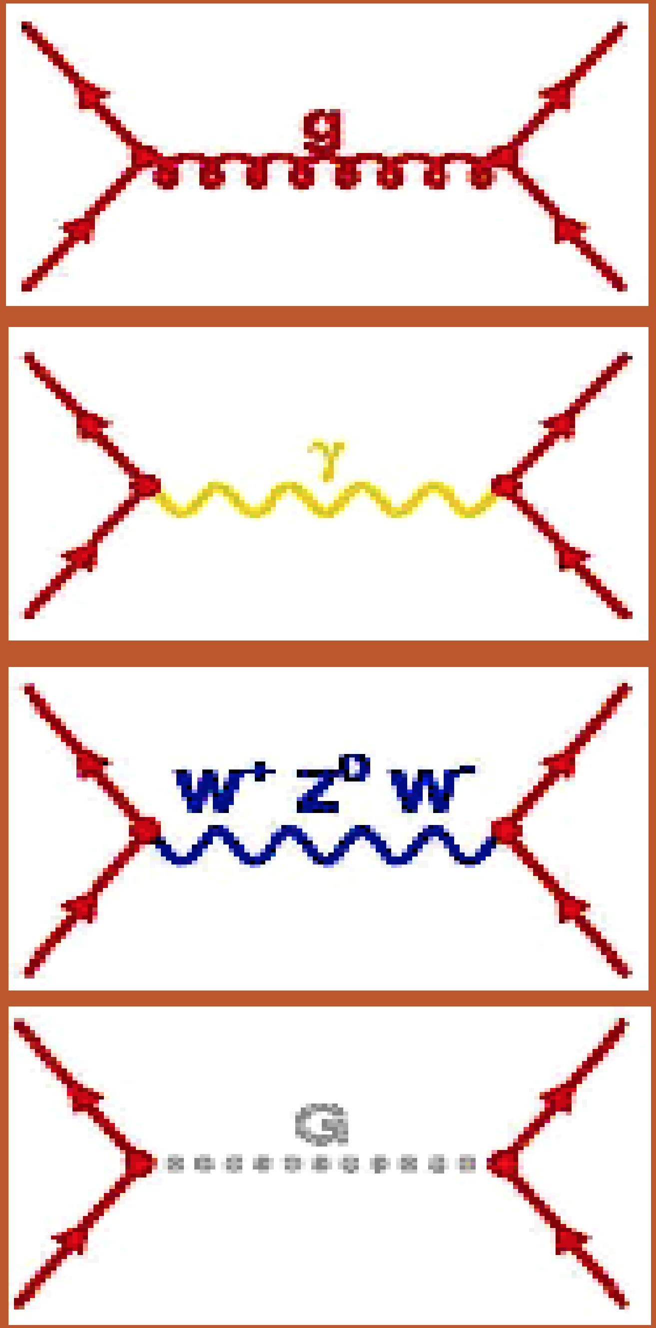

Experimental status of the phase between strong and EM amplitudes

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14/08/2025

四种相互作用

Properties of the Interactions

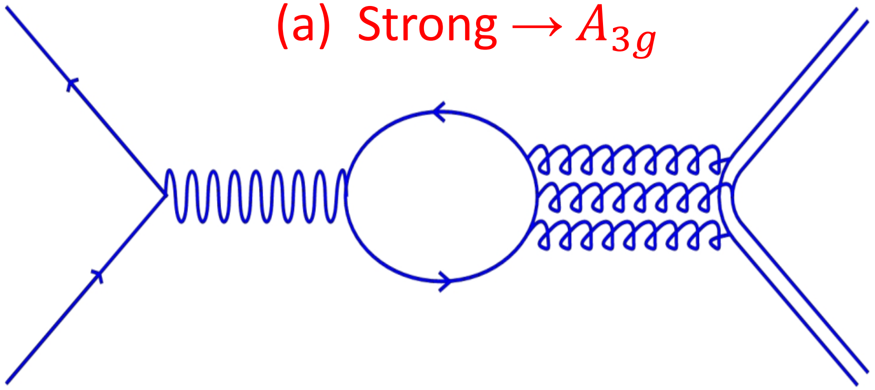
The strengths of the interactions (forces) are shown relative to the strength of the electromagnetic force for two u quarks separated by the specified distances.

Property	Gravitational Interaction	Weak Interaction (Electroweak)	Electromagnetic Interaction	Strong Interaction
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge
Particles experiencing:	All	Quarks, Leptons	Electrically Charged	Quarks, Gluons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons
Strength at 10^{-18} m	10^{-41}	0.8	1	25
Strength at 3×10^{-17} m	10^{-41}	10^{-4}	1	60

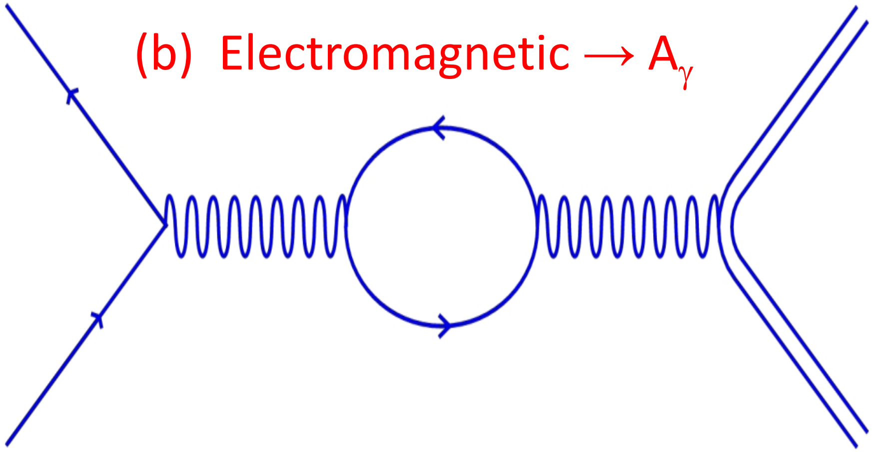
- 四种作用荷：引力只有吸引/弱力只有衰变/电磁力同斥异吸/强力如何吸引、排斥？
- 强　力：跑动耦合常数！(尺度越小越小：渐进自由)
- 弱　力：跑动耦合常数！(尺度越小越大)
- 电磁力：跑动耦合常数！(尺度越小越大)
- 引　力：耦合常数？跑动否？怎么跑？

How are they entangled in the certain decay?

Theory for the phase between strong and EM



(a) Strong $\longrightarrow A_{3g}$



(b) Electromagnetic $\longrightarrow A_{\gamma}$

(a) $e^{+}e^{-} \rightarrow R(q\underline{q}) \rightarrow$ hadrons via strong mechanism;

(b) $e^{+}e^{-} \rightarrow R(q\underline{q}) \rightarrow$ hadrons via EM mechanism;

pQCD regime: all are Real, phase between A_{3g} and A_{γ} should be $0°$ or $180°$

V.L. Chernyak and I.R. Zhinitsky, Nuclear Physics B 246, 52 (1998)

Theory for the phase between strong and EM

$$A_g^H = \sum_h \langle h|3g\rangle\langle 3g|\psi\rangle$$

$$A_\gamma^H = \sum_h \langle h|\gamma\rangle\langle \gamma|\psi\rangle$$

Clearly,

$A_g^{*H} A_\gamma^H = \langle\psi|3g\rangle\langle 3g|(\sum_h |h\rangle\langle h|)|\gamma\rangle\ \langle\gamma|\psi\rangle$ =0

is equivalent to

$$\langle 3g|\gamma\rangle = 0$$

Since $\sum_h |h\rangle\langle h| = 1$

Universality independent of final states or intermediate resonances.

For exclusive channels common to J/ψ and $\psi(2S)$, there cannot be significant differences in relative abundances if the three-gluon intermediate state makes any physical sense.

J.-M. Gerard, J. Weyers, Phys. Lett. B 462, 324 (1999) ;
P. Wang, C.Z. Yuan, X.H. Mo, Phys. Rev. D 69, 057502 (2004);
M. Suzuki, Phys. Rev. D 58, 111504 (1998); etc.

Phase in J/ψ

SU3 and SU3 Breaking in 1^-0^-[1,2,3,4], 0^-0^-[1,2,3], 1^-1^-[1], 1^+0^-[5], $B\bar{B}$[2,6,7]decays show the phase in J/ψ decays between A_g and A_γ is $|\Phi| \sim 90°$

- $PP(0^-0^-)(\pi^+\pi^-, K^+K^-, K_S K_L)$
- $VP(1^-0^-)(\rho\pi, \omega\pi^0, \phi\pi^0, \rho\eta, \omega\eta, \phi\eta, \rho\eta', \omega\eta', \phi\eta', \bar{K}^*K)$
- $VP(1^+0^-)\left(K_1^\pm(1400)K^\mp, K_1^\pm(1270)K^\mp\right)$
- $VV\ (1^-1^-)(\rho^+\rho^-, K^{*+}K^{*-}, K^{*0}\bar{K}^{*0})$
- $B\bar{B}(p\bar{p}, n\bar{n}, \Lambda\bar{\Lambda}, \Sigma^0\bar{\Sigma}^0, \Sigma^+\bar{\Sigma}^-, \Xi^0\bar{\Xi}^0, \Xi^+\bar{\Xi}^-, \Sigma^0\bar{\Lambda} + \bar{\Sigma}^0\Lambda)$

[1] L. Köpke and N. Wermes, Phys. Rep. 174, 67 (1989)
[2] G. Lopez Castro, J. L. Lucio M. and J. Pestieau, hep-ph/9902300v1 (1999)
[3] Mahiko Suzuki, Physical Review D 57, 5717 (1998)
[4] P. Wang, C.Z. Yuan, X.H. Mo, Phys. Rev. D 69, 057502 (2004)
[5] Mahiko Suzuki, Physical Review D 63, 054021 (2001)
[6] R. Baldini et al, Physics Letters B 444, 111-118 (1998)
[7] K. Zhu et al., Int. J Mod. Phys. A30, 1550148 (2015).

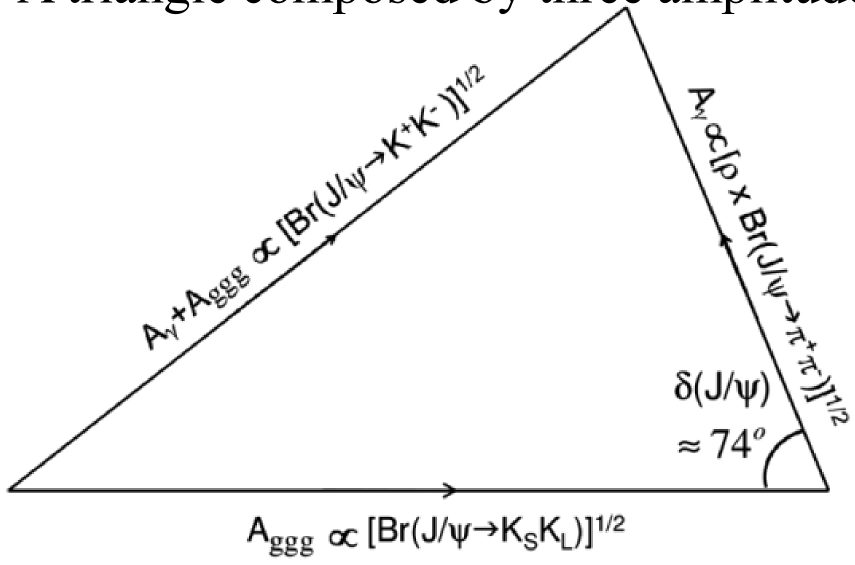
Decay	Amplitude	PDGx10^4	Fitx10^4	$\Delta\chi^2$
$\rho^0\ \pi^0$	$g\ e^{i\phi} + e$	169.0 ± 15.0	133.00	1.13
$K^{*+}\ K^-$	$g\ (1\text{-}s)\ e^{i\phi} + e$	51.2 ± 3.0	51.5	0.01
$K^{*0}\ K^0$	$g\ (1\text{-}s)e^{i\phi} - 2e$	43.9 ± 3.1	48.5	0.48
$\omega\ \eta$	$(g\ X+d)e^{i\phi} + eX$	17.4 ± 2.0	18.5	0.06
$\phi\ \eta$	$(g\ (1\text{-}2s)Y+d)e^{i\phi} - 2eY$	7.5 ± 0.8	3.9	4.02
$\rho\ \eta$	$3eX$	1.9 ± 0.2	2.2	0.30
$\omega\ \pi$	$3e$	4.5 ± 0.5	4.1	0.11
$\omega\ \eta'$	$(g\ X' + d')\ e^{i\phi} + eX'$	7.0 ± 7.0	11.9	0.10
$\phi\ \eta'$	$(g\ (1\text{-}2s)Y' + d')\ e^{i\phi} - 2eY'$	4.0 ± 0.7	6.1	1.87
$\rho\ \eta'$	$3eX'$	1.1 ± 0.2	1.1	0.04

Parameter		Fit
SU_3 strong Amplitude	g	7.22 ± 0.38
SU_3 breaking strange	s	0.18 ± 0.04
SU_3 breaking DOZI	r	-0.04 ± 0.02
e.m. Amplitude	e	0.75 ± 0.04
Phase	ϕ	**81.51 ± 6.75**

-- from Rinaldo Baldini

Phase in $J/\psi \to P\bar{P}$

A triangle composed by three amplitudes



$$\delta(\psi)_{\mathrm{PP}} = \cos^{-1}\left(\frac{\mathcal{B}(K_SK_L) + \rho\mathcal{B}(\pi^+\pi^-) - \mathcal{B}(K^+K^-)}{|2\sqrt{\mathcal{B}(K_SK_L) \times \rho \times \mathcal{B}(\pi^+\pi^-)}|}\right)$$

	Mark III [10]	BES [16]	CLEO 2012
$\mathcal{B}(J/\psi \to \pi^+\pi^-) \times 10^4$	1.58 ± 0.25	...	**1.47 ± 0.18**
$\mathcal{B}(J/\psi \to K^+K^-) \times 10^4$	2.39 ± 0.33	...	**2.86 ± 0.21**
$\mathcal{B}(J/\psi \to K_SK_L) \times 10^4$	1.01 ± 0.18	1.82 ± 0.13	**2.62 ± 0.21**
$\delta(J/\psi)$	$(88 \pm 11)^\circ$	...	**$(73.6 \pm 5.6)^\circ$**

Z. Metreveli, PRD 85, 092007 (2012)

With only two $K\bar{K}$ amplitudes

BABAR, PRD 92, 072008 (2015)

$$\mathcal{B}(\psi \to K^+K^-) = |A_\gamma^{K^+K^-} + A_s e^{i\varphi}|^2,$$
$$\mathcal{B}(\psi \to K_SK_L) = |\kappa A_\gamma^{K^+K^-} + A_s e^{i\varphi}|^2,$$

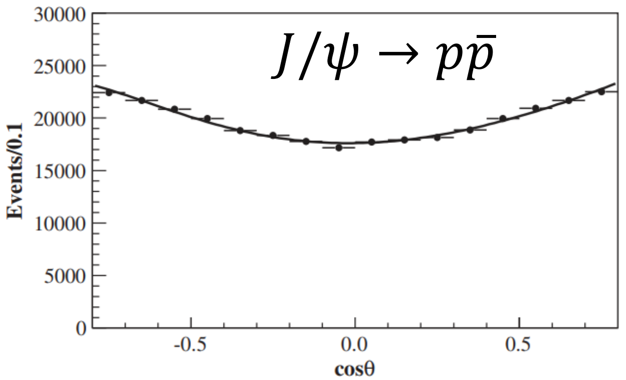
$J/\psi \to K_SK_L$	φ	$\varphi(\kappa = 0)$
BES [35]	$(97 \pm 5)^\circ$ $-(97 \pm 5)^\circ$	$(98 \pm 4)^\circ$ $-(96 \pm 4)^\circ$
Seth *et al.* [18]	$(111 \pm 5)^\circ$ $-(109 \pm 5)^\circ$	$(108 \pm 4)^\circ$ $-(107 \pm 4)^\circ$

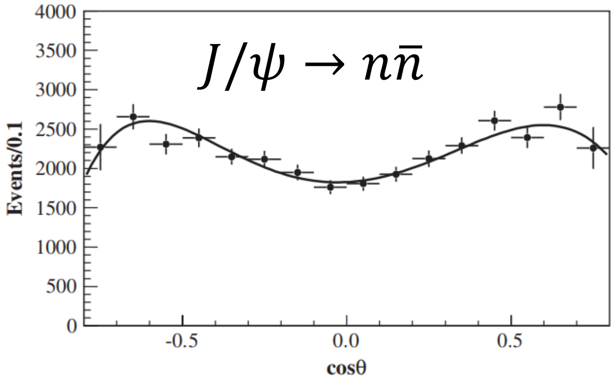
$\mathcal{B}(\psi \to K^+K^-) \times 10^4$		J/ψ
Measured value		$3.36 \pm 0.20 \pm 0.12$
Corrected with $\sin\varphi > 0$		$3.22 \pm 0.20 \pm 0.12$
Corrected with $\sin\varphi < 0$		$3.50 \pm 0.20 \pm 0.12$
$e^+e^- \to K^+K^-$ average		2.43 ± 0.26 [3,31,32]
$\psi(2S) \to J/\psi\pi^+\pi^-$, $J/\psi \to K^+K^-$	CLEO 2012	2.86 ± 0.21
$\boldsymbol{\psi(2S) \to J/\psi\pi^+\pi^-, J/\psi \to K^+K^-}$		$\boxed{(3.072 \pm 0.023 \pm 0.050)}$

BESIII recent result
PRD 110, 032006 (2024)

Phase in $J/\psi \to N\bar{N}$

BESIII, PRD 86, 032014 (2012)





- $E_p(E_n)$ and S are EM and strong amplitudes of $J/\psi \to p\bar{p}$ $(n\bar{n})$, ϕ is the phase angle between $E_p(E_n)$ and S.
- Assumption:
  - $E_n = -E_p$ and $S_p = S_n = S$

$Br(J/\psi \to p\bar{p}) = (2.112 \pm 0.004 \pm 0.031) \times 10^{-3}$

$\alpha = 0.595 \pm 0.012 \pm 0.015$

$Br(J/\psi \to n\bar{n}) = (2.07 \pm 0.01 \pm 0.17) \times 10^{-3}$

$\alpha = 0.50 \pm 0.04 \pm 0.21$

$$\boxed{\begin{aligned}\phi &= \cos^{-1}[(\mathcal{B}(J/\psi \to p\bar{p}) - S^2 - E_p^2)/(2SE_p)] \\ &= (88.7 \pm 8.1)^\circ.\end{aligned}}$$

- The strong interaction is dominant.
- $\boldsymbol{\Phi = (-85.9 \pm 1.7)^\circ}$ **or** $\boldsymbol{(+90.8 \pm 1.6)^\circ}$ combined with other baryon decays from BES, MarkII, DMII, BESII, BESIII experiments. *K. Zhu, X. H. Mo, C. Z. Yuan, Inter. J. Mod. Phys. A, 30, 1550148 (2015)*

Phase in $\psi(2S)$

From the analysis of BESIII data made by R. Baldini[1]:

- $\psi(2S) \to VP\ (1^-0^-)$: $\Phi = (159 \pm 12)^\circ$
- $\psi(2S) \to K^*K$ only: $\Phi = (159 \pm 24)^\circ$
- $\psi(2S) \to PP\ (0^-0^-)$: $\Phi = (95 \pm 11)^\circ$

Analysis by Mahiko Suzuki[2] with Babar data:

- $\psi(2S) \to 1^-0^-$: tends to have large phase,
- $\psi(2S) \to 1^+0^-$: $\Phi \sim 0^\circ$
- Difference could be caused by lower statistics of Babar data than that of BESIII.

PP(0^-0^-) mode from BES result[3]:

- $\psi(2S) \to K_S K_L, K^+K^-, \pi^+\pi^-$:

$\Phi = (-82 \pm 29)^\circ$ or $(121 \pm 27)^\circ$

Analysis[4] of $\psi(2S)$ decaying to baryon pairs from CLEO and BESII:

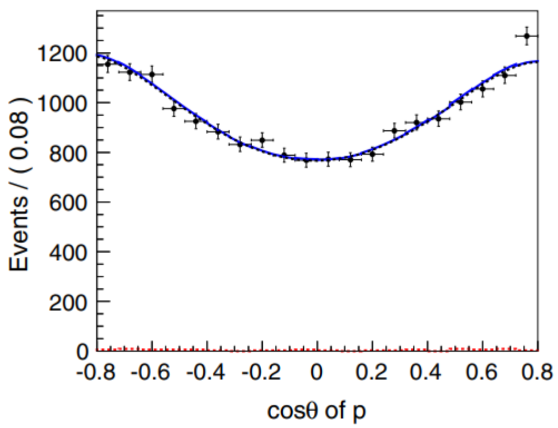
- **baryon pairs:**

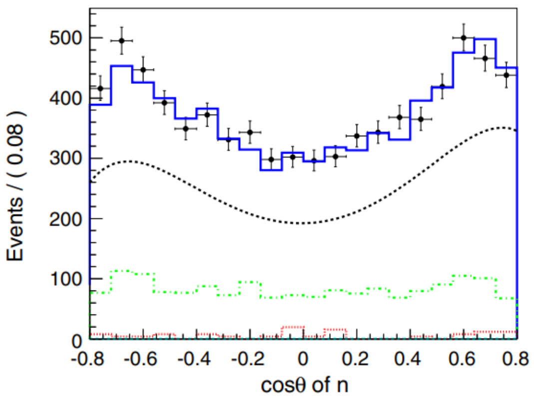
$\Phi = (-98 \pm 25)^\circ$ or $(+134 \pm 25)^\circ$

The Φ change between J/ψ and $\psi(2S)$ is a puzzle, very likely related to $\rho\pi$ puzzle

[1] Rinaldo Baldini Ferroli, Orsay (France), 2014
[2] Mahiko Suzuki, Phys. Rev. D 63, 054021 (2000)
[3] BES Collaboration, Phys. Rev. Lett. 92, 052001 (2004)
[4] K. Zhu, X. H. Mo, C. Z. Yuan, Inter. J. Mod. Phys. A, 30, 1550148 (2015)

Phase in $\boldsymbol{\psi(2S) \to N\bar{N}}$ *BESIII, PRD* 98, 032006 (2018)





- $Br(\psi(3686) \to n\bar{n}) = (3.06 \pm 0.06 \pm 0.14) \times 10^{-4}$
- $\alpha_{n\bar{n}} = 0.68 \pm 0.12 \pm 0.11$
- $Br(\psi(3686) \to p\bar{p}) = (3.05 \pm 0.20 \pm 0.12) \times 10^{-4}$
- $\alpha_{p\bar{p}} = 1.03 \pm 0.06 \pm 0.03$

- The α values are similar in $J/\psi \to N\bar{N}$, $\Phi{\sim}90°$.
- In $\psi(3686) \to N\bar{N}$, α values are different.
- A more complex mechanism in $\psi(3686) \to N\bar{N}$?
- It makes a similar and straight forward extraction of the phase angle impossible in the decay of $\psi(3686) \to N\bar{N}$, and further studies are deserved.

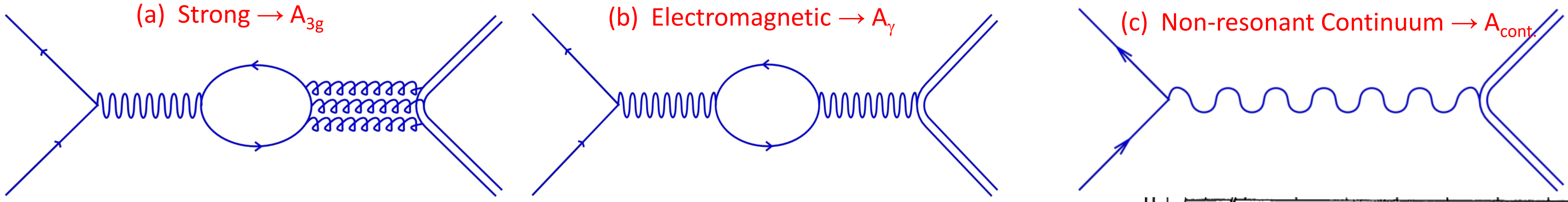
Phase in $\psi(3770)$

- From R. Baldini (Orsay (France), (2014)), $|\Phi| \sim 90°$

decay	continuum	Ψ"(3770)	sign	
$\rho\pi$	13.1 ± 2.8	7.4 ± 1.3	-	CLEOc, PRD 73(2006)012002
$\phi\eta$	2.1 ± 1.6	4.5 ± 0.7	+	CLEOc, PRD 73(2006)012002
$p\bar{p}$	0.74 ± 0.08	0.4 ± 0.02	-	BESIII Y.Liang, Nov (2012)

- From P. Wang (arxiv:hep/0410028v2 (2004)),
  - Φ holds $-90°$ in OZI suppressed decays of $\psi(3770)$.
  - From the $\rho\pi$ cross section measurement at $\psi(3770)$ and 3.67 GeV, $\rho\pi$ production is suppressed possibly by interference.

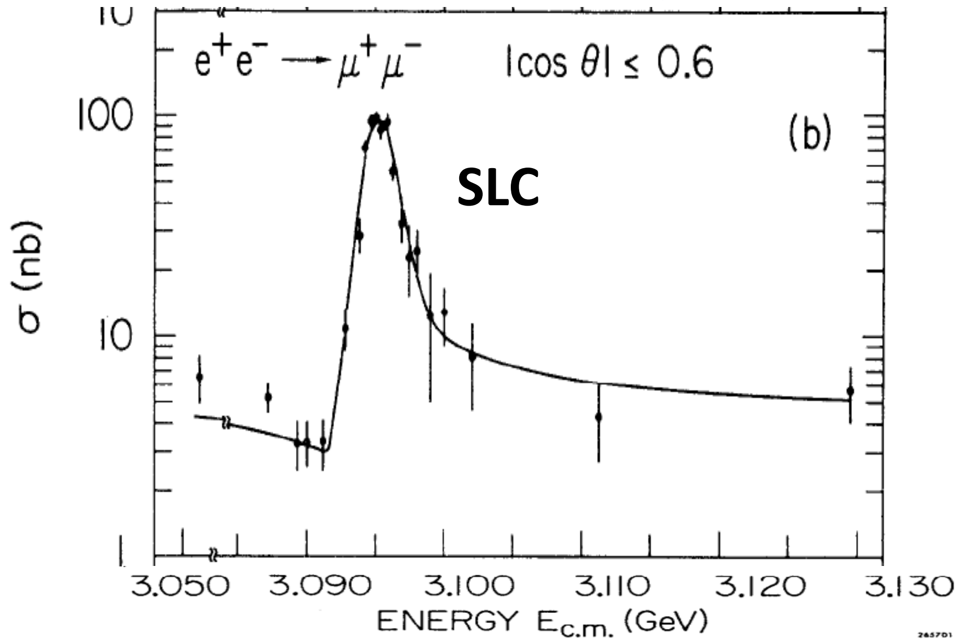
SU(3) independent--Scan method



$$\sigma_{born} = \left|A_{3g}e^{i\Phi_{g,cont.}} + A_\gamma e^{i\Phi_{\gamma,cont.}} + A_{cont.}\right|^2$$

If $\Phi_{\gamma,cont.} = 0°$,

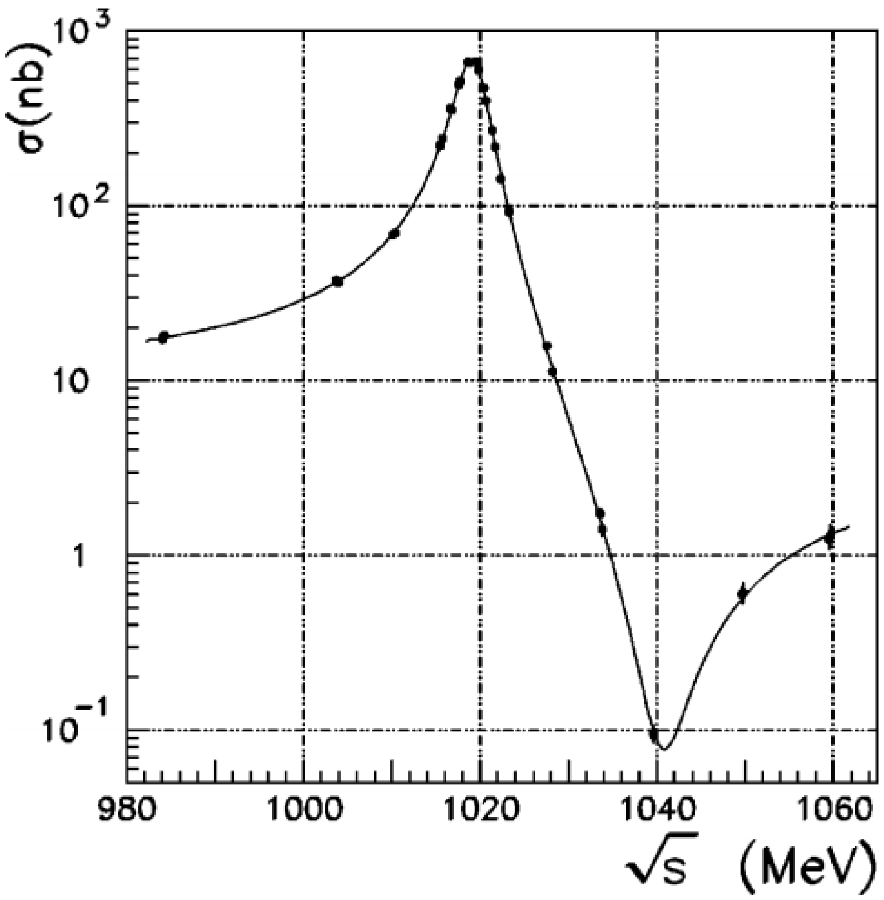
$$\sigma_{born} = \left|A_{3g}e^{i\Phi_{g,EM}} + A_\gamma + A_{cont.}\right|^2$$



◆The full interference between A_γ and A_{cont} has been observed at SLC (1975), BESII (1995) and KDER (2010). ($\Phi_{\gamma,cont.}$ =0°)

Model dependent experimental evidences from ϕ decays

The interference between ϕ and $\omega(\omega')$ was observed at SND.



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

  A_γ is dominate

- $e^+e^- \to \omega(\omega') \to \pi^+\pi^-\pi^0$:

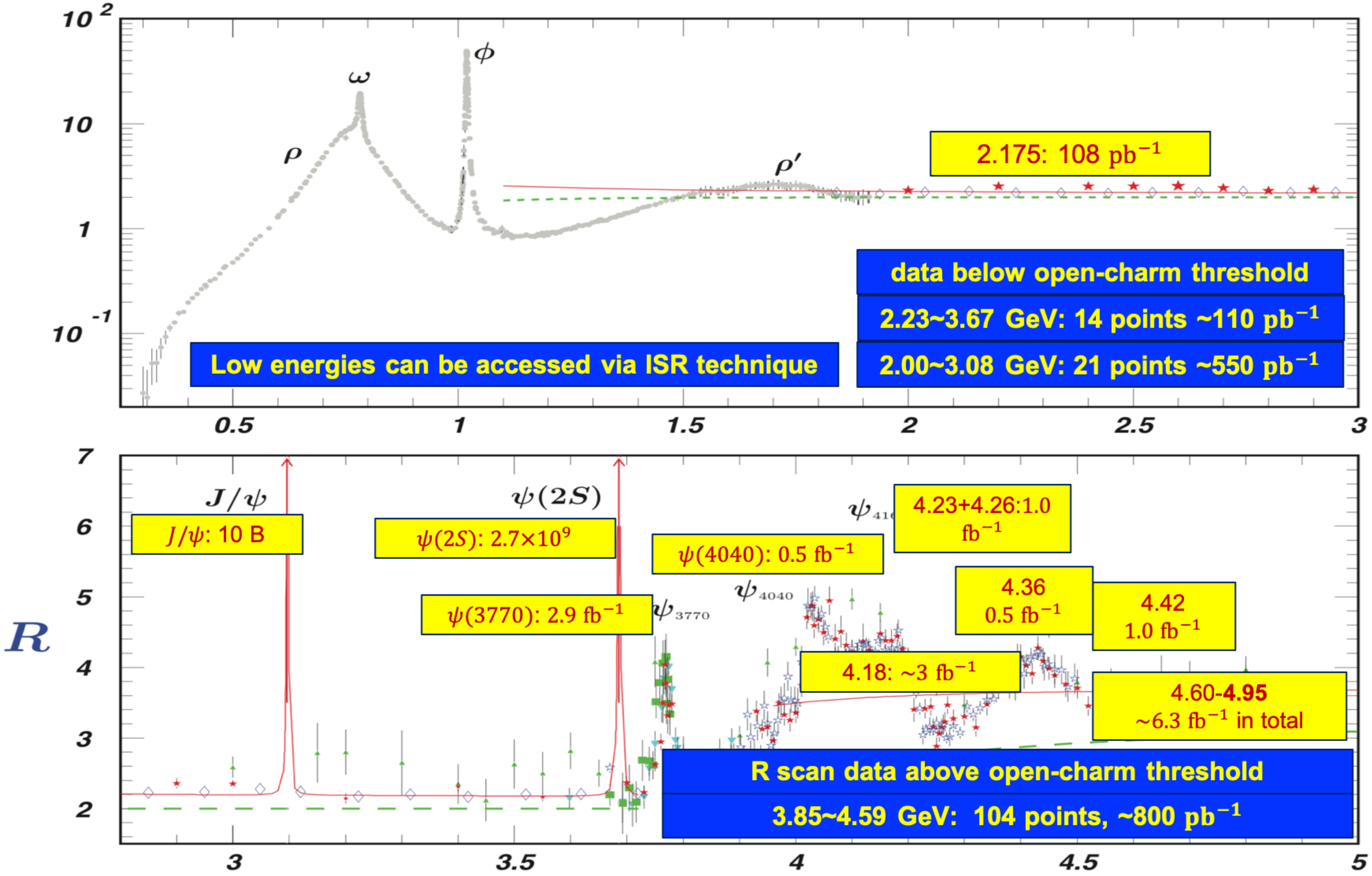
  A_{3g} is dominate

- $\Phi_{\phi-\omega(\omega')} \sim \Phi_{g,\gamma}$

- $\boldsymbol{\Phi_{\phi-\omega(\omega')} \sim 180°}$**[1]**

[1] SND coll., Phys. Rev. D 63, 072002 (2001)

BESIII datasets



Scan method and measurement

- The born cross section: $\sigma^0(W) = \left(\frac{\mathcal{A}}{W^2}\right)^2 \frac{4\pi\alpha^2}{W^2}\left|1 + \frac{3W^2\sqrt{\Gamma_{ee}\Gamma_{\mu\mu}}(1+\mathcal{C}e^{i\Phi_{g,\mathrm{EM}}})}{\alpha M(W^2 - M^2 + iM\Gamma)}\right|^2$
- The observed cross section:

$$\sigma^{\text{theory}}(W) = \int_{W-nS_E}^{W+nS_E} GS(W - W'')dW'' \int_0^{x_f} dx F(x,s)\sigma^0(s(1-x))$$

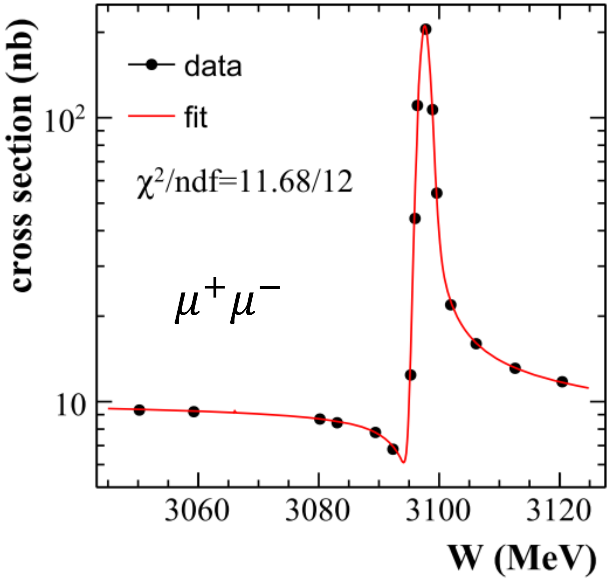
- Minimization method: $\chi^2 = \sum_{i=1}^{16} \frac{\left[\sigma_i^{\text{obs}} - f\sigma''(W_i)\right]^2}{(\Delta\sigma_i^{\text{obs}})^2 + \left[\Delta W_i \cdot \frac{d\sigma''(W)}{dW}\right]^2} + \left(\frac{1-f}{\Delta f}\right)^2$

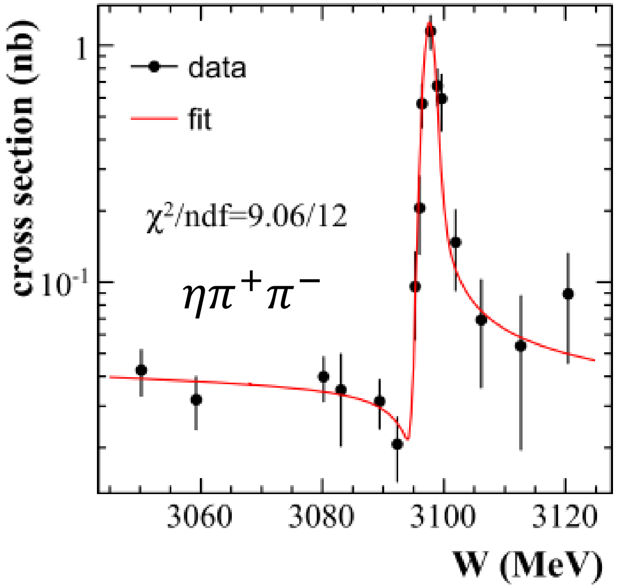
- Analytical formula was developed to reduce two integrations to one,

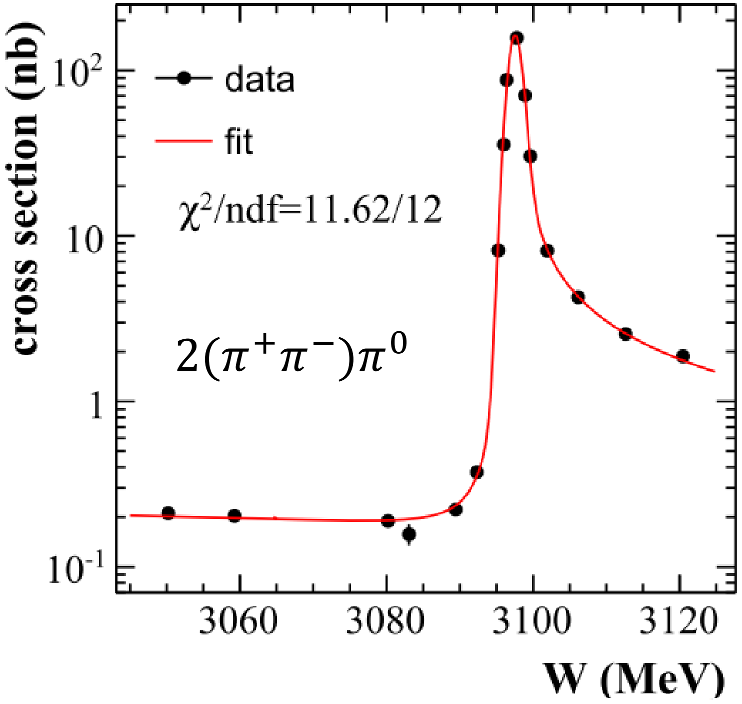
hep-hp 14:7,585-595(1990); CPC 41:083001(2017); CPC 48:113104 (2024); PRD 110:053010(2024);

Scan measurement of $e^+e^- \to J/\psi \to 2(\pi^+\pi^-)\pi^0$

BESIII, Phys. Lett. B 791, 375 (2019)







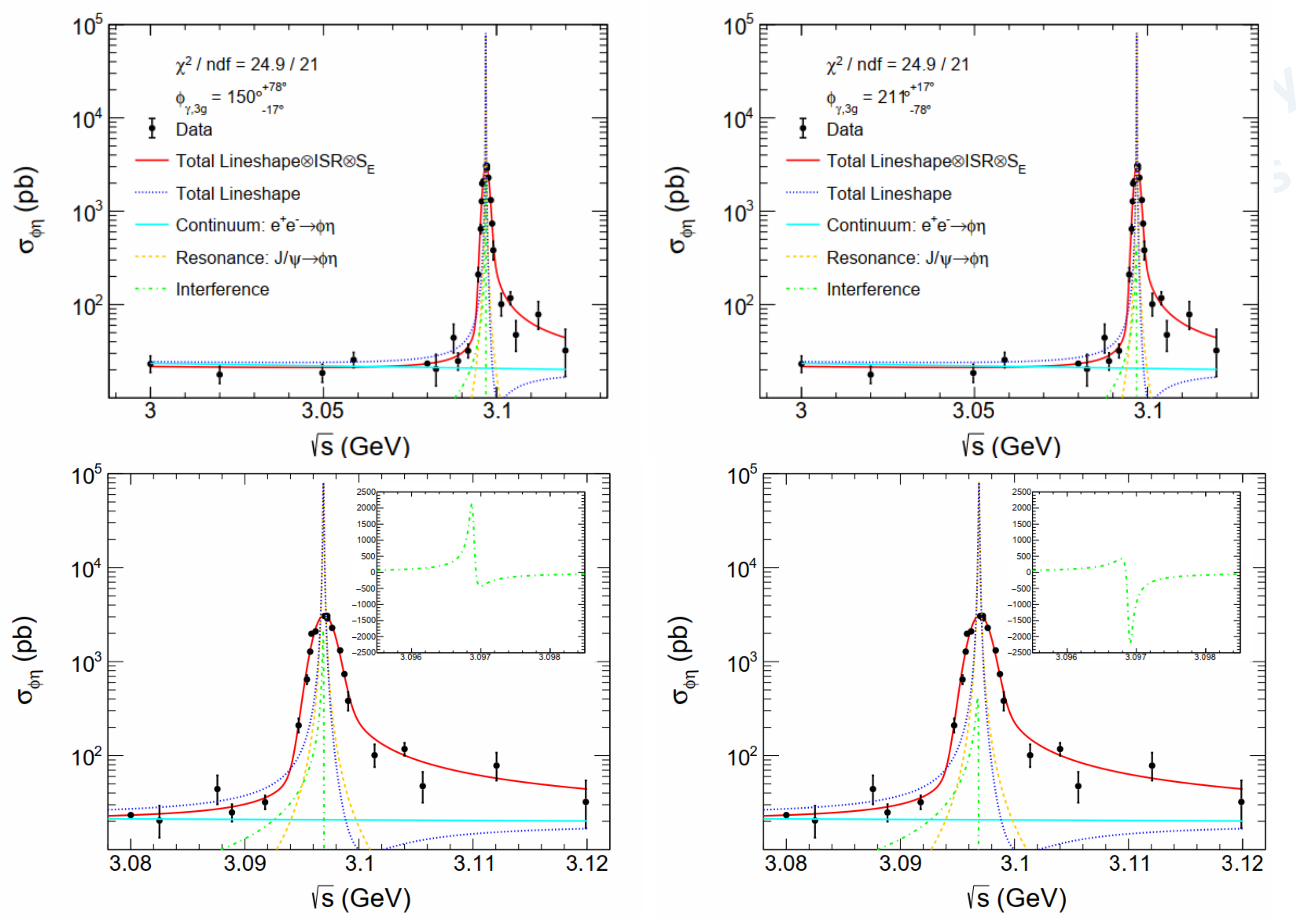
- $\Phi_{\gamma,cont.}^{\mu\mu} = (3.0 \pm 10.0)^\circ$
- $\Phi_{\gamma,cont.}^{\eta\pi^+\pi^-} = (-2 \pm 36)^\circ \; or \; (-22 \pm 36)^\circ$
- $S_E = (0.90 \pm 0.03)$ MeV

	$\Phi_{g,\mathrm{EM}}$	$\mathcal{B}_{5\pi}$ (%)
Solution I	$(84.9 \pm 3.6)^\circ$	4.73 ± 0.44
Solution II	$(-84.7 \pm 3.1)^\circ$	4.85 ± 0.45

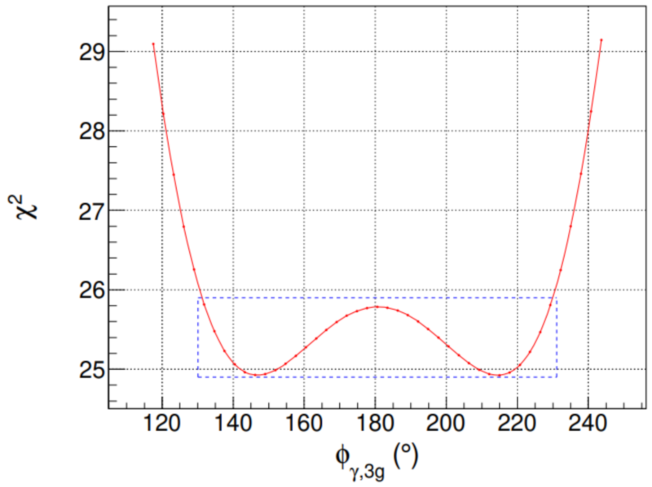
$\mathcal{B}_{PDG} = (4.1 \pm 0.5)\%$

The phase between A_γ and A_{3g} is found being consistent with 90°.

Scan measurement of $e^+e^- \to J/\psi \to \phi\eta$

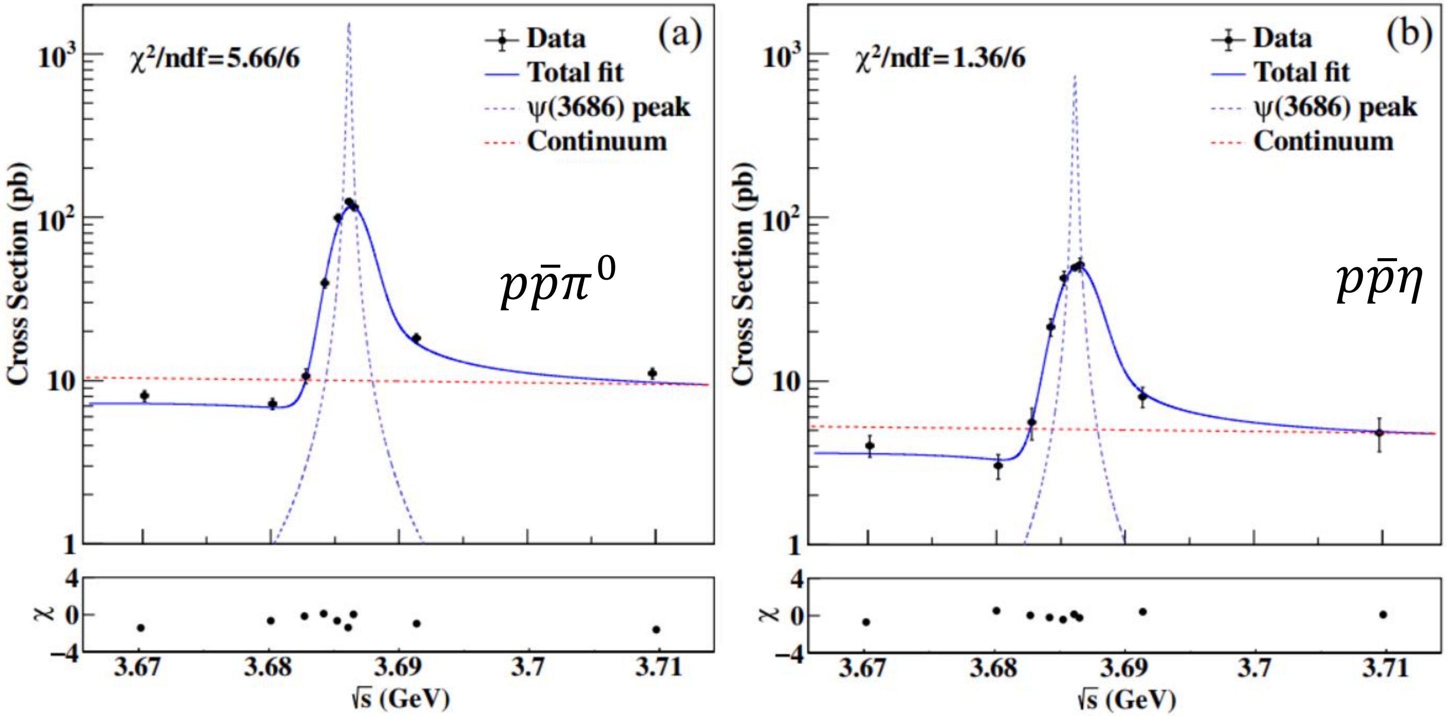


BESIII, submitted to JHEP, arXiv: 2505.05888



- Two solutions
- Indistinguishable within 1σ confidence
- $\Phi_{3g,\gamma} \in [133°, 228°]$

Scan measurement of $e^+e^- \to \psi(2S) \to p\bar{p}\pi^0(\eta)$



BESIII, Phys. Rev. D 111, 032011 (2025)

$$\sigma_{\mathrm{Born}} = |A_{\mathrm{con}} + A_{\mathrm{res}} \times e^{i\phi}|^2$$

$$A_{\mathrm{con}}(s) = a/s^n$$

$$A_{\mathrm{res}}(s) = \frac{\sqrt{12\pi\Gamma_{ee}\Gamma_{\mathrm{tot}}\mathcal{B}_f}}{s - M^2 + iM\Gamma_{\mathrm{tot}}}$$

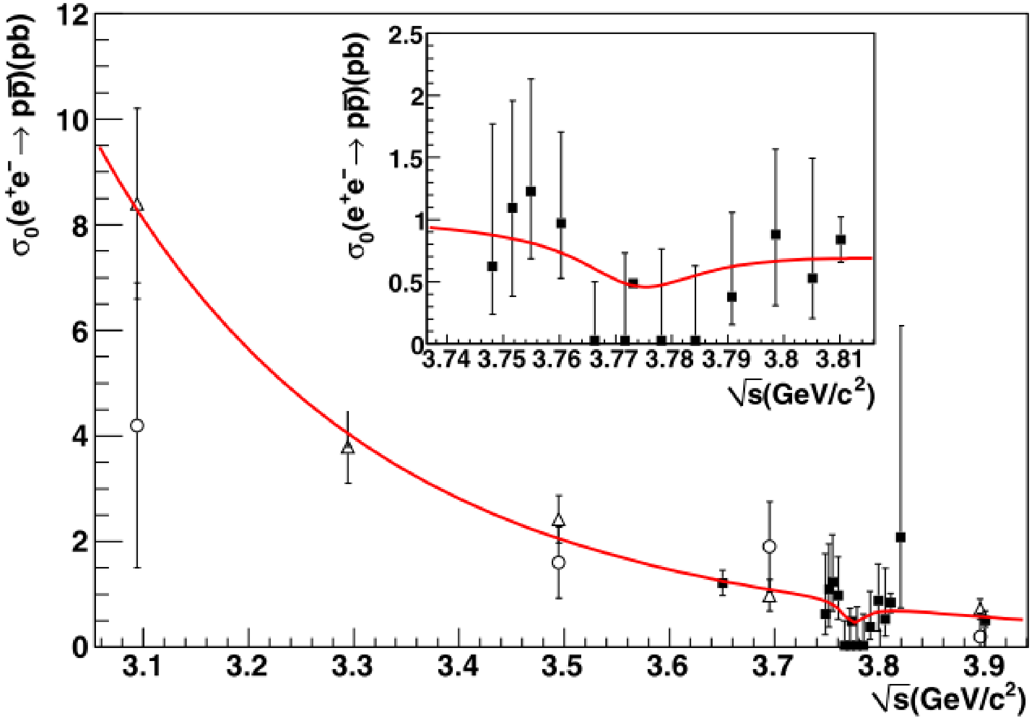
- Phase is consistent with $\pm 90°$ after converting.

channel	Solution	ϕ (°)	Br ($\times 10^{-6}$)	Φ (°)	Br_{PDG}($\times 10^{-6}$)
$\psi(2S) \to p\bar{p}\pi^0$	Constructive	65.0 ± 6.7	$133.9 \pm 11.2 \pm 2.3$	75.0 ± 8.9	153 ± 7
	Destructive	-68.9 ± 5.7	$183.7 \pm 13.7 \pm 3.2$	-77.9 ± 7.1	
$\psi(2S) \to p\bar{p}\eta$	Constructive	58.9 ± 14.1	$61.5 \pm 6.5 \pm 1.1$	69.8 ± 22.1	60 ± 4
	Destructive	-63.8 ± 12.1	$84.4 \pm 6.9 \pm 1.4$	-73.6 ± 17.5	

- The interference brings change in branching fraction results.

Scan measurement of $e^+e^- \to \psi(3770) \to p\bar{p}$

BESIII, Phys. Lett. B 735, 101 (2014)



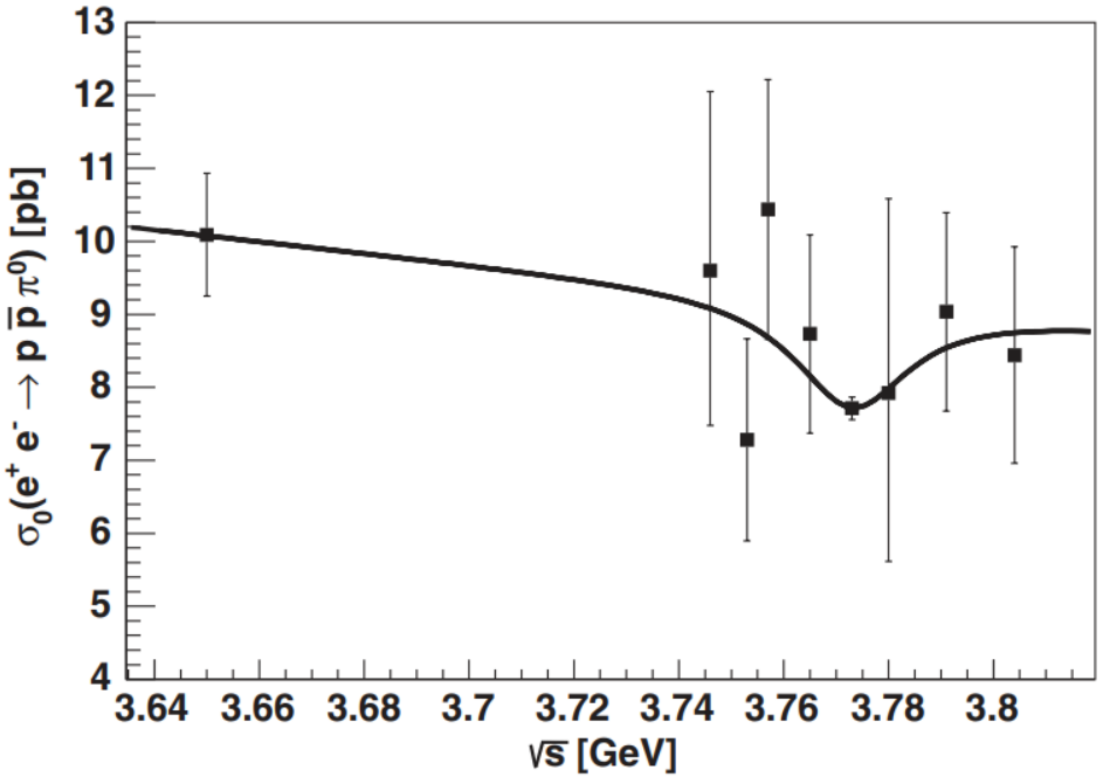
$$\sigma(s) = \left|A_{con} + A_\psi e^{i\phi}\right|^2$$
$$= \left|\sqrt{\sigma_{con}(s)} + \sqrt{\sigma_\psi}\frac{m_\psi \Gamma_\psi}{s - m_\psi^2 + i m_\psi \Gamma_\psi} e^{i\phi}\right|^2$$

$\sigma^{dressed}_{(\psi(3770)\to p\bar{p})}$ (pb)	ϕ (°)
$0.059^{+0.070}_{-0.020} \pm 0.012$	$255.8^{+39.0}_{-26.6} \pm 4.8$
$(< 0.166$ at 90% C.L.)	
$2.57^{+0.12}_{-0.13} \pm 0.12$	$266.9^{+6.1}_{-6.3} \pm 0.9$

Even the interference is between A_{con} and A_ψ, the phase $\Phi_{3g,\gamma}$ is still close to $-90°$ since A_g is much larger than A_γ

Scan measurement of $e^+e^- \to \psi(3770) \to p\bar{p}\pi^0$

BESIII, Phys. Rev. D 90, 032007 (2014)

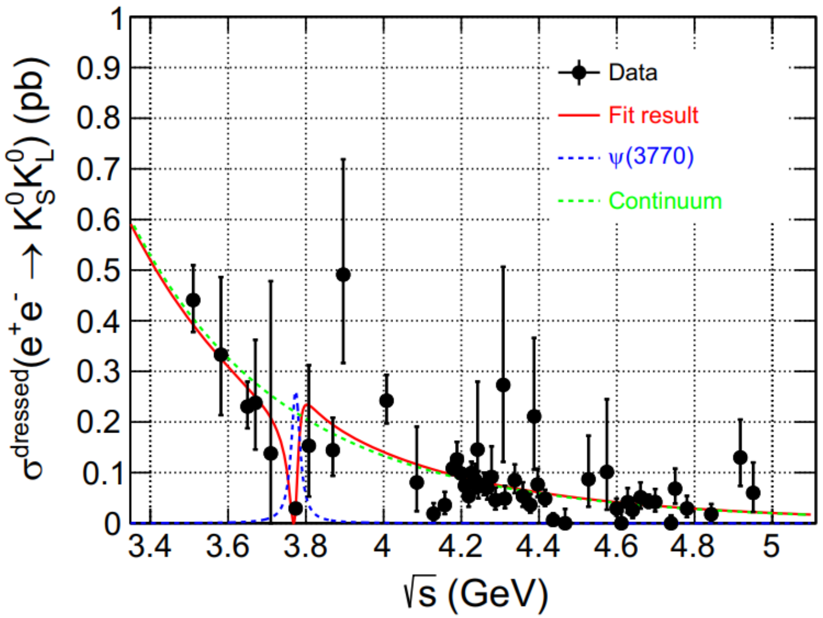


$$\sigma(s) = \left| \sqrt{\sigma_{\text{con}}} + \sqrt{\sigma_\psi} \frac{m\Gamma}{s - m^2 + im\Gamma} \exp(i\phi) \right|^2$$

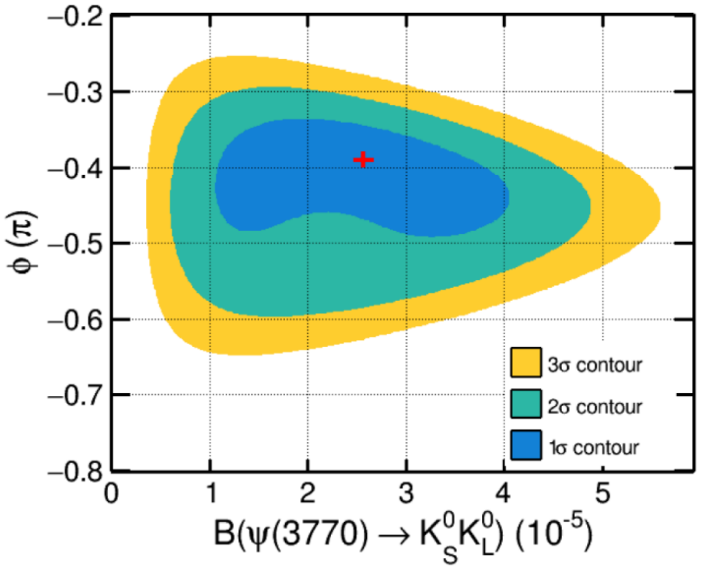
Solution	$\sigma_0^{\psi(3770)\to p\bar{p}\pi^0}$ [pb]	ϕ_{Fit} [°]	$\sigma_0^{p\bar{p}\to\psi(3770)\pi^0}$ [nb] at 5.26 GeV
1	< 0.22	$269.8^{+52.4}_{-48.0} \pm 11.0$	< 0.79
2	$33.8 \pm 1.8 \pm 2.1$	$269.7 \pm 2.3 \pm 0.3$	122 ± 10

- The phase $\Phi_{3g,\gamma}$ is still close to $-90°$ assuming A_g is much larger than A_γ
- *Significance for $\psi(3770)$ resonance ~ $1.5\,\sigma$*

Scan measurement of $e^+e^- \to \psi(3770) \to K_S K_L$



BESIII, Phys. Rev. Lett. 132, 131901 (2024)



$$\sigma^{\text{dressed}} = \left| BW \cdot e^{i\phi} + \frac{a}{(\sqrt{s})^n} \cdot \sqrt{\Phi(\sqrt{s})} \right|^2$$

$$BW = \frac{\sqrt{12\pi\Gamma_{ee}\Gamma B}}{s - M^2 + iM\Gamma}\sqrt{\frac{\Phi(s)}{\Phi(M)}},\ \Phi(s) = \frac{q^3}{s}$$

- $\mathcal{B} = (2.63^{+1.40}_{-1.59}) \times 10^{-5}$ and $\phi = \left(-0.39^{+0.05}_{-0.10}\right)\pi$ within 1σ likelihood contour.
- Significance of $\psi(3770)$ resonance contribution determined to be 10σ.
- First observe the charmless decay $\psi(3770) \to K_S K_L$.

Scan measurement -- upcoming

channel	J/ψ	$\psi(3686)$	$\psi(3770)$
K^+K^-	Francesca De Mori(Turino), report	Yadi Wang(NCEPU),draft	
K_SK_L		Jie Yuan(NCEPU),report	Bolun Zhang(IHEP), PRL132, 131901 (2024)
$\pi^+\pi^-$	Yipeng Zhao(NCEPU), under study	Yipeng Zhao(NCEPU), under study	Yipeng Zhao(NCEPU), under study
$\pi^+\pi^-\pi^0(\rho\pi)$	Tengjiao Wang (IHEP), report	Yijia Zeng(NKU)+Tengjiao Wang(IHEP)+Chen Xie(NJU), report	Yijia Zeng(NKU)+Tengjiao Wang(IHEP)+Chen Xie(NJU), report
$\pi^+\pi^-\eta(\rho\eta)$		Junhua Li+Caiying Pang(GXNU), BAM-889	Zhiqing Liu (SDU)
$\pi^+\pi^-\eta'(\rho\eta')$			
$K^+K^-\pi^0(K^{*\pm}K^{\mp})$	Tianyou Li (NKU), BAM-968	Tianyou Li(NKU)+Chen Xie(NJU), report	Chen Xie(NJU)+Tianyou Li(NKU), report
$K_SK^\pm\pi^\mp(K^{*0}\bar{K}^0)$	Chen Xie (NJU), BAM-996	Chen Xie(NJU), report	Chen Xie(NJU), report
$\omega\eta$	Zhikun Xi (WHU), report	Yiqi Du (WHU), report	Jiaojiao Song(HNNU)+ Yateng Zhang(ZZU), report
$\omega\eta'$	Hailing Song (USTC)+Yanning Wang (WHU)	Zhifei Tian (WHU), report	Jiaojiao Song(HNNU)+ Yateng Zhang(ZZU), report
$\phi\pi$			
$\phi\eta$	Zequn Sun(IHEP)+Nefedov Yury(JINR), submitted to JHEP		Junhao Yin(NKU), report
$\phi\eta'$	Yanwen Luo+Jianxin Wang(WHU), report		

channel	J/ψ	$\psi(3686)$	$\psi(3770)$
$p\bar{p}$	Marco Destifanis(Turino), BAM-106	Yanan Wang(NCEPU), BAM-822, draft	
$\Sigma^{+}\bar{\Sigma}^{-}$	Jiajun Liu(SCU), BAM-729, draft		JHEP05(2024)022
$\Sigma^{0}\bar{\Sigma}^{0}$	Muzaffar Irshad+Hao Zhang(USTC), BAM-612		LZU
$\Lambda/\bar{\Lambda}+X$	Zihao Qu(SCU), BAM-702, draft, CWR		
$\Xi^{-}\bar{\Xi}^{+}$			JHEP11(2023)228
$\Xi^{0}\bar{\Xi}^{0}$			JHEP11(2024)062
$\Lambda\bar{\Lambda}$	Jianyong Zhang (IHEP), report		PRD 104, L091104 (2021)
$K^{-}\bar{\Xi}^{+}\Lambda, K^{-}\bar{\Xi}^{+}\Sigma^{0}$			JHEP07(2024)258

Hopefully, there will be 3-5 papers will be published in 2025!

Require more efforts from our referees.

Summary

- The phase between strong and EM can be measured with SU(3) dependent method and scan method.
- Critical problems about the phase is a mystery:
  - Is the phase universal? Independent of initial or final state?
  - What is the sign of the phase?
- Input from theorists is highly welcome!

$$\left.\begin{array}{l}\text{Inter. between } A_{EM} \text{ and } A_g \\ \\ \text{Inter. between } A_{cont} \text{ and } A_{res}\end{array}\right\} \Rightarrow$$

Measurements (Br) deviate from its true value (heavily).

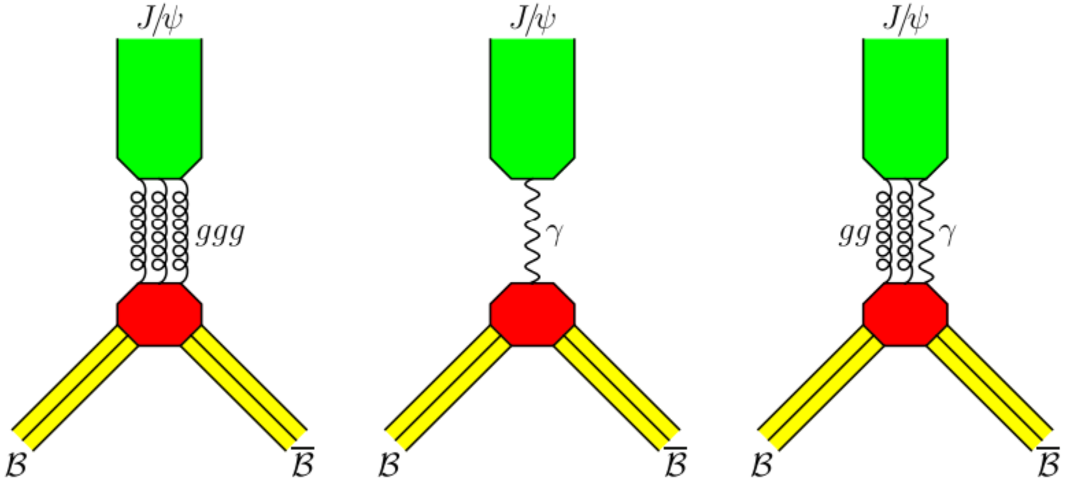
Must be considered in all measurements!

Thanks for your attention!

Model dependent experimental evidences

from J/ψ decays

R. Baldini, A. Mangoni, S. Pacetti, K. Zhu;
Phy. Lett. B 799, 135041 (2019)



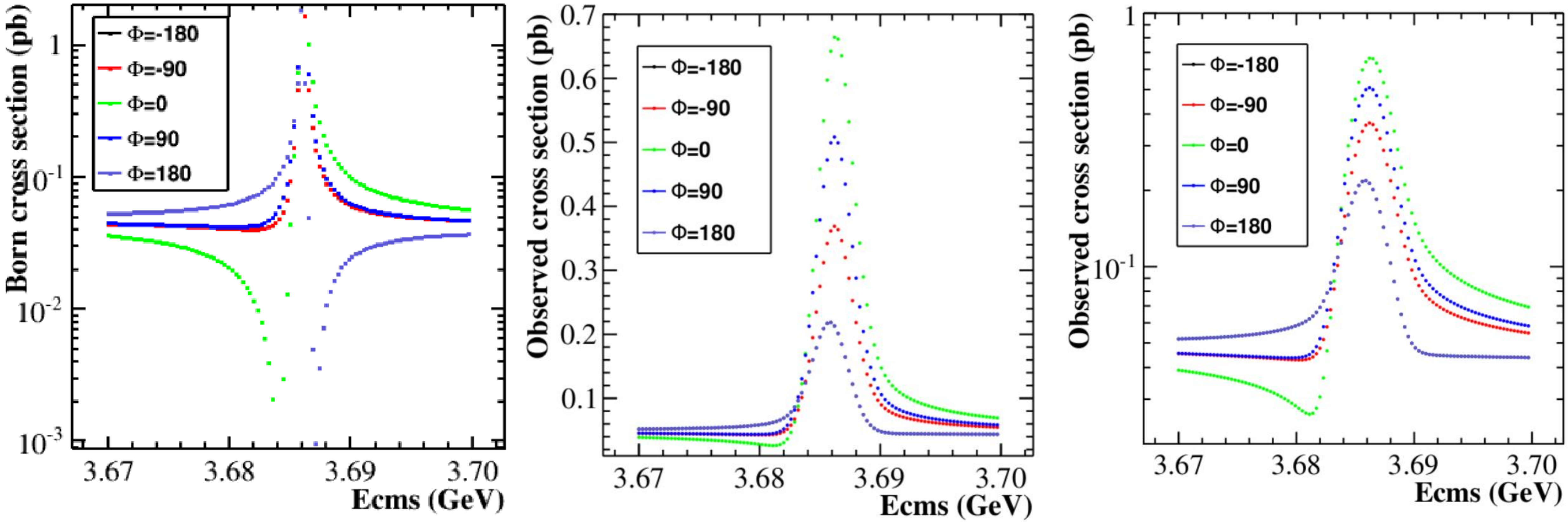
$\mathcal{B}\overline{\mathcal{B}}$	$\mathrm{BR}^{\mathrm{exp}}_{\mathcal{B}\overline{\mathcal{B}}} \times 10^3$	$\mathrm{BR}_{\mathcal{B}\overline{\mathcal{B}}} \times 10^3$
$\Sigma^0\overline{\Sigma}^0$	1.164 ± 0.004	1.160 ± 0.041
$\Lambda\overline{\Lambda}$	1.943 ± 0.003	1.940 ± 0.055
$\Lambda\overline{\Sigma}^0 + \text{c.c.}$	0.0283 ± 0.0023	0.0280 ± 0.0024
$p\overline{p}$	2.121 ± 0.029	2.10 ± 0.16
$n\overline{n}$	2.09 ± 0.16	2.10 ± 0.12
$\Sigma^+\overline{\Sigma}^-$	1.50 ± 0.24	1.110 ± 0.086
$\Sigma^-\overline{\Sigma}^+$	/	0.857 ± 0.051
$\Xi^0\overline{\Xi}^0$	1.17 ± 0.04	1.180 ± 0.072
$\Xi^-\overline{\Xi}^+$	0.97 ± 0.08	0.979 ± 0.065

- Consider the small contribution from $A_{gg\gamma}$
- Assume $A_{gg\gamma}$ has the same phase as A_{3g} to A_γ
- Perform SU(3) analysis based on experimental branching ratios of J/ψ decaying to baryons

$$\boxed{\Phi = (73 \pm 8)^\circ}$$

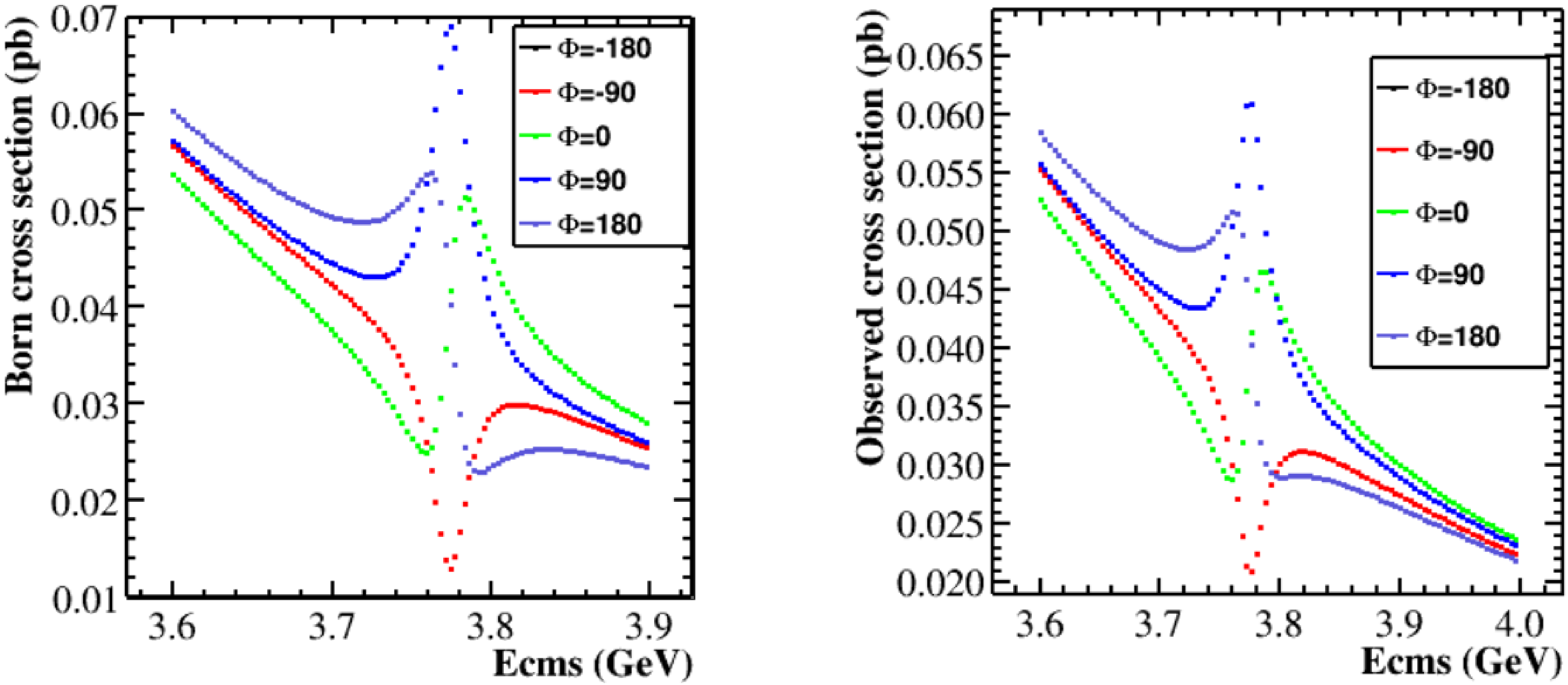
Br result from SU(3) very close to PDG

Prediction for line-shapes of $\psi(3686)$



- For narrow resonances, the beam energy spread is much larger than the natural width.
- The observed cross section and Born cross section are very different.

Prediction for line-shapes of $\psi(3770)$



- For wide resonances, the beam energy spread is smaller than the natural width.
- The observed cross section and Born cross section are very similar.