# Measurement of cross section lineshape of $e^+e^- \to \phi\eta$ in energy region 2.0 - 3.08 GeV

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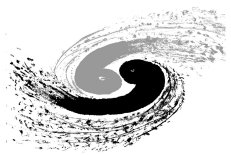
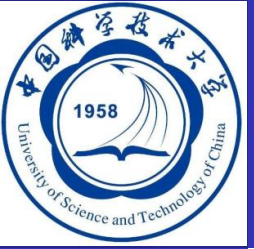
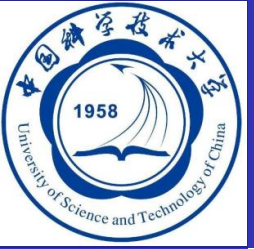


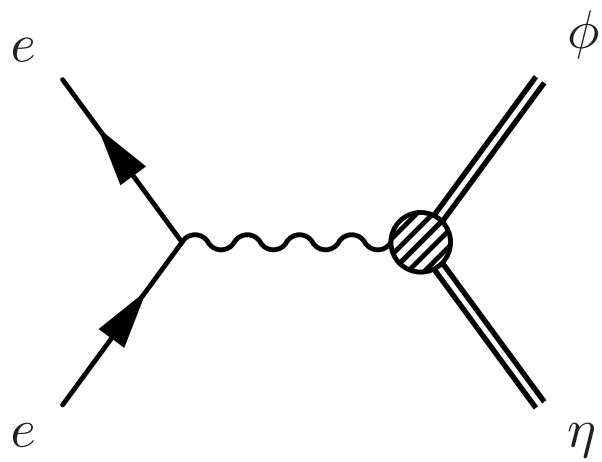
# Outline



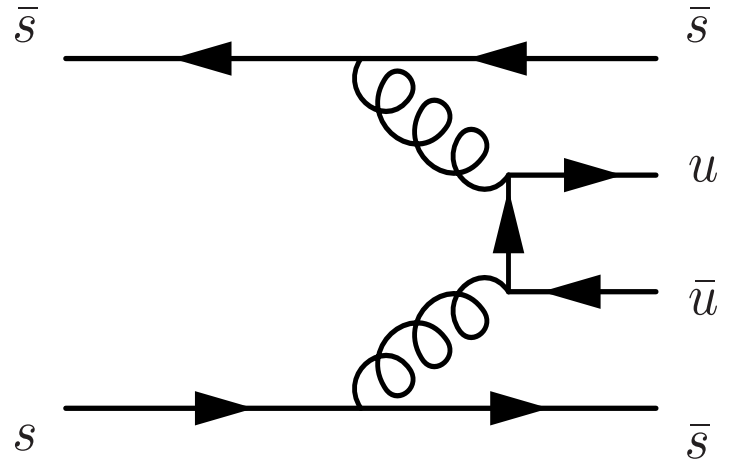
# Outline

# Introduction: Motivation I

- $\phi(2170)$ resonance is produced via ISR in $e^+e^-$ collision, its quantum numbers are assigned as $J^{PC} = 1^{--}$.




(a) $e^+e^- \to \phi\eta$




(b) $\phi \to K^+K^-$

- This observation stimulated theoretical speculation that $\phi(2170)$ may be an s-quark counterpart of the Y(4260). Phys. Rev. D **95**, 142001 (2005), Phys. Rev. D **99**, 182004 (2007)
- $\phi(2170)$ are expected to be generated in new R-SCAN data. BESIII 2015 Coll. summer Meeting

# Introduction: Motivation II

- The essence of $\phi(2170)$ discussed by theoretical: $3^3S_1$ $s\bar{s}$ quarkonium, $2^3D_1$ $s\bar{s}$ quarkonium and $\Lambda\bar{\Lambda}$ structure are not able to describe all experimental observations. Phys. Lett. B **657**, 49 (2007)

| Y(2125) as $2^3D_1$ $s\bar{s}$ quarkonium | | | Y(2125) as $s\bar{s}g$ hybrid | Y(2125) as $3^3S_1$ $s\bar{s}$ quarkonium |
|---|---|---|---|---|
| Decay moded | $\Gamma_{LJ}$ in $^3P_0$ model | $\Gamma_{LJ}$ in flux tube model | In flux tube model | In $^3P_0$ model |
| ... | ... | ... | ... | ... |
| $\phi\eta$ | $\Gamma_{LJ} = 0$ | $\Gamma_{LJ}$ =0 | 1.2 | 21 |
| ... | ... | ... | ... | ... |

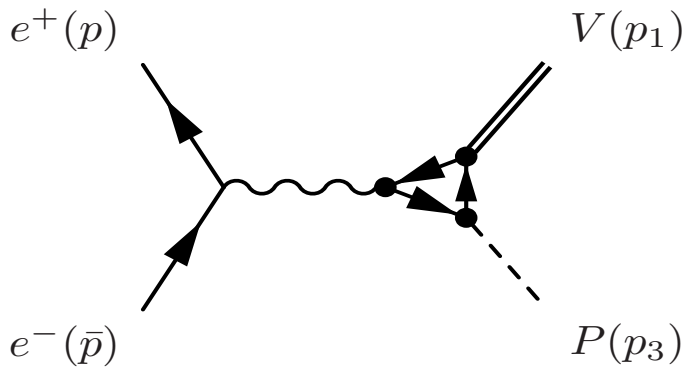
- The $e^+e^- \to \phi\eta$ is a good channel for study of excited $\phi(2170)$ states. Phys. Rev. D **79**, 014036 (2009)

| Decay | Products | Squared amplitude |
|---|---|---|
| ... | ... | ... |
| $\phi^* \to VP$ | $\phi\eta$ | $2(-\sqrt{2}sin\phi_V^* sin\phi_V sin\phi_P + cos\phi_V^* cos\phi_V cos\phi_P)^2$ |
| ... | ... | ... |

# Introduction: Motivation III

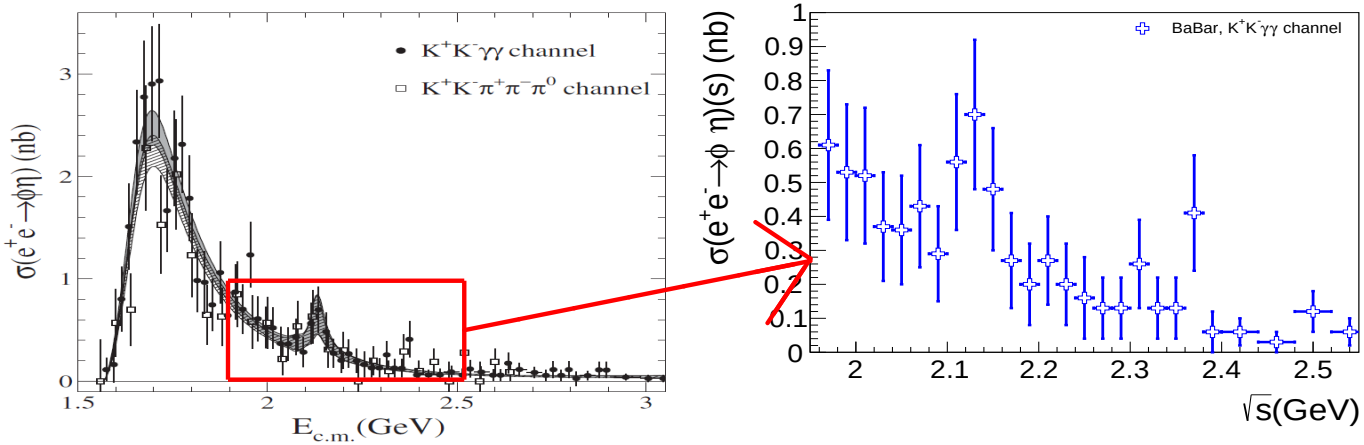


- Based on chiral perturbation framework, the Nambu-Jona-Lasinion (NJL) model is also used to calculate $e^+e^- \to$ vector + pesodoscalar. Int. J. Mod. Phys. A **24**, 2629 (2009)

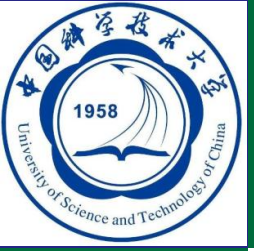



Using chiral Nambu-Jona-Lasinio model.

- Improve the uncertainty of cross section and shed light on the nature of $\phi(2170)$ state. Phys. Rev. D **77**, 092002 (2008)




The statistical error is quite large and it is about 50% in statistical error.



# Data sets and event selection $e^+e^- \to p\bar{p}$

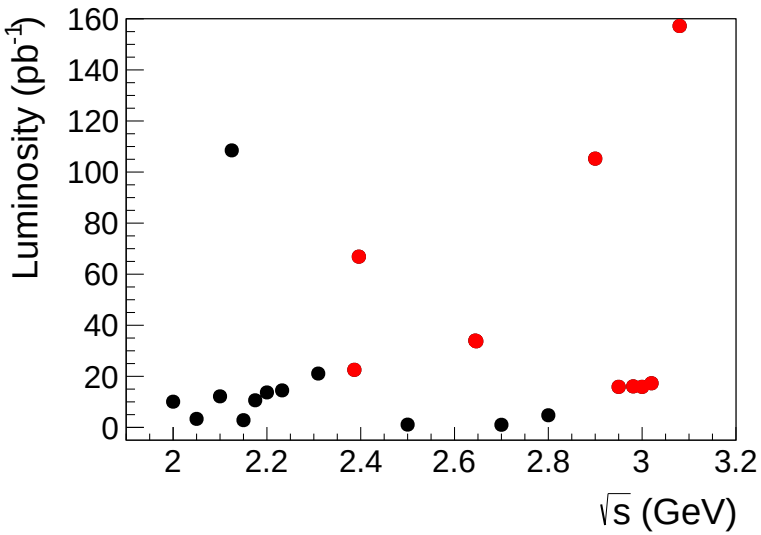
# Data sets

- Boss version: BOSS6.6.5.p01 and BOSS6.6.4.p01.
- Data sets
  - 2015 R-scan data (Zhen Gao's work BESIII 2015 Coll. summer Meeting)
  - 2012 R-scan data (Zhen Gao's work Chin. Phys. C. **Vol. 40**, No. 6 (2017) 063001.)
  - 2015 Y(2175) data (Jingqing Zhang's work arXiv:1705.09722)
- The integrated luminosity of the analysed data sets is quoted here.

| $\sqrt{s}$(GeV) | Run No. | Lumi($pb^{-1}$) | $\sqrt{s}$(GeV) | Run No. | Lumi($pb^{-1}$) |
|---|---|---|---|---|---|
| 2 | 41729-41909 | 10.074 | 2.6444 | 40128-40296 | 34.003 |
| 2.05 | 41911-41958 | 3.343 | 2.6464 | 40300-40435 | 33.722 |
| 2.1 | 41588-41727 | 12.167 | 2.7 | 40436-40439 | 1.034 |
| 2.12655 | 42004-43253 | 108.490 | 2.8 | 28553-28575, | 3.753 |
| 2.15 | 41533-41570 | 2.841 | | 40440-40443 | 1.008 |
| 2.175 | 41416-41532 | 10.625 | 2.9 | 39775-40069 | 105.253 |
| 2.2 | 40989-41121 | 13.699 | 2.95 | 39619-39650 | 15.942 |
| 2.2324 | 28624-28648, | 2.645 | 2.981 | 39651-39679 | 16.071 |
| | 41122-41239 | 11.856 | 3 | 39680-39710 | 15.881 |
| 2.3094 | 41240-41411 | 21.089 | 3.02 | 39711-39738 | 17.290 |
| 2.3864 | 40806-40951 | 22.549 | 3.08 | 27147-27233, 28241-28266, | 31.019 |
| 2.396 | 40459-40769 | 66.869 | | 39355-39618 | 126.185 |
| 2.5 | 40771-40776 | 1.098 | - | - | - |

# Data sets

- The integrated luminosity of the analysed data sets is quoted in the figure below.




- Table summarizes the signal and background event topology obtained MC study.
- $q\bar{q}$: at least 3 times as much as expected.
- $K^+K^-$ MC is from Dong's work BAM-00250.

MC Topology of $\phi\eta$.

| Process | Decay chain | Final result | Number | Generator |
|---|---|---|---|---|
| $e^+e^- \to \phi\eta$ | $\phi \to K^+K^-$, $\eta \to \gamma\gamma$ | $e^+e^- \to K^+K^-\gamma\gamma$ | 10M | DIY ConExc |
| $e^+e^- \to q\bar{q}$ | - | $e^+e^- \to q\bar{q}$ | 3.5∼4.5M | ConExc |
| $e^+e^- \to K^+K^-\eta$ | $\eta \to \gamma\gamma$ | $e^+e^- \to K^+K^-\gamma\gamma$ | 10M | DIY ConExc |
| $e^+e^- \to K^{*+}K^-\pi^0$ | $K^{*+} \to K^+\pi^0$, $\pi^0 \to \gamma\gamma$, $\pi^0 \to \gamma\gamma$ | $e^+e^- \to K^+K^-\gamma\gamma\gamma\gamma$ | 10M | DIY ConExc |
| $e^+e^- \to K^+K^-\pi^0\pi^0$ | $\pi^0 \to \gamma\gamma$, $\pi^0 \to \gamma\gamma$ | $e^+e^- \to K^+K^-\gamma\gamma\gamma\gamma$ | 10M | DIY ConExc |
| $e^+e^- \to K^+K^{*-}\pi^0$ | $K^{*-} \to K^-\pi^0$, $\pi^0 \to \gamma\gamma$, $\pi^0 \to \gamma\gamma$ | $e^+e^- \to K^+K^-\gamma\gamma\gamma\gamma$ | 10M | DIY ConExc |
| $e^+e^- \to (\gamma)K^+K^-$ | - | $e^+e^- \to (\gamma)K^+K^-$ | 0.5M | ConExc |

# Event selection



- Good charged tracks

$$|V_r| < 1.0 \text{ cm},\ V_z < 10 \text{ cm and } |cos\theta| < 0.93$$

- Charged tracks in a good event

$$N_{charged} = 2 \text{ and } N_{K^+} = N_{K^-} = 1$$

- Particle identification: use dE/dx and TOF

$$Prob(K) > Prob(\pi, p)$$