ϕ(2170) as**
  - ✓ **$s\bar{s}g$ hybrid**
  - ✓ **2^3D_1 or 3^3S_1 $s\bar{s}$**
  - ✓ **tetraquark**
  - ✓ **Molecular state $\Lambda\bar{\Lambda}$**
  - ✓ **$\phi f_0(980)$ resonance with FSI**
  - ✓ **Three body system ϕKK**
  - ✓ **Estimated or ruled out: not yet**
- **aspects of ϕ(2170) are still not fully understood.**

1^{--} $s\bar{s}g$ hybrid

1^{--} $s\bar{s}g$	alt	2.2GeV	standard	IKP	Ding
	PRD59, 034016				PLB650,390
K^*K	13	26	23	16	3.7
$\phi\eta$	2	19	11	3	1.2
$\phi\eta'$	0.01	2	0.1	0.02	0.4
$KK_2^*(1430)$	0.1	2	0.07	2	15
$KK_1(1270)$	23.2	16.6	18.1	26	35.3
$KK_1(1400)$	43.1	40.6	32.04	63.7	70.1
$h_1(1380)\eta$	0.07	0.6	0.04	0.3	0
$KK^*(1410)$	3	55	11	9	23
Width(MeV)	84	155	95	120	148.7

- **Theory prediction: model & input parameters dependent**

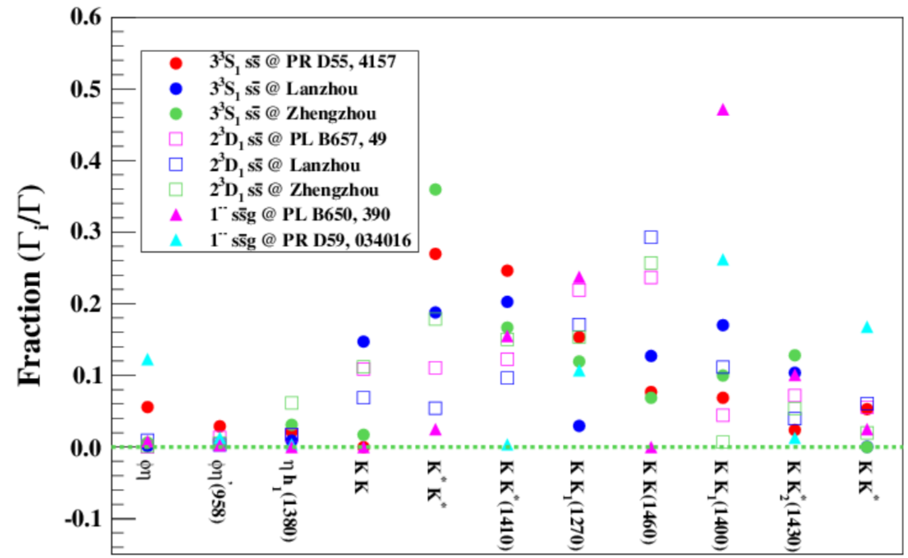
1^{--} $s\bar{s}g$ hybrid



- **Fraction Γ_i/Γ: weakly model & input parameters dependent**
- **Dominant decay modes: KK$_1$(1400) & KK$_1$(1270)**

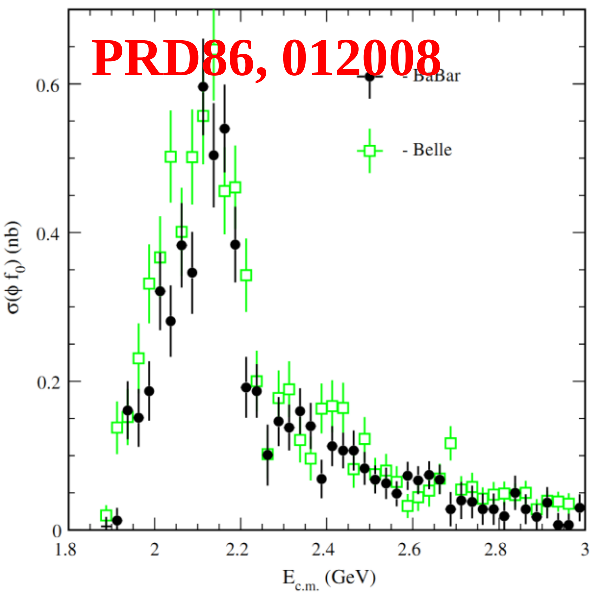
$\phi(2170)$

$\phi(2170)$	Mass (MeV)	Width (MeV)
3^3S_1	2050	378
2^3D_1		167.21
		211.9
hybrid		148.7
		155
		120
	2100-2200	
	2500-2600	
$s\bar{s}s\bar{s}$	2210±90	
	2300±400	
	2176	
$\Lambda\bar{\Lambda}$		80.1-95
PDG	2188±10	83±12



- **KKππ**: **benchmark process**
  - ✓ K^*K^*: $s\bar{s}g$ (forbidden), 3^3S_1 (favored)
  - ✓ $KK_1(1400)$: $s\bar{s}g$ (favored)
  - ✓ $KK(1460)$: $s\bar{s}g$ (forbidden), 2^3D_1 (favored)
- $\phi\eta$: 2^3D_1 (forbidden), tetraquark (favored)
- $\phi\eta'$: tetraquark (favored)
- $\eta h_1(1380)$: $s\bar{s}g$ (forbidden)
- KK: $s\bar{s}g$ (forbidden), $^3S_1\Lambda\bar{\Lambda}$ (favored)

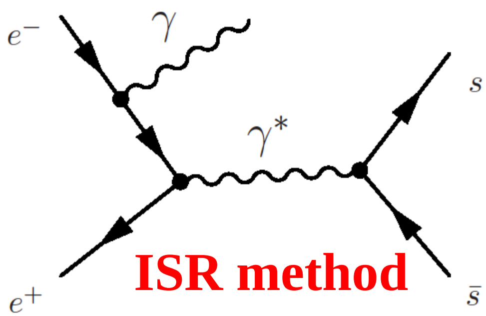
ϕ(2170) @ ISR method



$\phi(2170)$ MASS

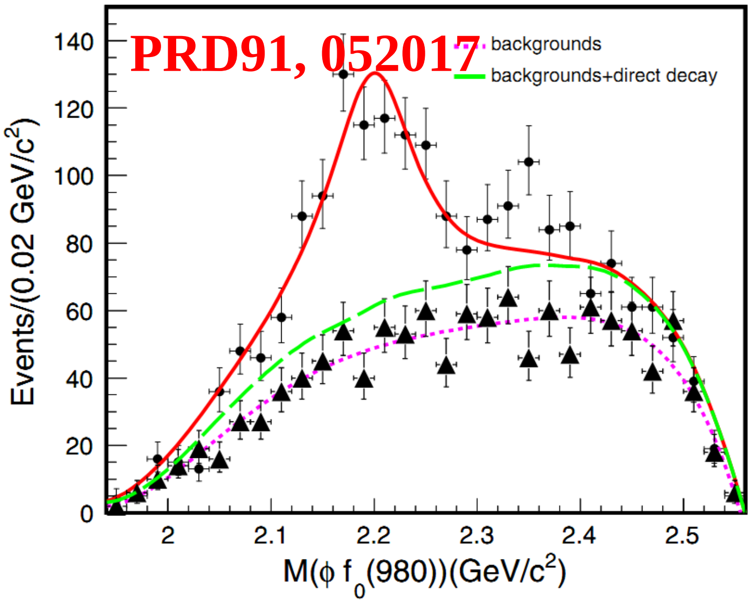
PDG

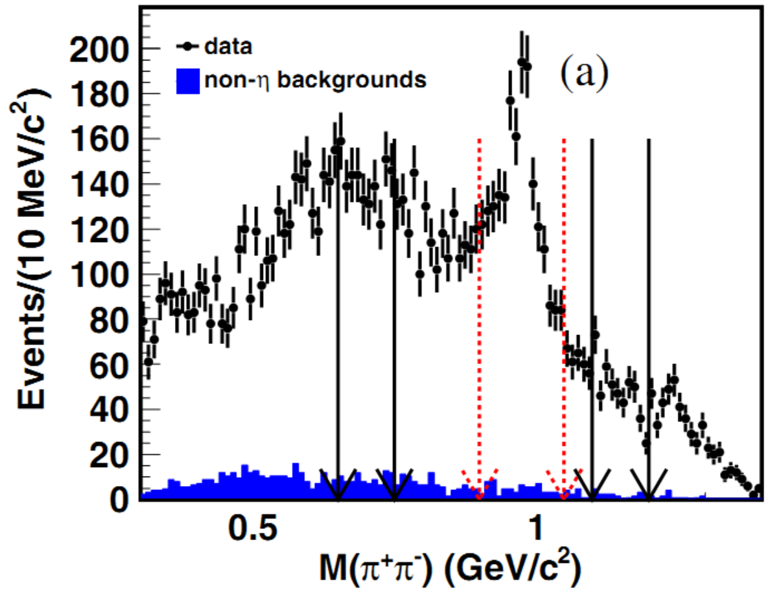
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
2188±10 OUR AVERAGE		Error includes scale factor of 1.8. See the ideogram below.		
2200± 6± 5	471	ABLIKIM	15H BES3	$J/\psi \to \eta\phi\pi^+\pi^-$
2180± 8± 8		[1,2] LEES	12F BABR	10.6 $e^+e^- \to \phi\pi^+\pi^-\gamma$
2186±10± 6	52	ABLIKIM	08F BES	$J/\psi \to \eta\phi f_0(980)$
2125±22±10	483	AUBERT	08S BABR	10.6 $e^+e^- \to \phi\eta\gamma$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$2079\pm13^{+79}_{-28}$	4.8k	[3] SHEN	09 BELL	10.6 $e^+e^- \to K^+K^-\pi^+\pi^-\gamma$
2192±14	116	[4] AUBERT	07AK BABR	10.6 $e^+e^- \to K^+K^-\pi^+\pi^-\gamma$
2169±20	149	[4] AUBERT	07AK BABR	10.6 $e^+e^- \to K^+K^-\pi^0\pi^0\gamma$
2175±10±15	201	[1,5] AUBERT,BE	06D BABR	10.6 $e^+e^- \to K^+K^-\pi\pi\gamma$

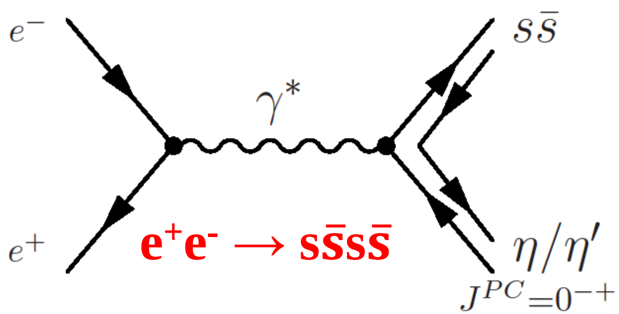


- **Varied $\sqrt{s}$ in one experiment !**
- **Limited samples for ϕ(2170)**
- **674 fb^{-1} @ Belle ⇒ 50 ab^{-1} @ Belle II**

$\phi(2170)$ @ $e^+e^- \to s\bar{s}s\bar{s}$

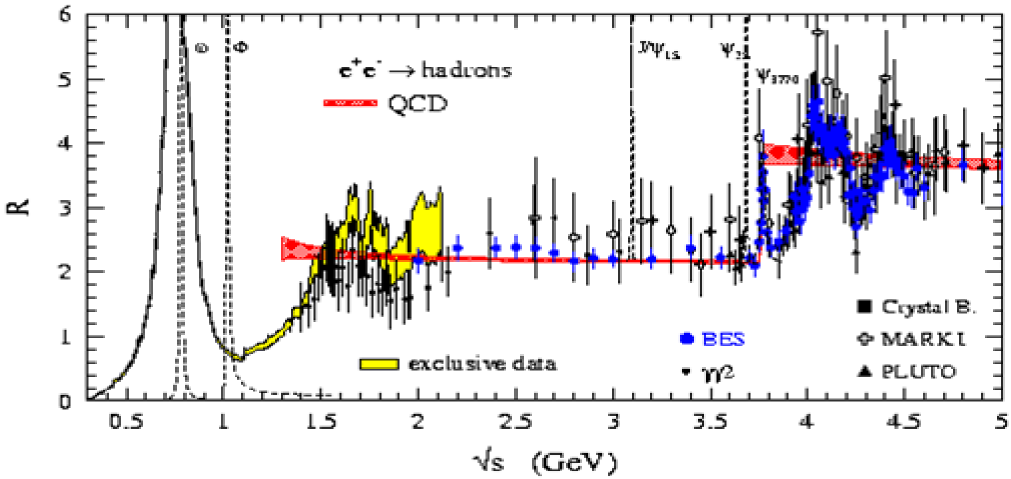


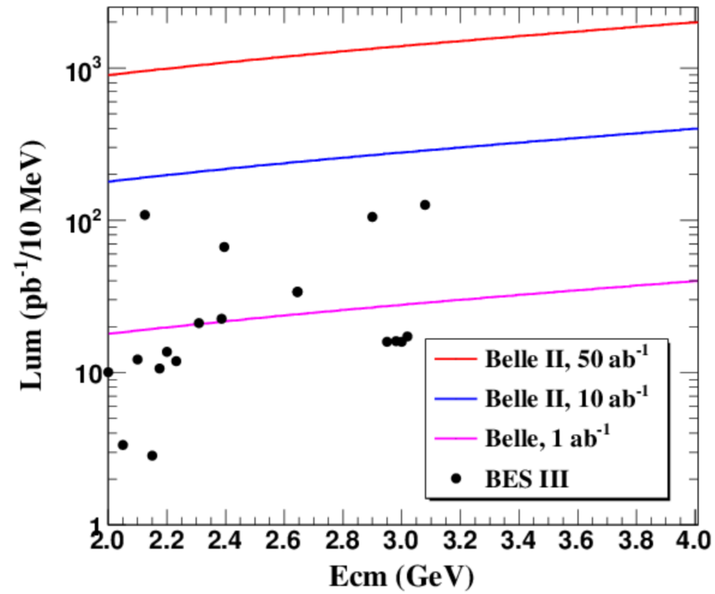


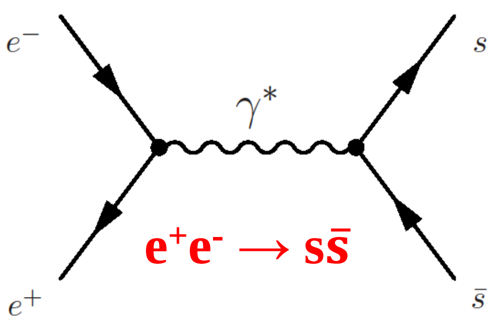


- $\phi\ f_0(980)$ @ $J/\psi \to \eta\ \phi\ f_0(980)$
- **background level: not negligible**

ϕ(2170) @ energy scan method

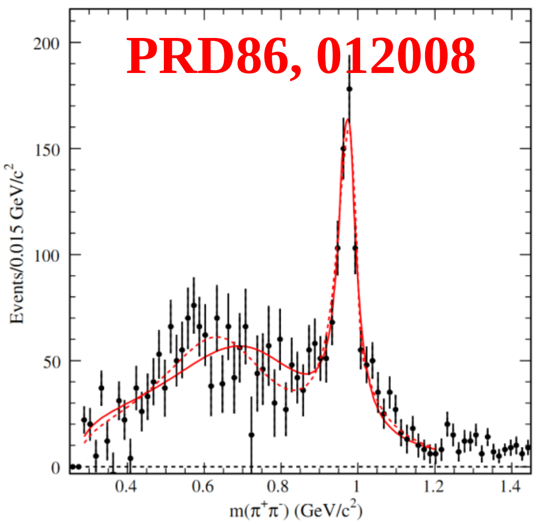


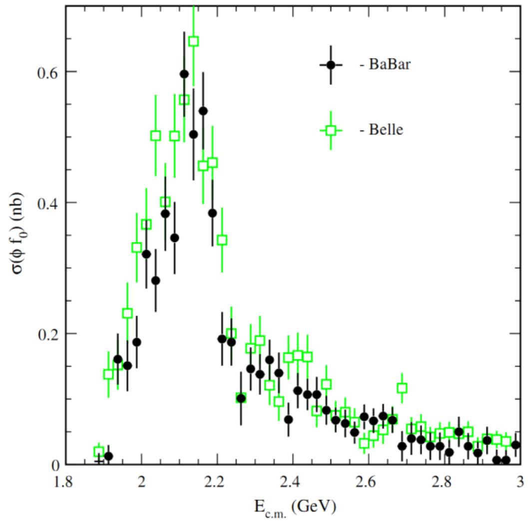




- ϕ(2170) with energy scan method
- Limited energy points
- Perform PWA & Dalitz analysis

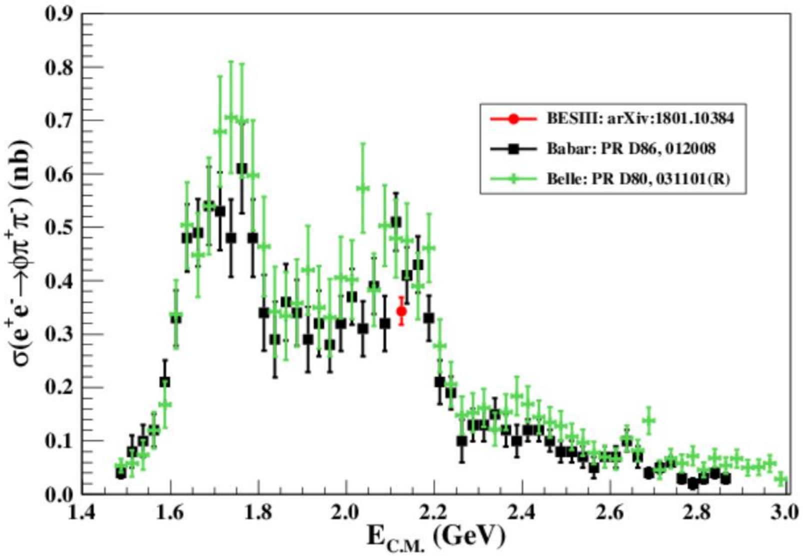
$e^+ e^- \to \phi\, f_0(980)$

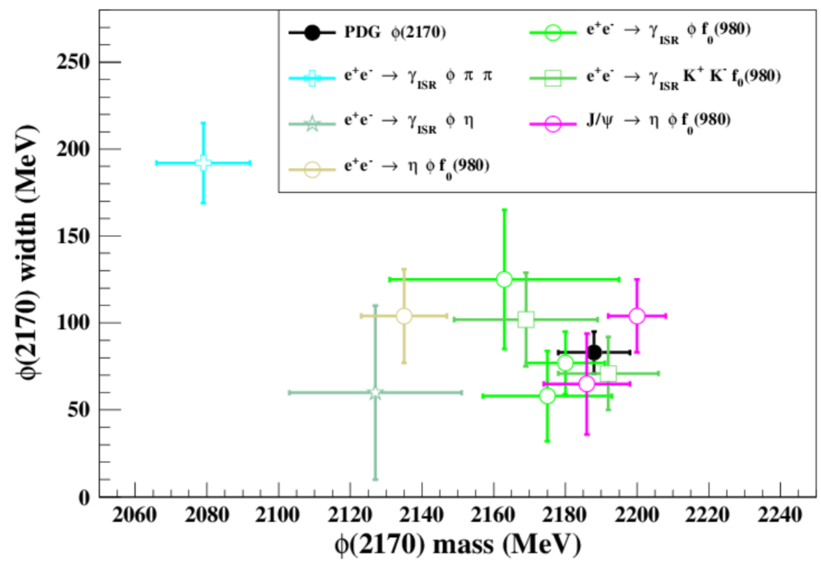




- **Select $f_0(980)$ by $0.85 < m_{\pi\pi} < 1.1$GeV**
  - ✓ **Neglect interference between $\phi f_0(980)$ and $\phi\pi\pi$ intermediate state**
  - ✓ **About 10% non- $\phi\, f_0(980)$ count as $\phi\, f_0(980)$ signal**

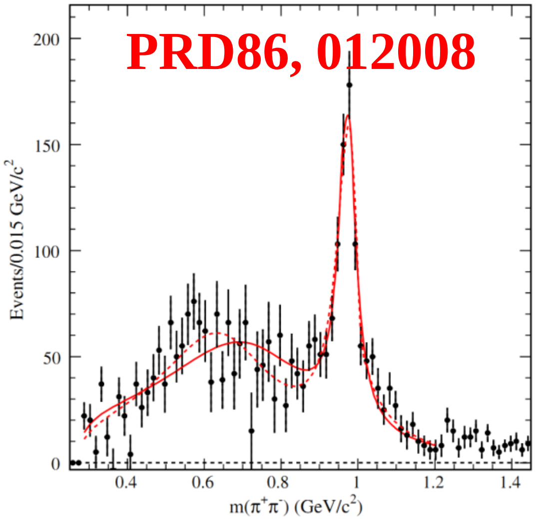
$e^+ e^- \to \phi\pi\pi$

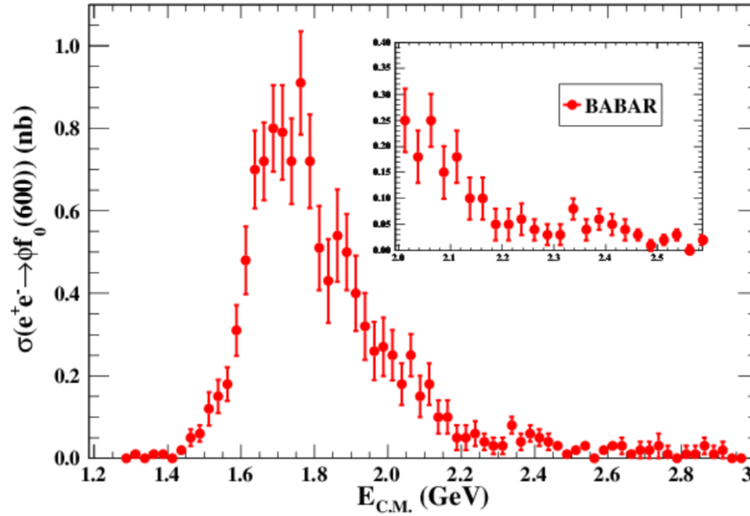




- **Belle & Babar results: general consistency, small systematic difference around 2.4GeV.**
  - ✓ **Belle data: structure around 2.4GeV with 1.5σ.**
- **ϕ(2170) mass & width: difference**
  - ✓ **$\phi\pi\pi$: $M=2.079 \pm 0.013$ GeV; $\Gamma = 0.192 \pm 0.023$ GeV**
  - ✓ **$\phi f_0(980)$: $M=2.163 \pm 0.032$ GeV; $\Gamma = 0.125 \pm 0.040$ GeV**

$e^+ e^- \to \phi f_0(600)$

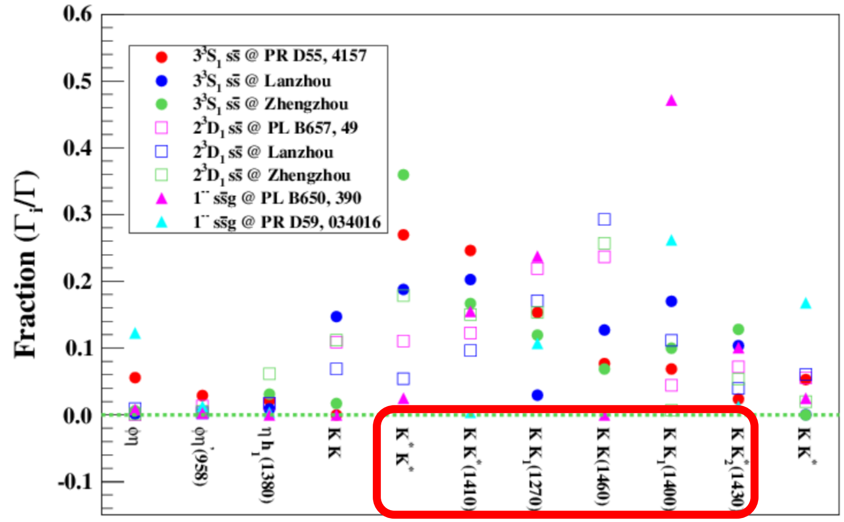


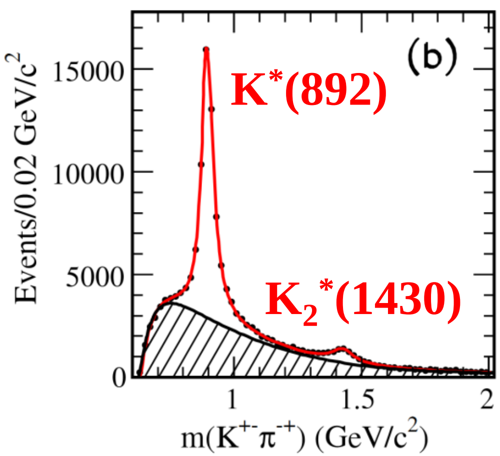


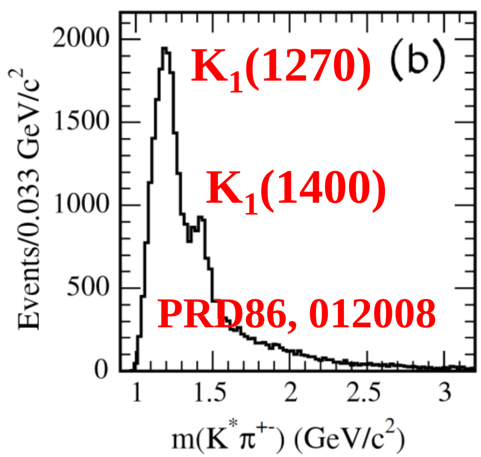
- select $f_0(600)$ with $m_{\pi\pi} < 0.85$ GeV: non-$f_0(600)$ events ?
- 2^3S_1 $\phi(1680) \to \phi f_0(600)$: Yes
- $\phi(2175) \to \phi f_0(600)$: No
- $\phi(2175)$ as 3^3S_1?

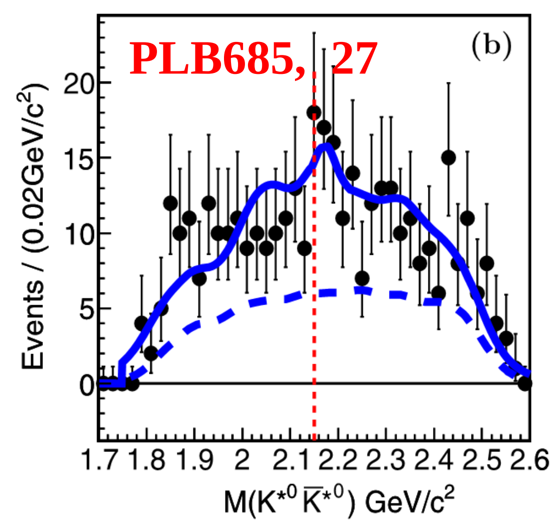
$e^+ e^- \to$ K K π π

- $e^+e^- \to KK\pi\pi$: important to distinguish $\phi(2170)$ theory models
- BABAR: $K^*(892)$, $K_2^*(1430)$, $K_1(1270)$ and $K_1(1400)$
- $J/\psi \to \eta\phi(2170) \to \eta K^* K^*$
  - ✓ BES: 58M J/ψ, a upper limit







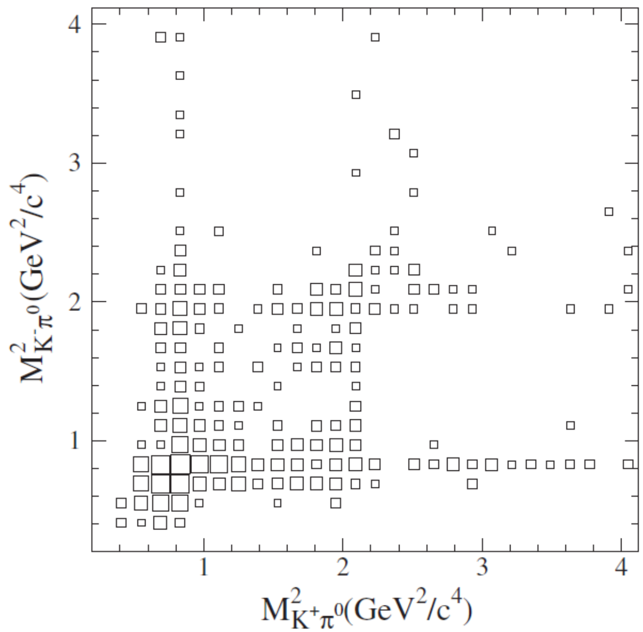


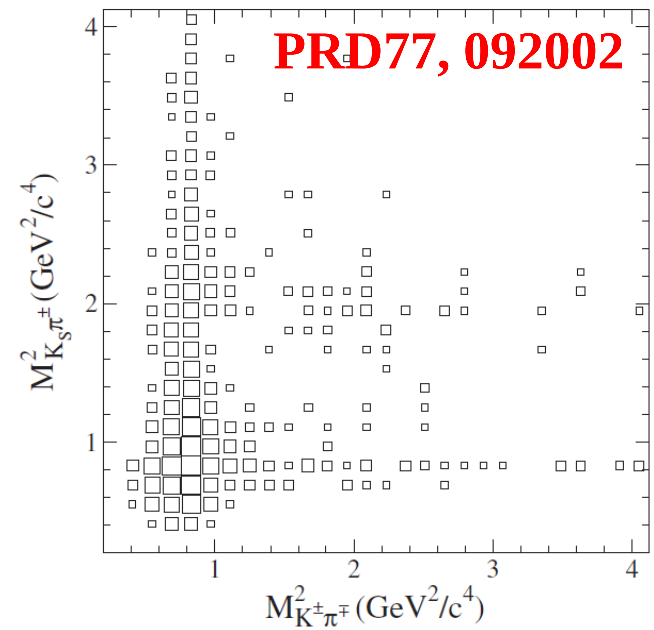
$e^+ e^- \to K K \pi \pi$

Modes	$2^3D_1\ s\bar{s}$	$1^{--}\ s\bar{s}g$	$3^3S_1\ s\bar{s}$	$K^+K^-\pi^+\pi^-$	$K^+K^-\pi^0\pi^0$	$K^+K^-\pi^0$
	Flux tube	Flux tube	$^3P_0$			
K^*K^*	23.5	0	102	14.8%	7.4%	
KK(1460)	50.2	0	29	25.7%	6.4%	
$KK^*(1410)$	26.0	23	93	27.0%	6.4%	1.6%
$KK_1(1270)$	46.4	35.3	58	23.7%	4.0%	
$KK_1(1400)$	9.4	70.1	26	29.5%	7.4%	
$KK_2^*(1430)$	15.3	15.0	9.0	9.5%	1.9%	11.1%
$\phi\eta$	0	1.2	21			
$\phi\eta'$	2.8	0.4	11			

- Mode $K^+K^-\pi^+\pi^-$ is better than $K^+K^-\pi^0\pi^0$
- $KK_2^*(1430)$: (favored) $K^+K^-\pi^0$
- Notice: charged & neutral K meson; Brs

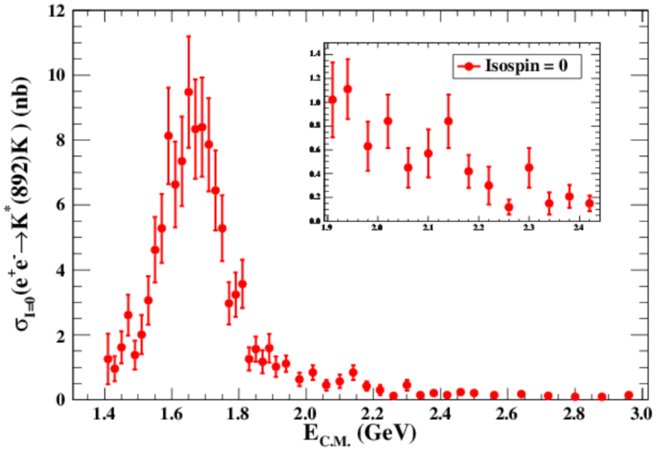
$e^+ e^- \rightarrow K^+K^-\pi^0$ and $K_sK^{\pm}\pi^{\mp}$

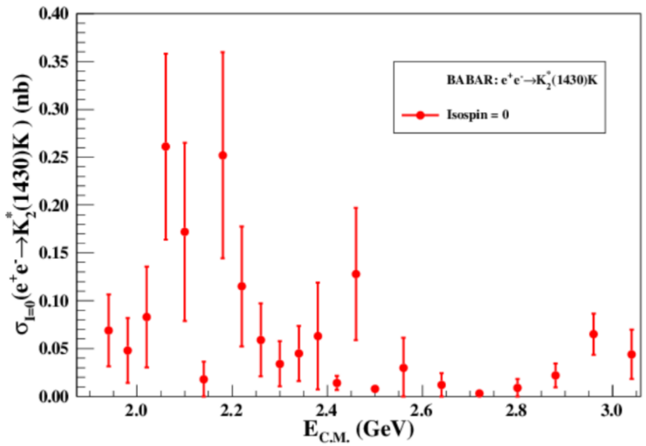




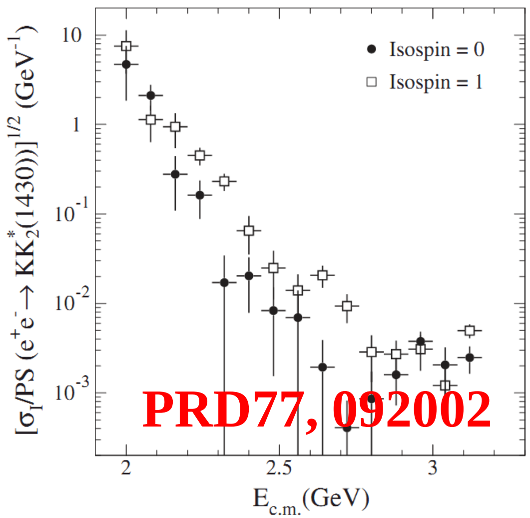
- $K^+K^-\pi^0$: symmetric population density with respect to exchange of $K^+\pi^0 \leftrightarrow K^-\pi^0$
- $K_sK^{\pm}\pi^{\mp}$: $K^{*\pm}(892)K^{\mp}$ and $K^{*0}(892)K^0_S$, or $K_2^{*\pm}(1430)K^{\mp}$ and $K_2^{*0}(1430)K^0_S$, asymmetric population density
- Extract isoscalar and isovector component by $K_sK^{\pm}\pi^{\mp}$

$e^+ e^- \to K^*K \to KK\pi$





- $\phi(2170)$ @ $\phi f_0(980)$
  - ✓ isoscalar
  - ✓ Babar's isoscalar K*K
- Threshold effect @ 2.25GeV
  - ✓ Resonance ?
  - ✓ Need precision data



$e^+ e^- \to K_s K^{\pm} \pi^{\mp}$: Dalitz analysis

- **Dalitz density function: with isospin**

$$\mathcal{D}[(p_\pi + p_K)^2, (p_{\bar{K}} + p_\pi)^2, E_{\rm c.m.}] = \sum_{\substack{I,I'=0,1 \\ K^*,K^{*\prime}=K^*(892),K_2^*(1430)}} f_{I,K^*} f^*_{I',K^{*\prime}} \vec{A}_{I,K^*} \cdot \vec{A}^*_{I',K^{*\prime}},$$

$$\vec{A}_{I,K^*} = C_{I,K^*} \vec{T}_{K^*}(\vec{p}_\pi - \vec{p}_K, \vec{p}_{\bar{K}}) \cdot BW_{K^*}[(p_\pi + p_K)^2] + C_{I,\bar{K}^*} \vec{T}_{\bar{K}^*}(\vec{p}_{\bar{K}} - \vec{p}_\pi, \vec{p}_K) \cdot BW_{\bar{K}^*}[(p_{\bar{K}} + p_\pi)^2],$$

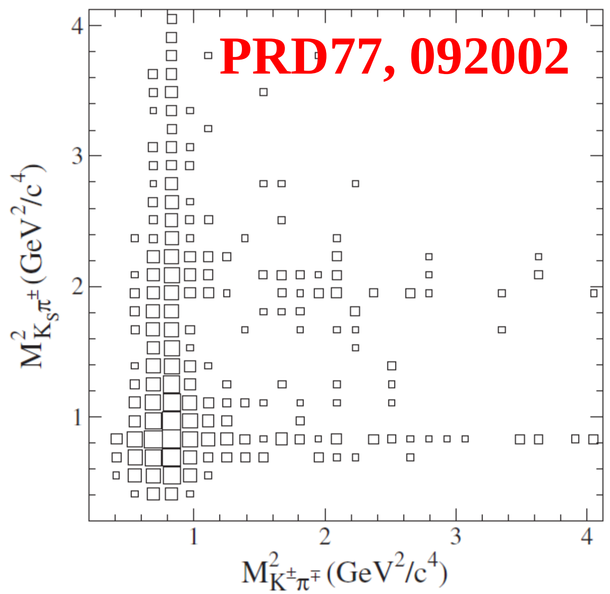


TABLE V. Values of the Zemach tensor $\vec{T}_{K^*}$ [20] in the two cases under consideration.

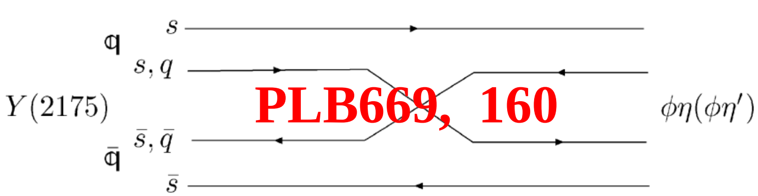
Meson K^*	J^P	L	$\vec{T}_{K^*}(\vec{p}_1 - \vec{p}_2, \vec{p}_3)$
$K^*(892)$	1^-	P	$(\vec{p}_1 - \vec{p}_2) \times \vec{p}_3$
$K_2^*(1430)$	2^+	D	$[(\vec{p}_1 - \vec{p}_2) \cdot \vec{p}_3](\vec{p}_1 - \vec{p}_2) \times \vec{p}_3$

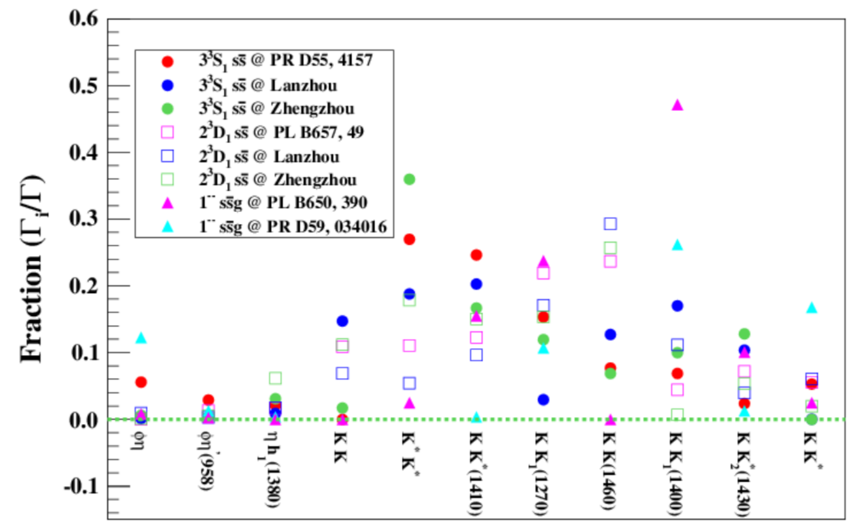
$$C_{I,K^*} = \begin{cases} (-1)^I & \text{for charged } K^* \\ 1 & \text{for neutral } K^* \end{cases}$$

- **BESIII data: more resonances, need theorist's help**

$e^+ e^- \to \phi\eta$ and $\phi\eta'$

- $\phi\eta$ and $\phi\eta'$ modes: isoscalar
  - ✓ ϕ^* and ω^* (OZI suppressed)
  - ✓ useful to measure parameters
- Tetraquark favorites $\phi\eta$ and $\phi\eta'$



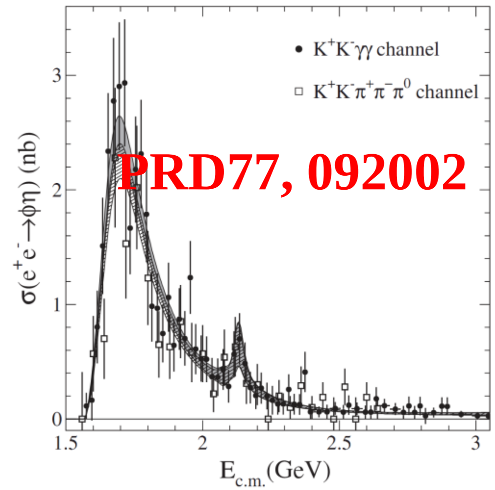


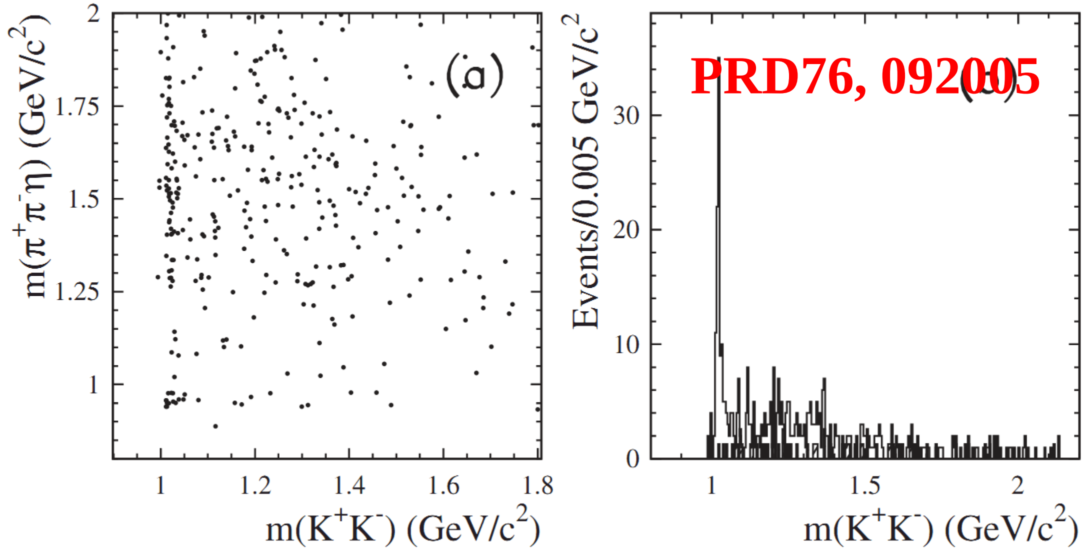
- 1^{--} $s\bar{s}g$ hybrid has large $\Gamma_{\phi\eta}$ and smaller $\Gamma_{\phi\eta'}$

1^{--} $s\bar{s}g$	alt	2.2GeV	standard	IKP	Ding
	PRD59, 034016				PLB650,390
$\phi\eta$	2	19	11	3	1.2
$\phi\eta'$	0.01	2	0.1	0.02	0.4

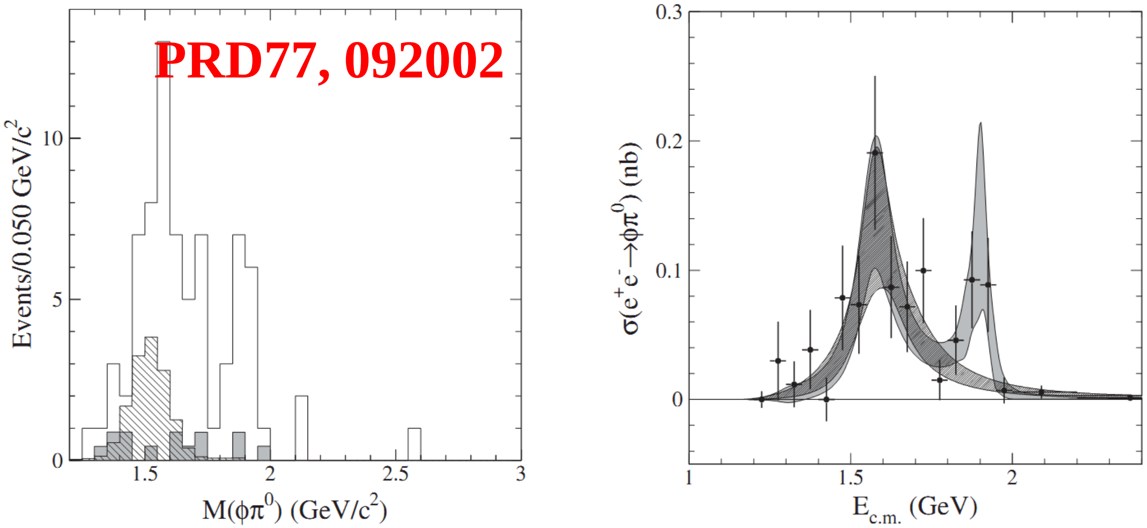
$e^+ e^- \to \phi\eta$ and $\phi\eta'$

- **BABAR measured $\phi\eta$ mode**
  - ✓ **~50% stat. uncertainty around 2.2GeV**
  - ✓ **$Br_{\phi\eta}\Gamma_{ee} = 1.7\pm0.7\pm1.3$eV**
  - ✓ **$Br_{\phi f0(980)}\Gamma_{ee} = 2.5\pm0.8\pm0.4$eV**
- **BABAR: $\phi\eta'$ signal**



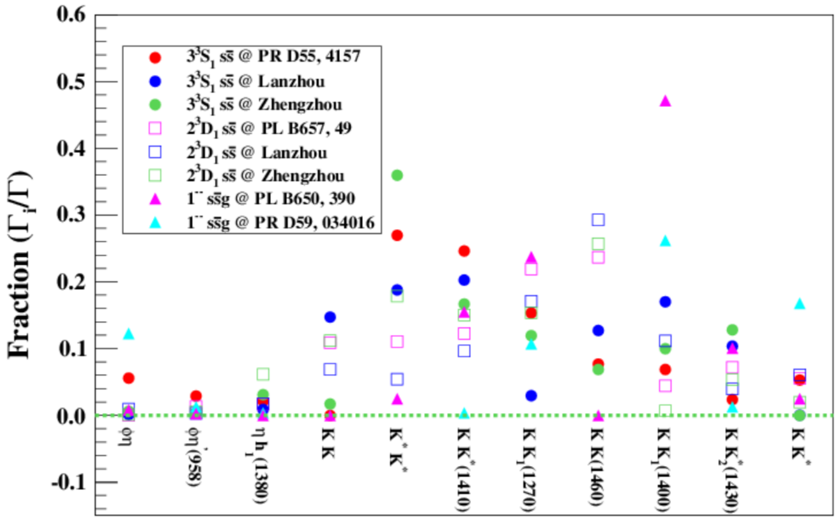


$e^+ e^- \to \phi\pi^0$



- $\phi\pi^0$ **mode: iso-vector**
  - ✓ **Only ρ*, OZI suppressed**
  - ✓ **Promising for a search for exotic isovector resonance**
  - ✓ **Possible candidate for multi-quark states**
- **BESIII: data at 2.0-3.08GeV ?**

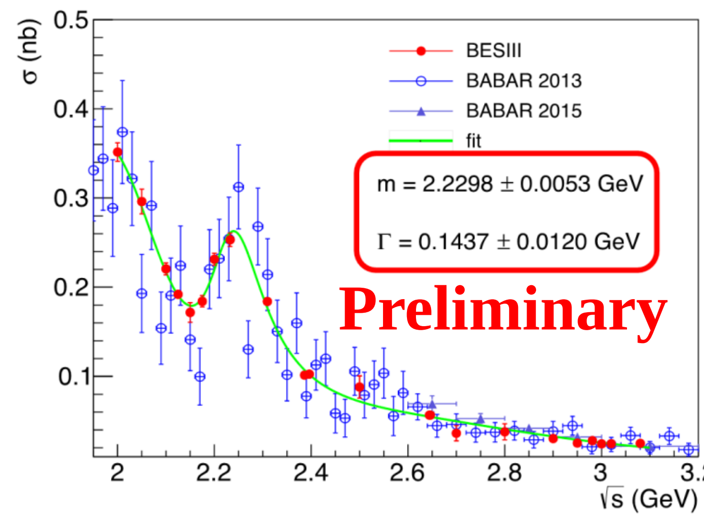
$e^+ e^- \to K^+ K^-$



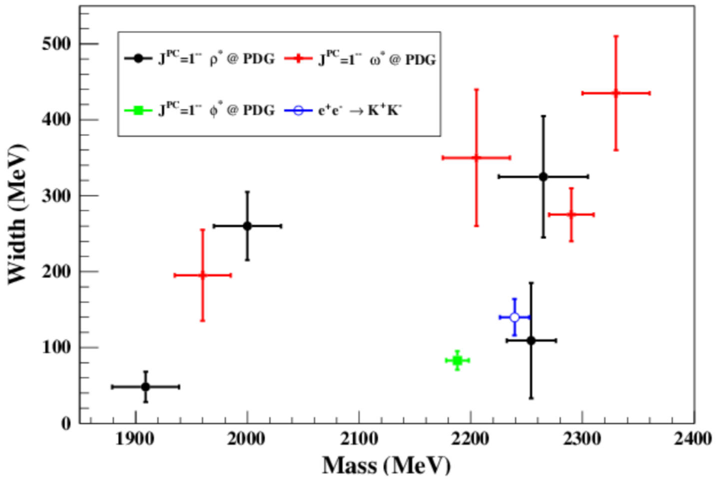
$\phi(2170)$ decay	This work $^3S_1\Lambda\bar{\Lambda}$	$^3P_0$ model within $s\bar{s}$ [10]	Data [5]
KK	73.8–87.7	...	...
$\phi f_0(980)$	0.25–0.3	<10	Seen
$\omega\sigma$	4.2–4.9	...	...
$K^*K_0^*(800)$	1.8–2.1	...	...
Total	80.1–95		83 ± 12

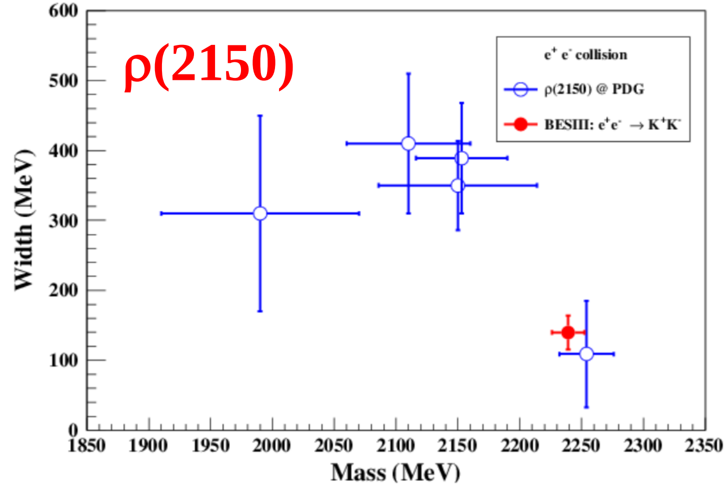
PRD96, 074027

- K^+K^- @ $\phi(2170)$
  - ✓ Obvious discrepancy between different theory models
  - ✓ isoscalar: ω^*/ϕ^*; isovector: ρ^*
- $\sigma(e^+e^- \to K^+K^-)$ @ [2.0-3.08]GeV

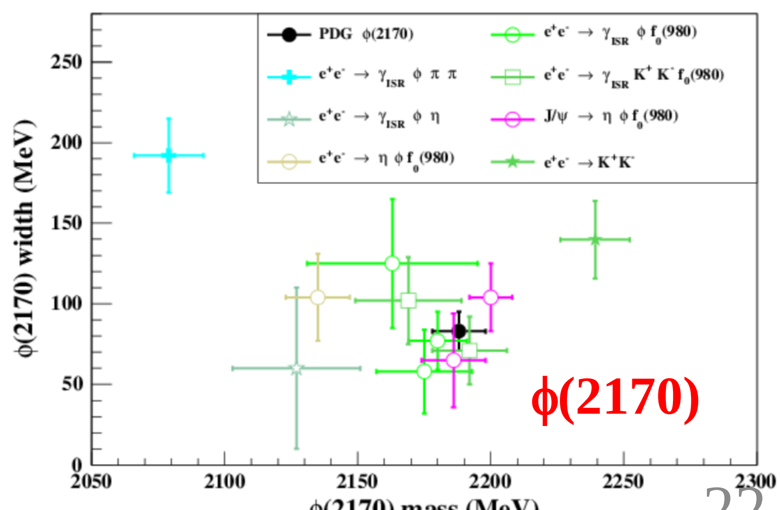


$e^+ e^- \rightarrow K^+ K^-$

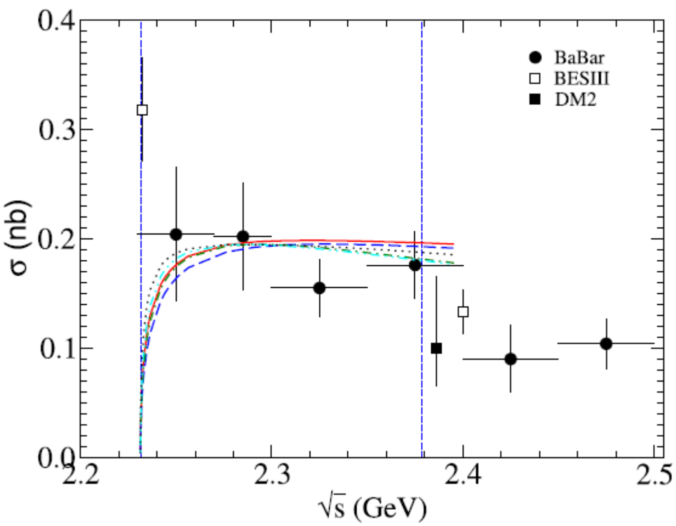


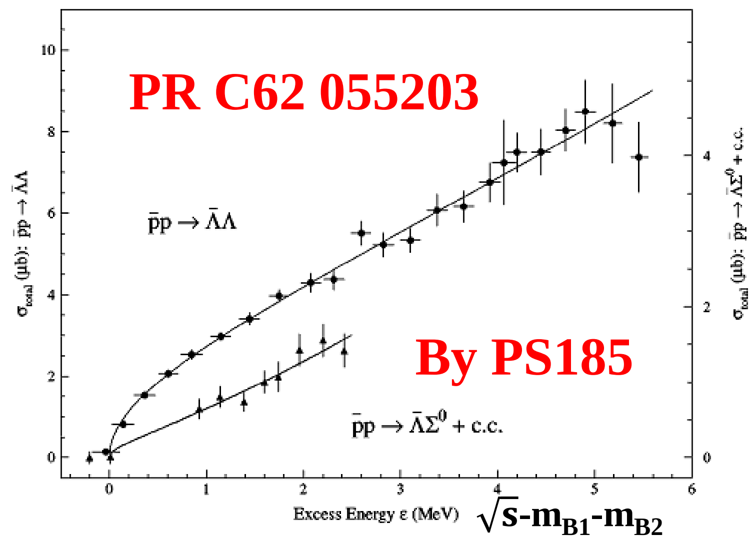


- **Compare K^+K^- resonance**
  - ✓ **$J^{PC}=1^{--}$ vector: ω*/ϕ*/ρ***
  - ✓ **ρ(2150) @ e^+e^- collision**
  - ✓ **ϕ(2150) experimental results**
- **K^+K^- resonance: ρ(2150) ?**



$e^+ e^- \to \Lambda\bar{\Lambda}$





Decay mode	Mass(MeV)	Width(MeV)
K^+K^-	2229.8±5.3	143.7±12.0
$\Lambda\bar{\Lambda}$	???	???

J^{PC}	M(MeV)	Γ(MeV)	M(MeV)	Γ(MeV)
0^{++}	2314 ± 25	144 ± 20	2337 ± 14	217 ± 33
2^{++}	2387 ± 35	33 ± 100	–	–
3^{++}	2334 ± 25	200 ± 20	2303 ± 15	214 ± 29
3^{--}	2278 ± 28	224 ± 50	2255 ± 15	175 ± 30
1^{--}	2290 ± 20	275 ± 30	–	–

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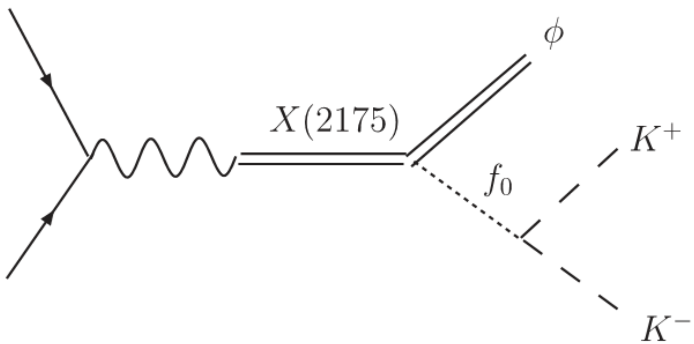
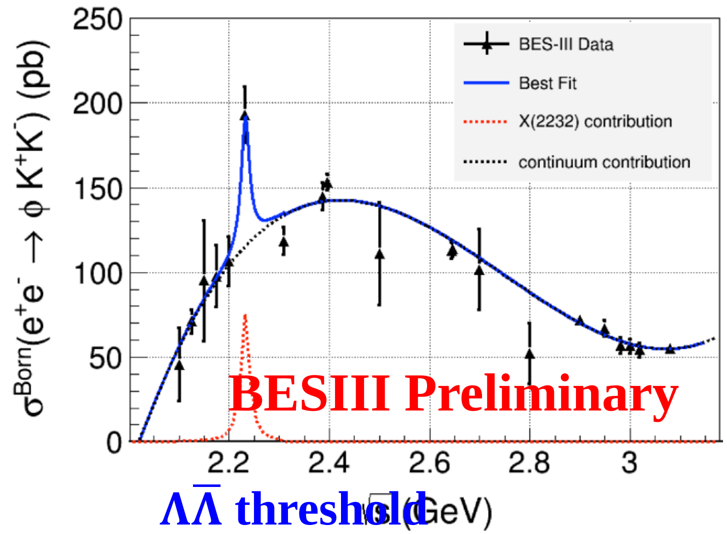
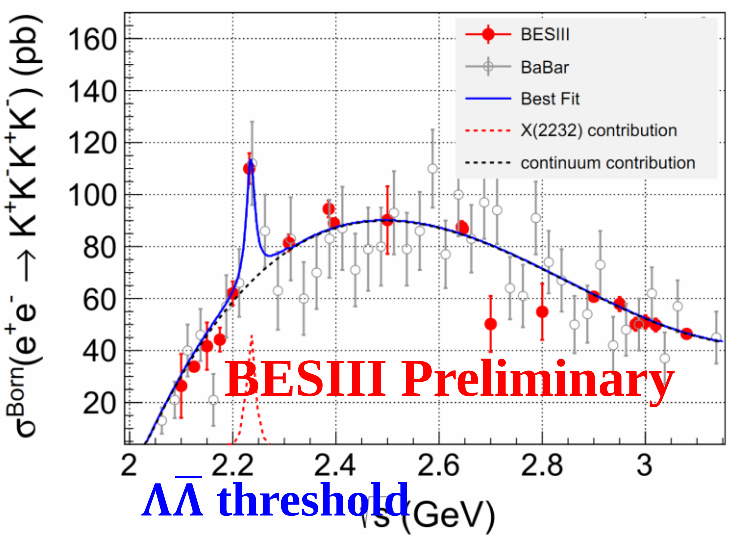
$e^+ e^- \to \phi K^+ K^-$

- $\phi(2170)$: resonant of ϕKK



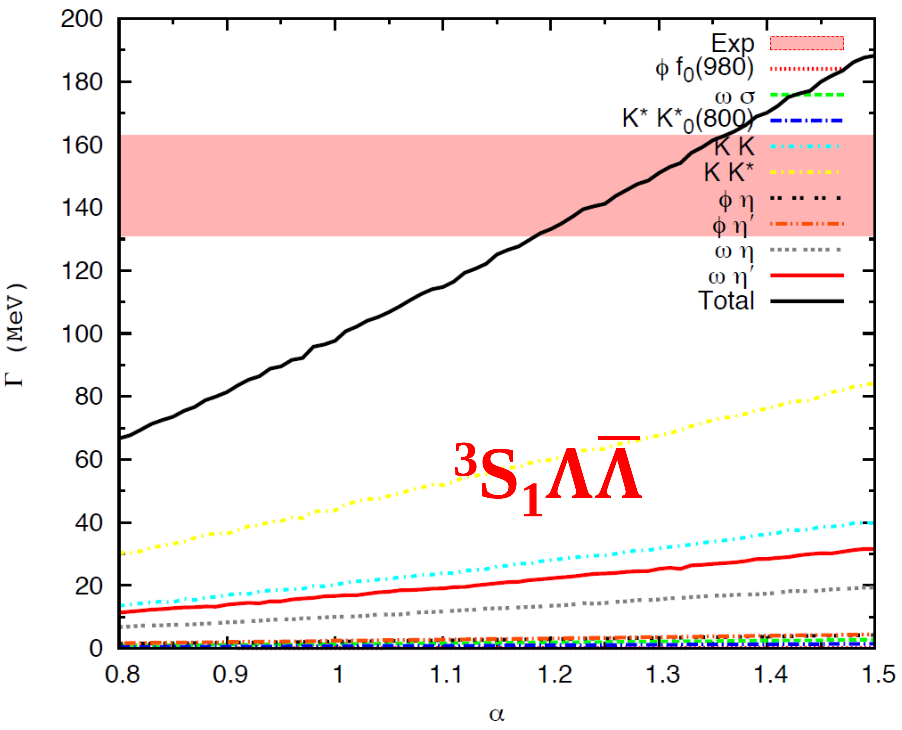




- A hint for a resonance around $\Lambda\bar{\Lambda}$ threshold
  - ✓ Mass = 2232±3.5MeV;
  - ✓ Width < 20 MeV
- Three body system ϕKK: ✗

Non-strange modes

- **PRD68, 054014:** **True evidence for $s\bar{s}$ would be observation of large branching fraction to hidden strangeness modes such as $\phi\eta$, or weak branching fraction to all accessible non-strange modes.**



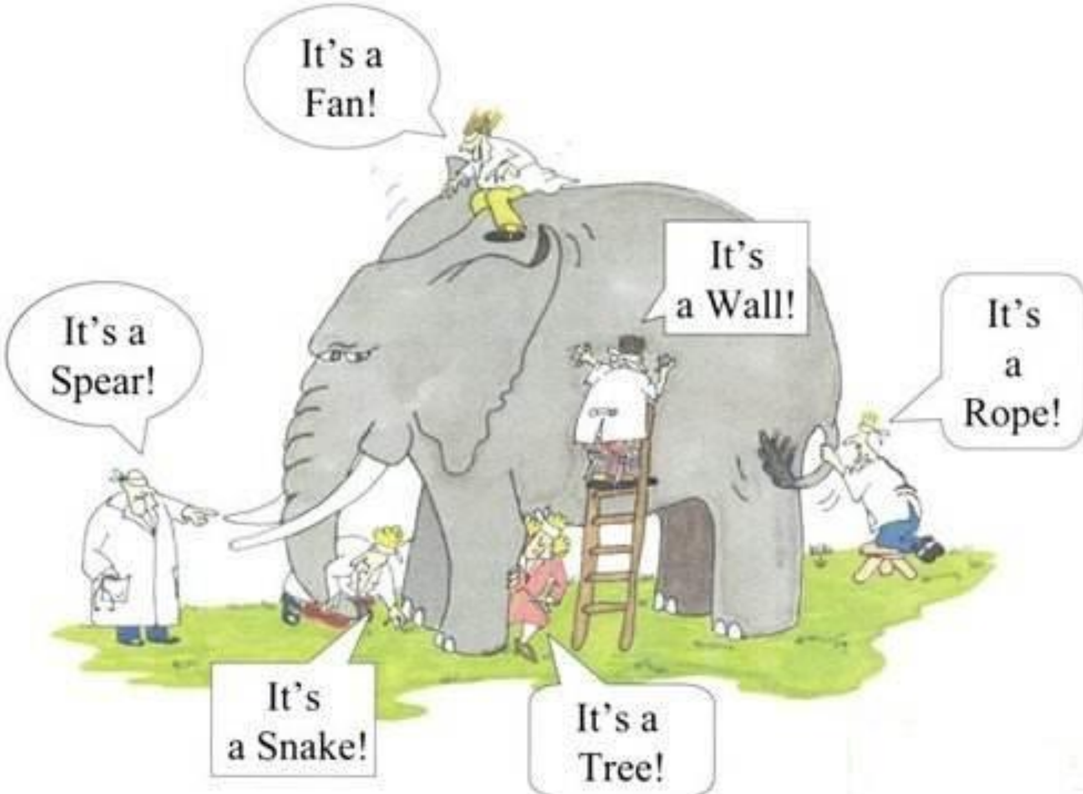
Analysis topics

Data set	$\sqrt{s}$ (GeV)	Luminosity (pb^{-1})
1	2.0000	10.074
2	2.0500	3.343
3	2.1000	12.167
4	2.1250	108.490
5	2.1500	2.841
6	2.1750	10.625
7	2.2000	13.699
8	2.2324	11.856
9	2.3094	21.089
10	2.3864	22.549
11	2.3960	66.869
12	2.6444	33.722
13	2.6464	34.003
14	2.9000	105.253
15	2.9500	15.942
16	2.9810	16.071
17	3.0000	15.881
18	3.0200	17.290
19	3.0800	126.185

- **BESIII R scan @[2.00, 3.08]GeV**

Decay modes	
KK	$\phi\eta$
K^*K	$\phi\eta'$
K^*K^*	$h_1(1380)\eta$
KK(1460)	$\omega\eta$
$KK^*(1410)$	$\omega\eta'$
$KK_1(1270)$	$\rho\eta$
$KK_1(1400)$	$\rho\eta'$
$KK_2^*(1430)$	$\omega\pi^+\pi^-$
	$\rho\pi^+\pi^-$

How to understand $\phi(2170)$?



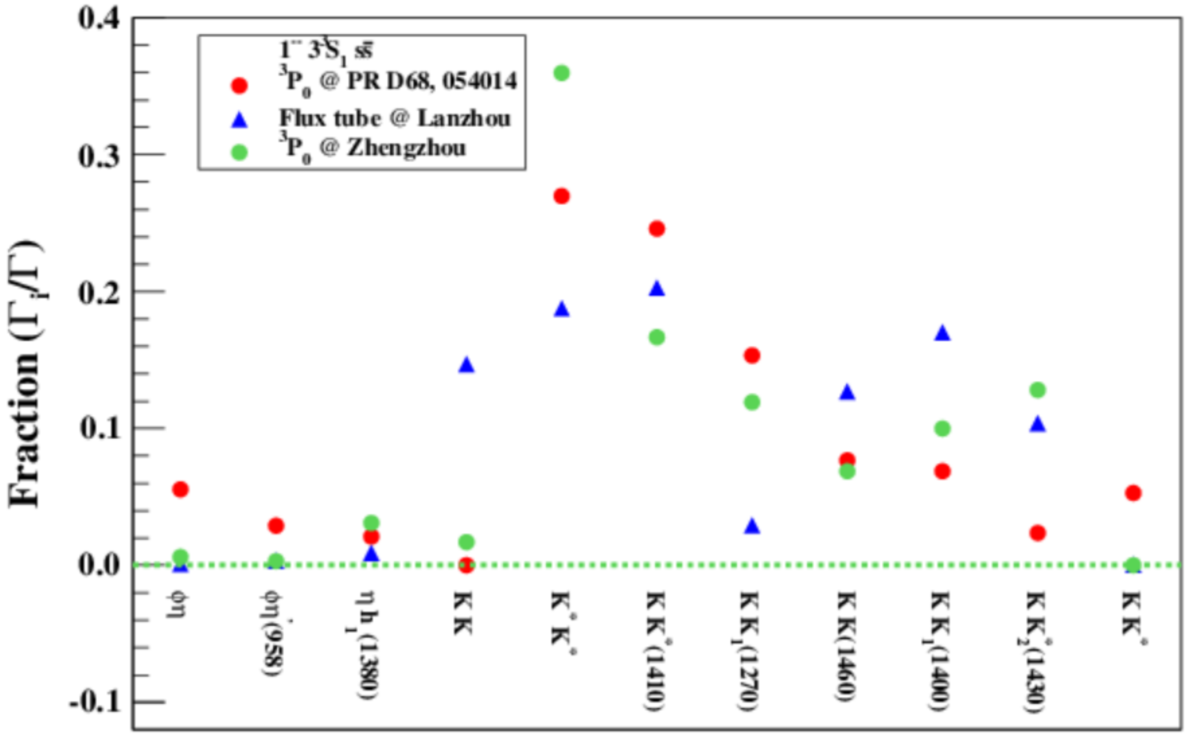
- **Study of $\phi(2170)$ exclusive decays**

Example 3^3S_1 $s\bar{s}$

Decay modes	3^3S_1 $s\bar{s}$	
	$^3P_0$ model	Lanzhou
KK	0	35.8
K^*K	20	0.1
K^*K^*	102	45.7
KK(1460)	29	30.9
$KK^*(1410)$	93	49.3
$KK_1(1270)$	58	7.1
$KK_1(1400)$	26	41.4
$KK_2^*(1430)$	9.0	25.2
$\phi\eta$	21	0.3
$\phi\eta'$	11	0.8

- **Reduction to Absurdity**
  - ✓ 3^3S_1 $s\bar{s}$: $\Gamma_{K^*K^*} > \Gamma_{KK1(1270)}$
  - ✓ If Exp. $\phi(2170)$ @ $KK_1(1270)$
  - ✓ If Exp. no $\phi(2170)$ @ K^*K^*
  - ✓ If Exp. similar ε_{eff}
  - ✓ Theory 3^3S_1 $s\bar{s}$ wrong
- **Similar check for several modes**
  - ✓ $KK^*(1410)$
  - ✓ KK(1460)
  - ✓ KK for Lanzhou model
- **$\phi(2170)$ as pure 3^3S_1 $s\bar{s}$: Yes/No**
- **Q: reliable $\Gamma_{K^*K^*} > \Gamma_{KK1(1270)}$?**
  - ✓ Depend on understand of K^* ?
  - ✓ Model dependence ?

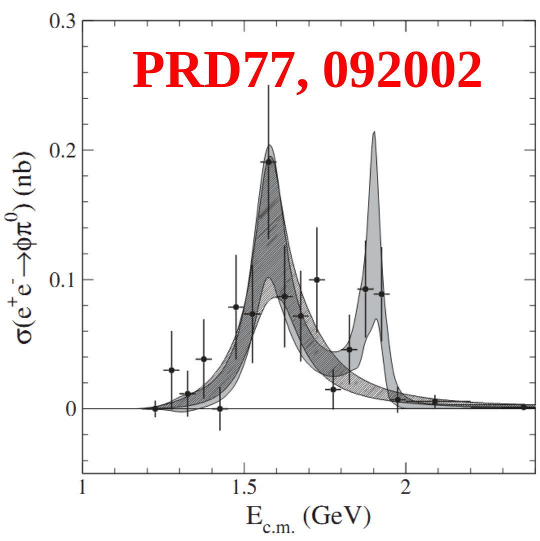
$1^{--}\ 3^3S_1\ s\bar{s}$



- **Fraction Γ_i/Γ: weakly model & input parameters dependent**
- **Dominant decay modes: $KK^*(1410)$ & K^*K^***
- **$\Gamma_{K^*K^*} > \Gamma_{KK1(1270)}$: dependence on K^* ? please revisit it.**

We do we want ?

- Mixing between $s\bar{s}g$ hybrid, 2^3D_1 or 3^3S_1 $s\bar{s}$
- Tetraquark: predicted numbers on partial width.
- Molecular state $\Lambda\bar{\Lambda}$: modes with $K^*(892)$, $K_2^*(1430)$, $K_1(1270)$ and $K_1(1400)$.
- How to extract reliable Brach Ratio (Br) from energy dependence of cross section ?



$$\sigma_f(s) = 12\pi \mathcal{P}_f(s) \left| A_f^{\text{n.r.}}(s) + \sum_R \boxed{\sqrt{\mathcal{B}_f^R \Gamma_{ee}^R}} \frac{\sqrt{\Gamma_R / \mathcal{P}_f(M_R^2)}\, e^{i\Psi_R}}{M_R^2 - s - i\sqrt{s}\,\Gamma_R(s)} \right|^2$$

✓ extracted $\mathrm{Br}\Gamma_{ee}$

We do we want ?

Reliable BrΓ_{ee} due to constructive & destructive resolution ?

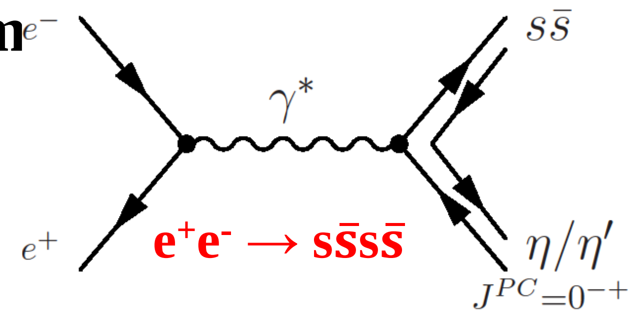
parameters	Solution Ⅰ	Solution Ⅱ	Solution Ⅲ	Solution Ⅳ
$M(\phi(1680))$		1673 ± 6		
$M(\mathrm{Y}(2175))$		2171 ± 16		
$\Gamma_{\mathrm{tot}}(\mathrm{Y}(2175))$		134 ± 22		
$\boxed{\mathcal{B}\times\Gamma_{e^+e^-}(\mathrm{Y}(2175))}$	$\boxed{8.0\pm3.3}$	$\boxed{49.6\pm2.0}$	$\boxed{6.7\pm1.3}$	$\boxed{59.6\pm1.9}$
ϕ_1	172 ± 38	-116 ± 3	153 ± 7	-97 ± 2
$M(\mathrm{X}(2400))$		2436 ± 34		
$\Gamma_{\mathrm{tot}}(X(2400))$		99 ± 105		
$\mathcal{B}\times\Gamma_{e^+e^-}(X(2400))$	15.8 ± 12.8	0.8 ± 0.4	0.6 ± 0.3	21.5 ± 1.3
ϕ_2	-92 ± 22	91 ± 21	151 ± 17	-150 ± 3

ϕ $f_0(980)$

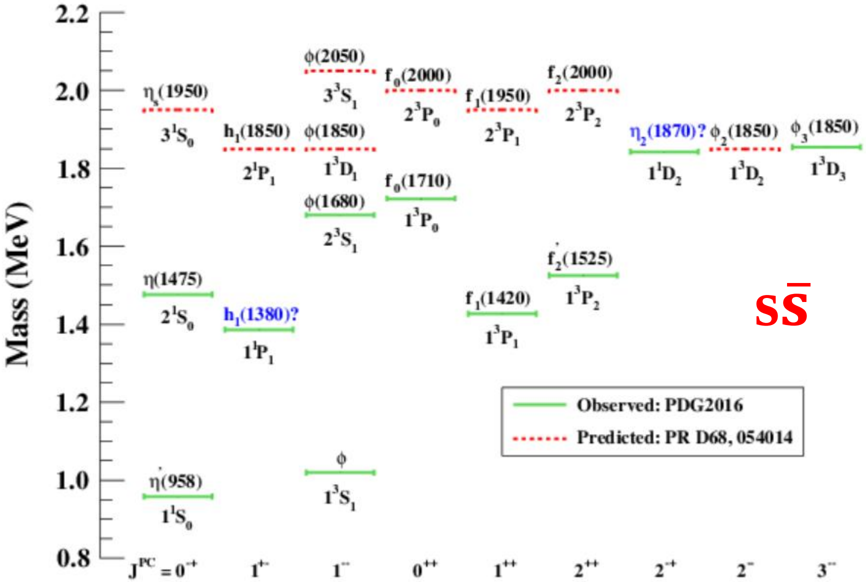
CP C34, 1045

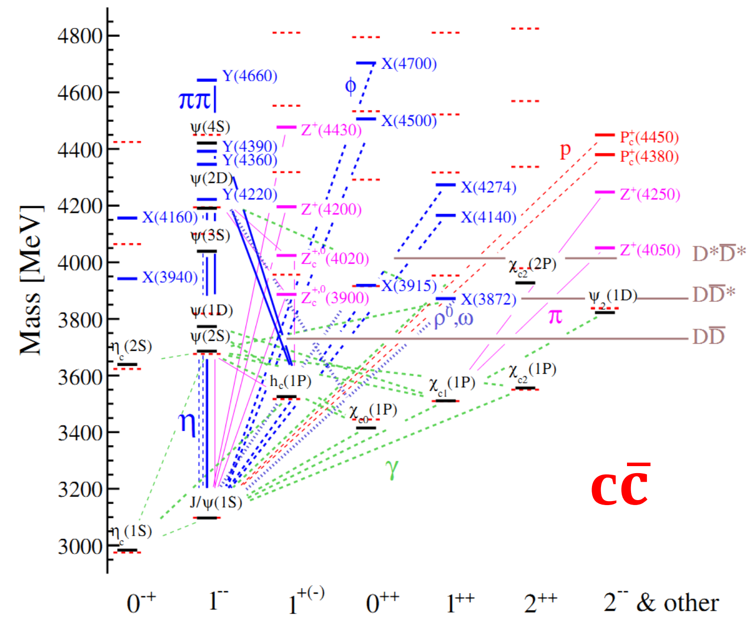
Babar: 2.3±0.3±0.3

- **revisit strange quarkonium spectrum**
  - ✓ **PRD 68, (2003) 054014**
  - ✓ **By Lattice QCD ?**



Strange quarkonium



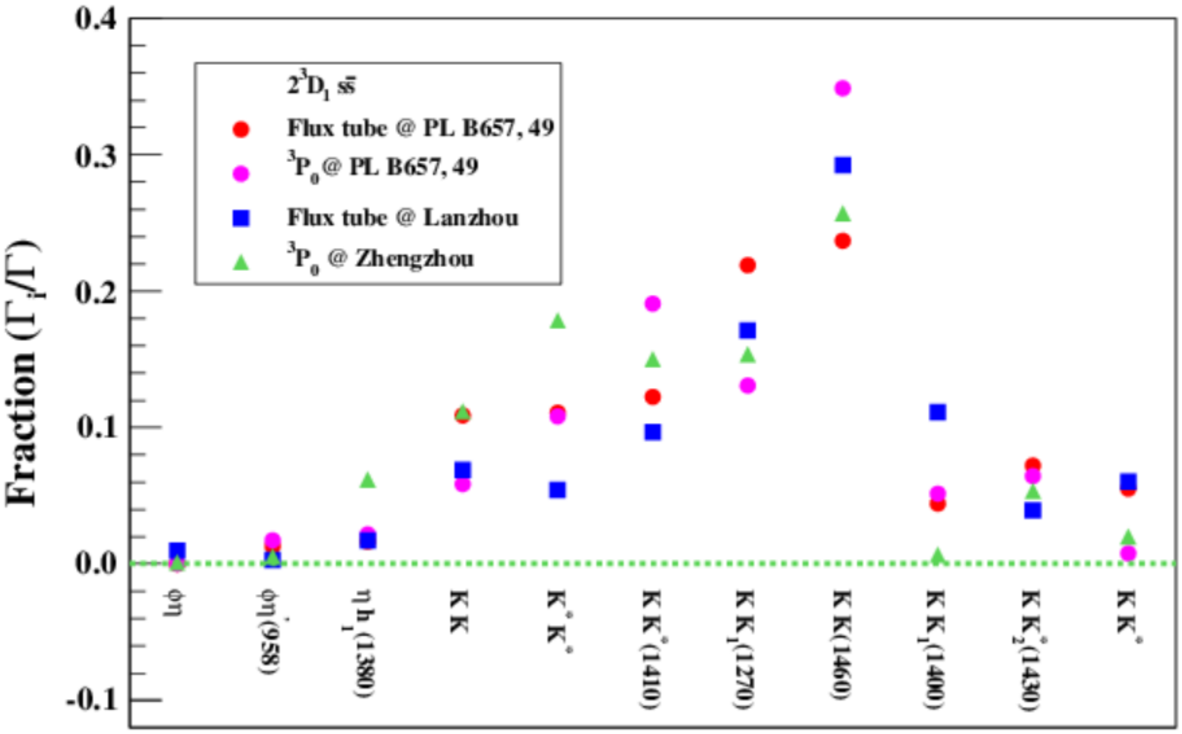


- Compared with $c\bar{c}$ and $b\bar{b}$, $s\bar{s}$ is a terra incognita
- Strange quarkonium is the bridge between lighter quark sector and charmonium & bottonium
- Difficulty: small mass, $s\bar{s}$ and $n\bar{n}$

Summary and outlook

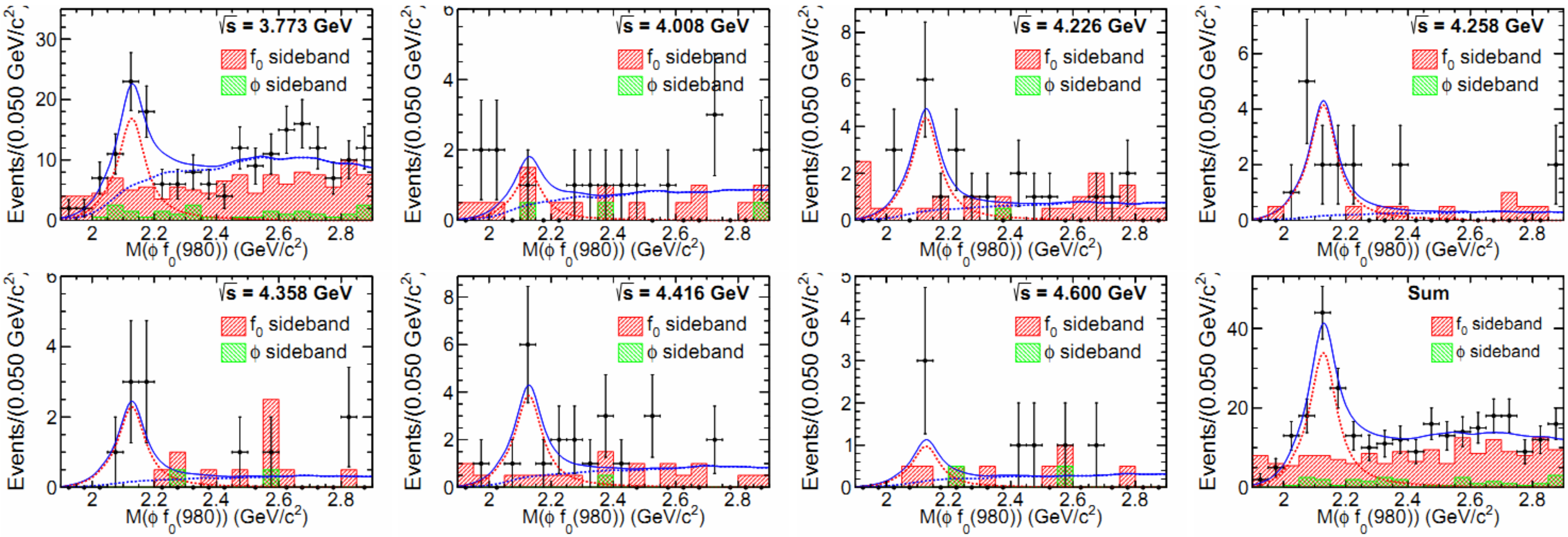
- **Aspects of $\phi(2170)$ are still not fully understood**
- **Using BESIII R scan data, we are extensively studying $\phi(2170)$**
  - ✓ **$\phi(2170)$ as pure 3^3S_1 $s\bar{s}$: ???**
  - ✓ **$\phi(2170)$ as pure 2^3D_1 $s\bar{s}$: ???**
  - ✓ **$\phi(2170)$ as molecular state $\Lambda\bar{\Lambda}$: ???**
  - ✓ **$\phi(2170)$ as three body system ϕKK: ???**
  - ✓ **$\phi(2170)$ as 1^{--} $s\bar{s}g$ hybrid: ???**
  - ✓ **$\phi(2170)$ as tetraquark: ???**
- **Compared with $c\bar{c}$ and $b\bar{b}$, $s\bar{s}$ is a terra incognita**

$1^{-}\ 2^3D_1\ s\bar{s}$



- **Fraction Γ_i/Γ: weakly model & input parameters dependent**
- **Dominant decay modes: KK(1460) & $KK_1(1270)$**

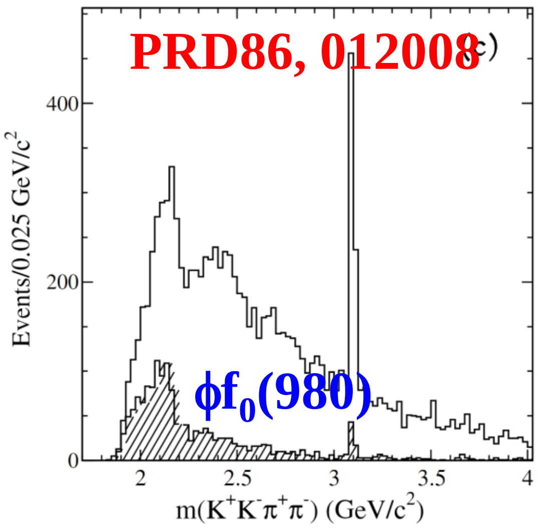
$\phi(2170)$ @ $e^+e^- \to s\bar{s}s\bar{s}$

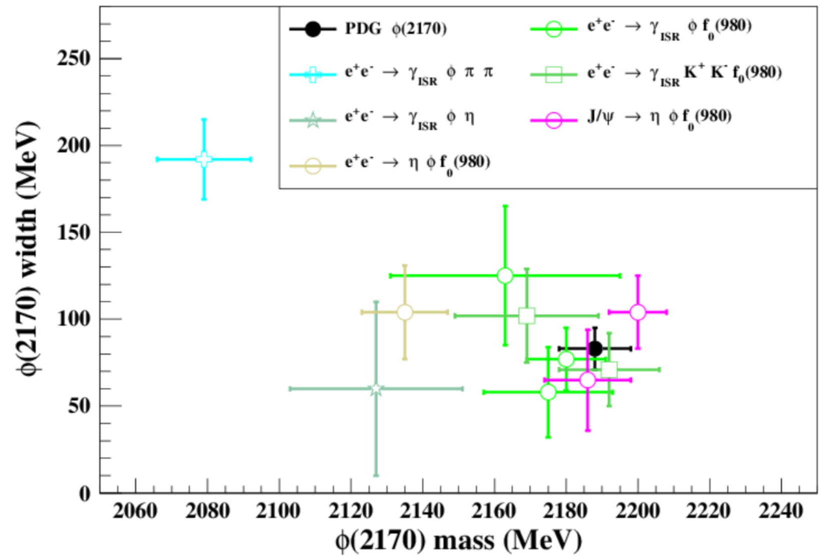


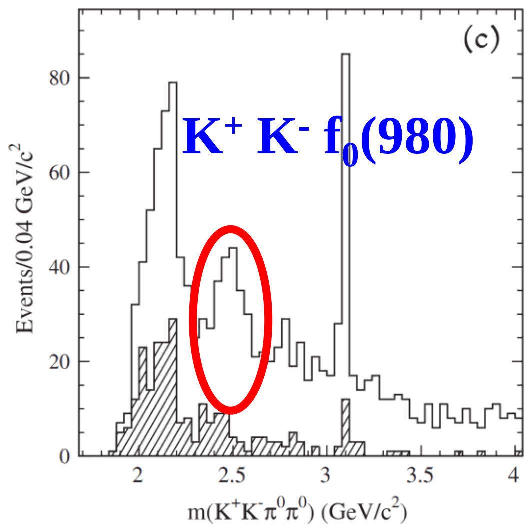
arXiv:1709.04323

- $\phi\ f_0(980)$ @ $e^+ e^- \to \eta\ \phi\ f_0(980)$ with $\sqrt{s}$ = [3.773, 4.600]GeV
- Limited samples for $\phi(2170)$

$e^+ e^- \rightarrow K^+ K^- f_0(980)$

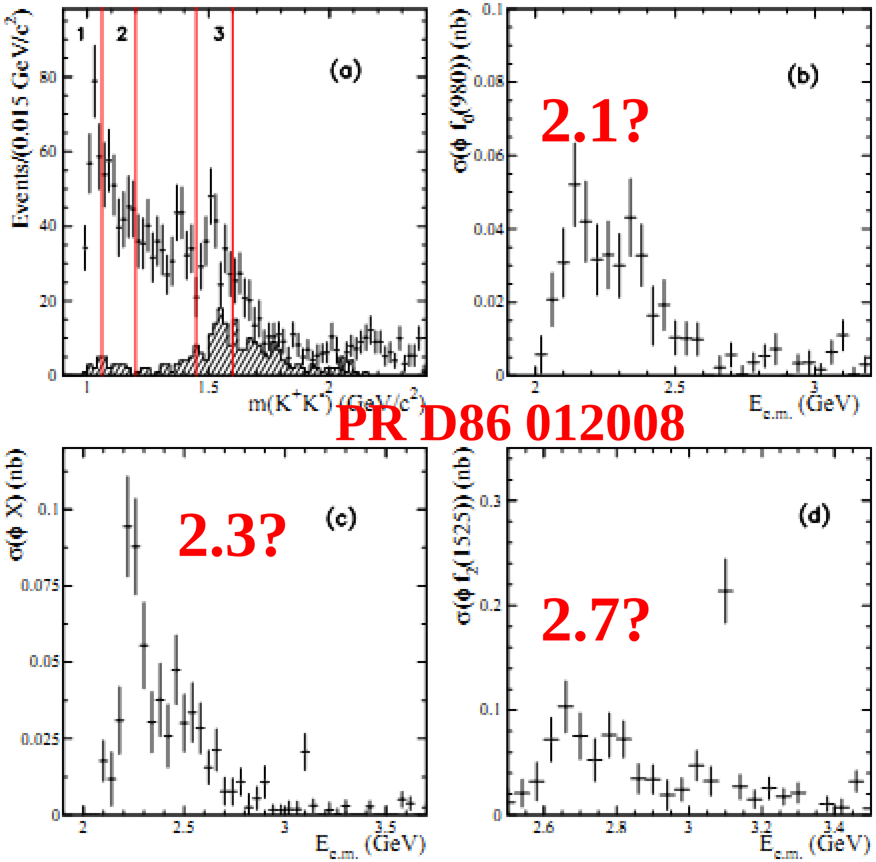






- $\phi(2170)$ @ $K^+ K^- f_0(980)$
- Structure around 2.5GeV ?

$e^+ e^- \rightarrow \phi K^+ K^-$



- m_{KK} @ ϕK+K-
  - ✓ (b) $m_{KK} < 1.06$GeV
  - ✓ (c) $1.06 < m_{KK} < 1.45$GeV
  - ✓ (d) $1.45 < m_{KK} < 1.6$GeV
- $\phi f_0(1370)$ and $\phi f_2'(1525)$
  - ✓ $\phi f_0(600)$: $\phi(1680)$
  - ✓ $\phi f_0(980)$: $\phi(2170)$