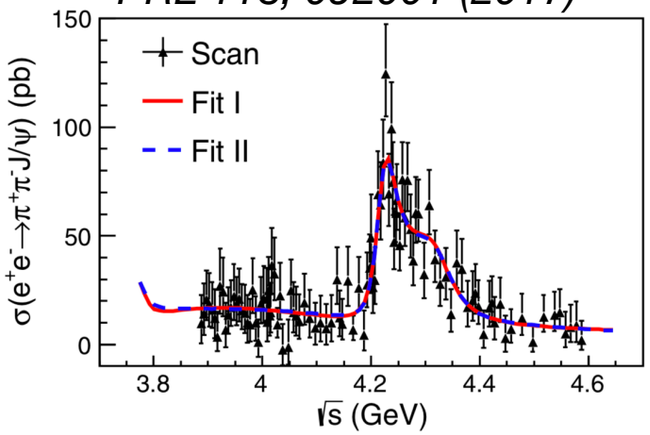
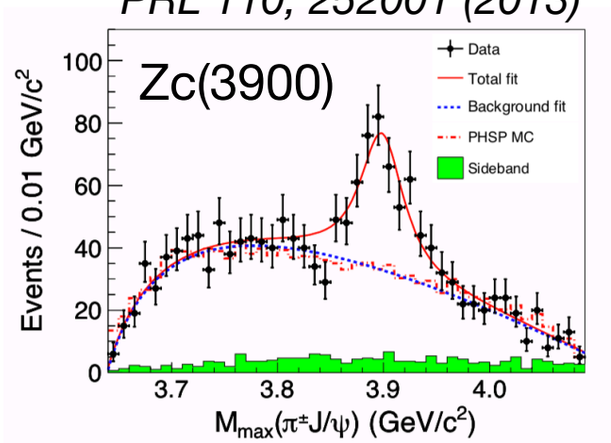
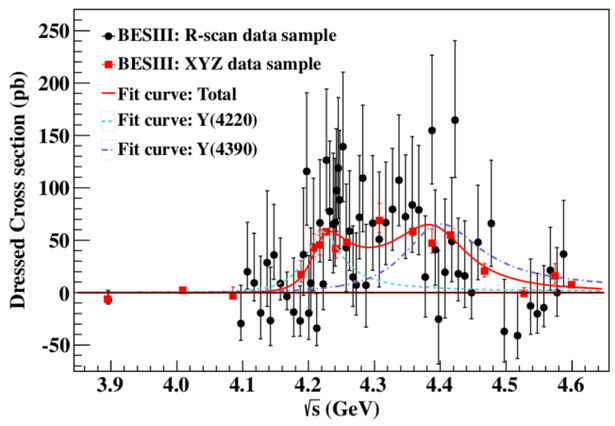
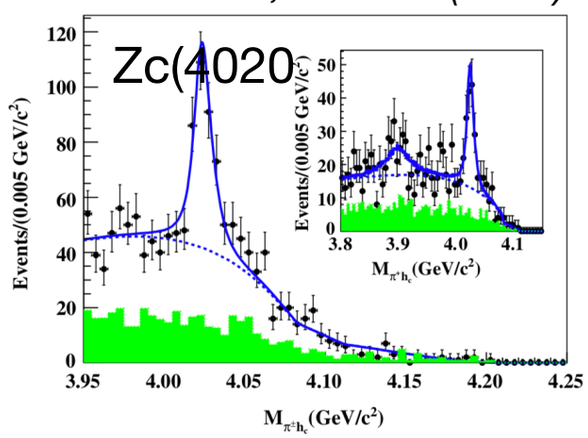
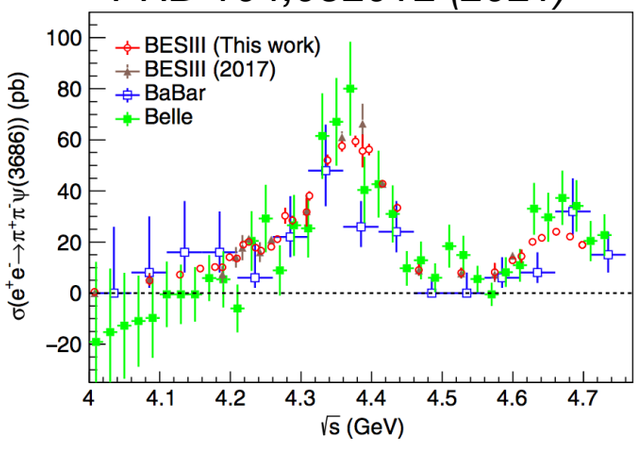
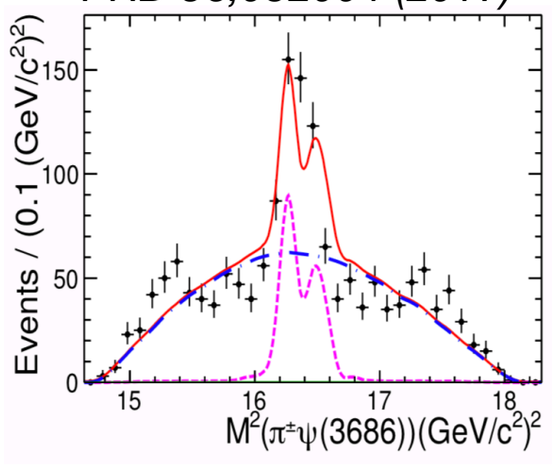
The study of $e^+e^- \to K\bar{K}+(c\bar{c})$ at BESIII

第十届XYZ研讨会，2025年4月11-15，长沙

Chunhua Li
Nanjing Normal University

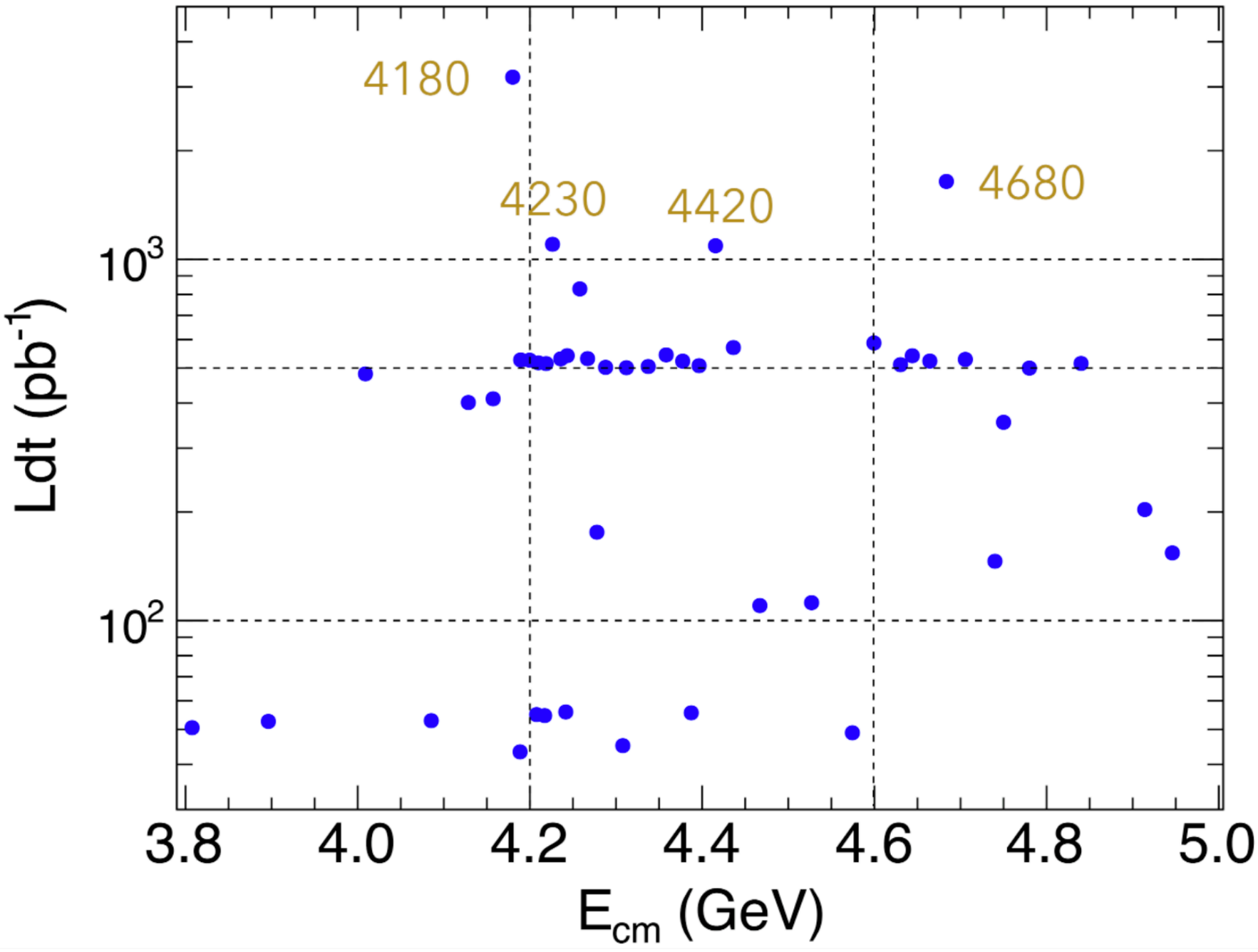
$e^+e^- \to \pi\pi + (c\bar{c})$ at BESIII

	Y	Z
$\pi\pi J/\psi$	*PRL 118, 092001 (2017)* 	*PRL 110, 252001 (2013)* 
$\pi\pi h_c$	*PRL 118, 092002 (2017)* 	*PRL 111, 242001 (2013)* 
$\pi\pi\psi(2S)$	*PRD 104,052012 (2021)* 	*PRD 96,032004 (2017)* 
$e^+e^- \to KK + (c\bar{c})$?		

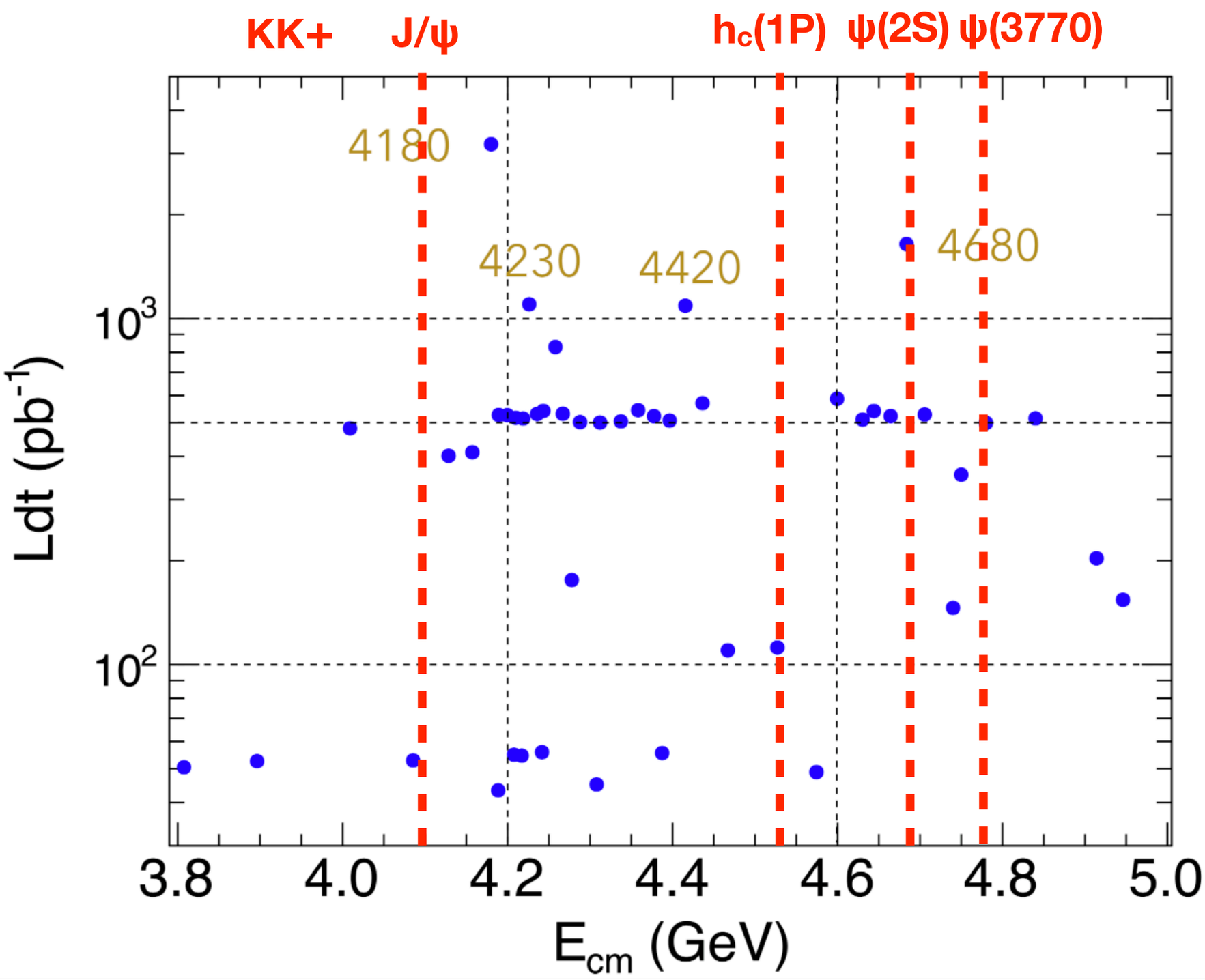
$e^+e^- \to K\bar{K}+(c\bar{c})$ at BESIII

- $e^+e^- \to KKJ/\psi$
- $e^+e^- \to KK\psi(2S)$
- $e^+e^- \to KsKs\ h_c(1P)$
- $e^+e^- \to K^+K^-\psi(3770)$

XYZ Data at BESIII

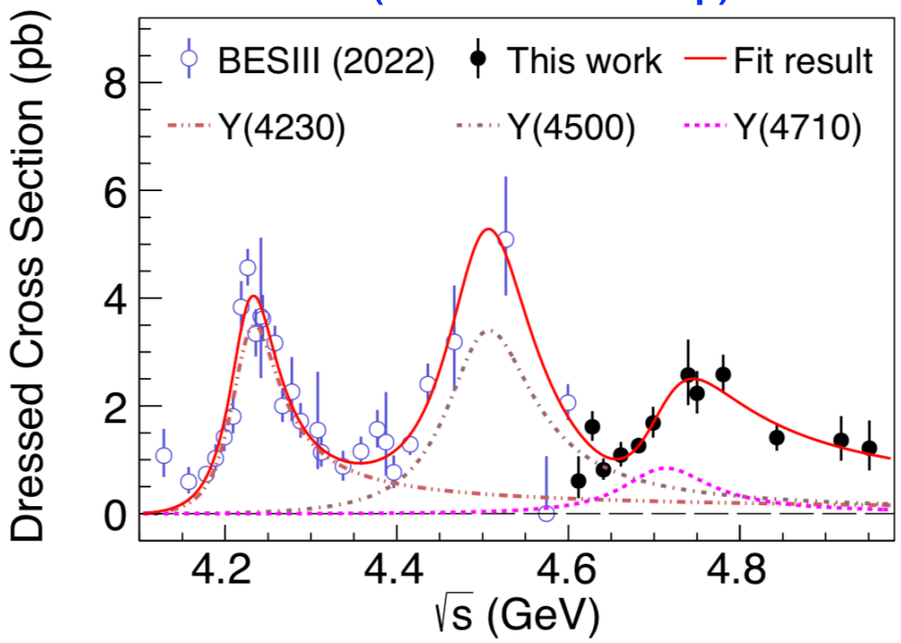


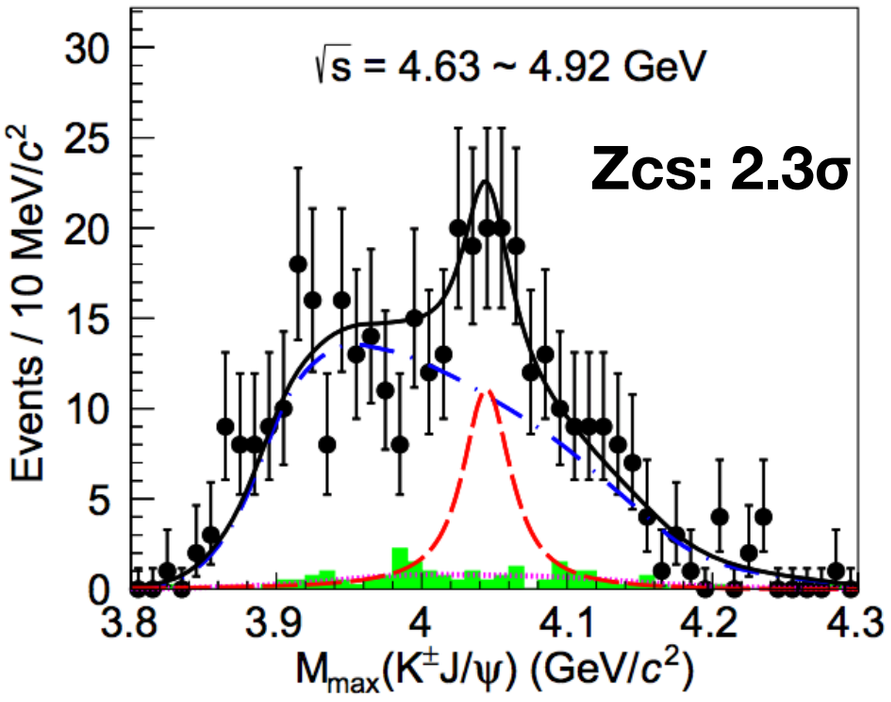
XYZ Data at BESIII



$e^+e^- \to KKJ/\psi$

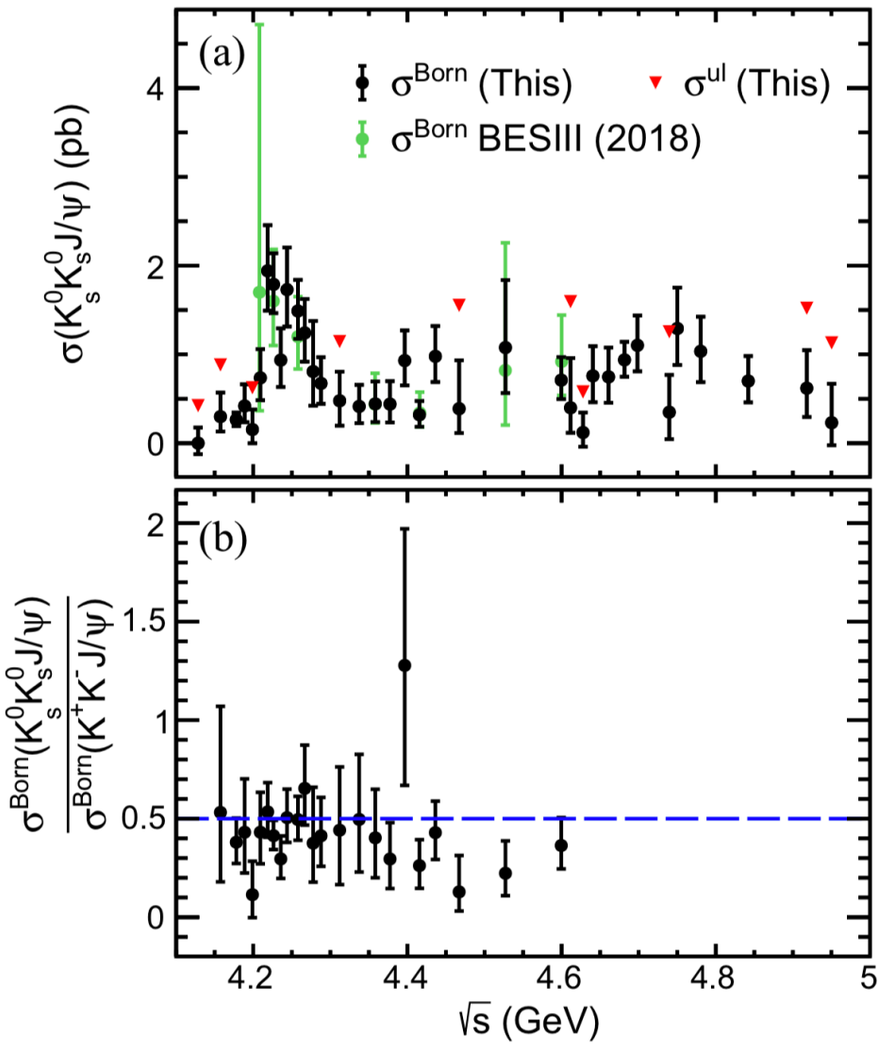
$\sigma(ee \to K^+K^-J/\psi)$





PRL 131,211902 (2023)

$\sigma(ee \to K_sK_sJ/\psi)$



PRD 107, 092005 (2023)

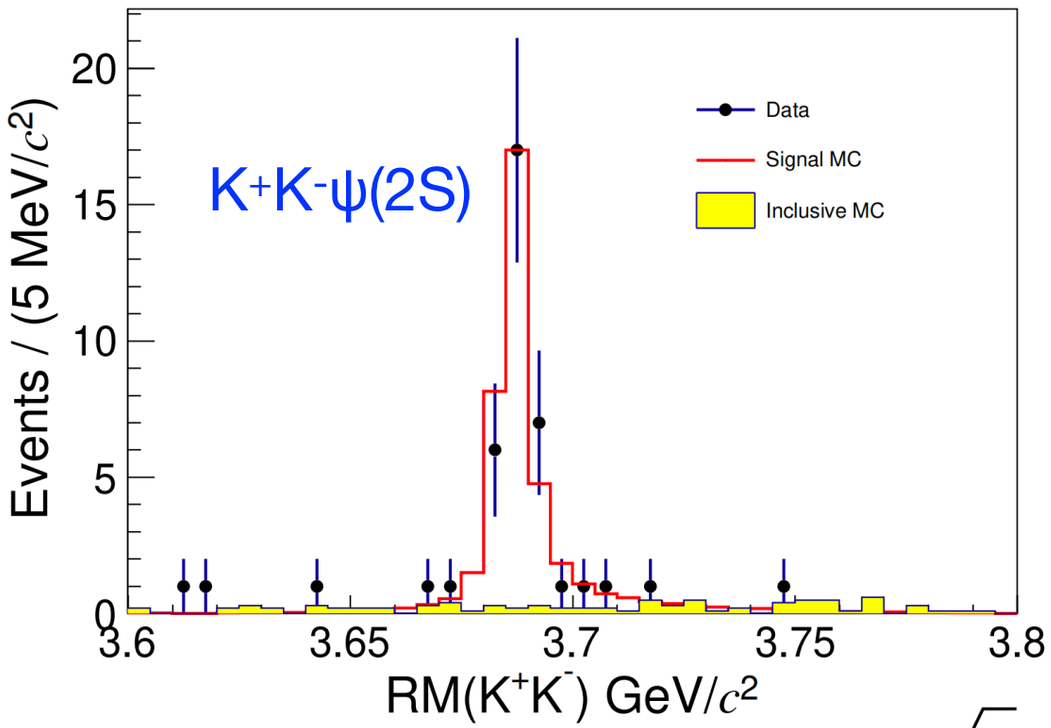
$e^+e^- \rightarrow KK\psi(2S)$

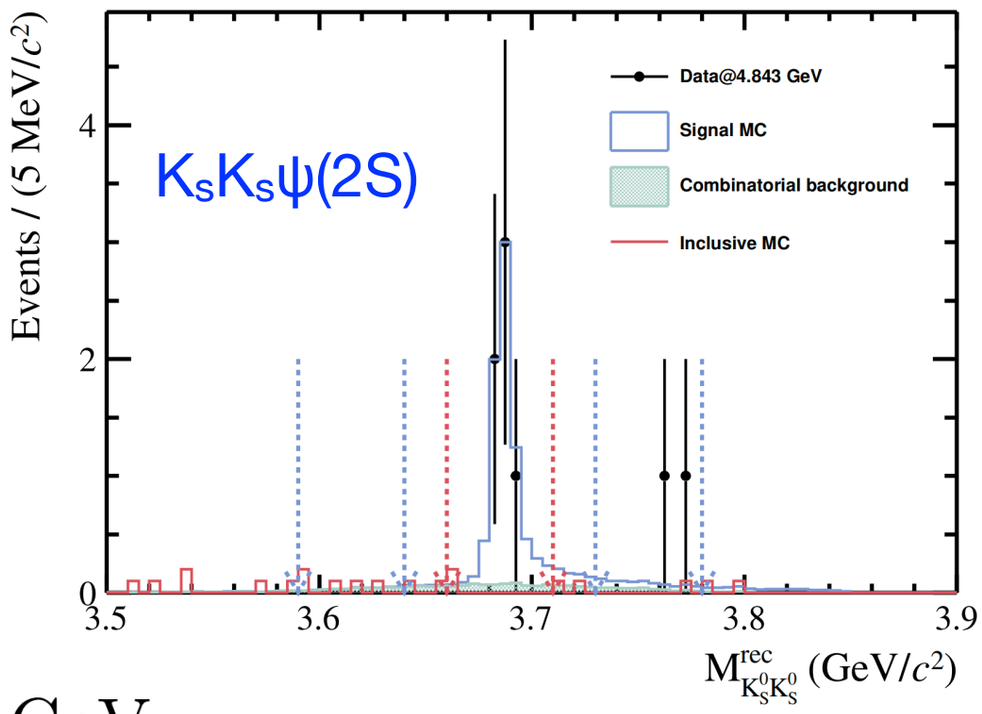
- Challenge: low kaon momentum→low detection efficiency
- Approaches to reconstruct the e+e-→KK(2S) signals
  - $e^+e^- \rightarrow K^+K^-\psi(2S), \psi(2S) \rightarrow J/\psi + anything, J/\psi \rightarrow \ell^+\ell^-, \ell = e, \mu$
  - $e^+e^- \rightarrow K^+K^-\psi(2S), \psi(2S) \rightarrow J/\psi\pi^+\pi^-$ by missing one Kaon, $J/\psi \rightarrow \ell^+\ell^-$
  - $e^+e^- \rightarrow K^+K^-\psi(2S), \psi(2S) \rightarrow \ell^+\ell^-$
  - $e^+e^- \rightarrow K^+K^-\psi(2S), \psi(2S) \rightarrow \ell^+\ell^-$ by missing one Kaon

$e^+e^- \to KK\psi(2S)$

arXiv: 2407.20009
JHEP 02 (2005) 120

- Challenge: low kaon momentum→low detection efficiency
- Approaches to reconstruct the e+e-→KK(2S) signals
  - $e^+e^- \to K^+K^-\psi(2S), \psi(2S) \to J/\psi + anything, J/\psi \to \ell^+\ell^-, \ell = e, \mu$
  - $e^+e^- \to K^+K^-\psi(2S), \psi(2S) \to J/\psi\pi^+\pi^-$ by missing one Kaon, $J/\psi \to \ell^+\ell^-$
  - $e^+e^- \to K^+K^-\psi(2S), \psi(2S) \to \ell^+\ell^-$
  - $e^+e^- \to K^+K^-\psi(2S), \psi(2S) \to \ell^+\ell^-$ by missing one Kaon

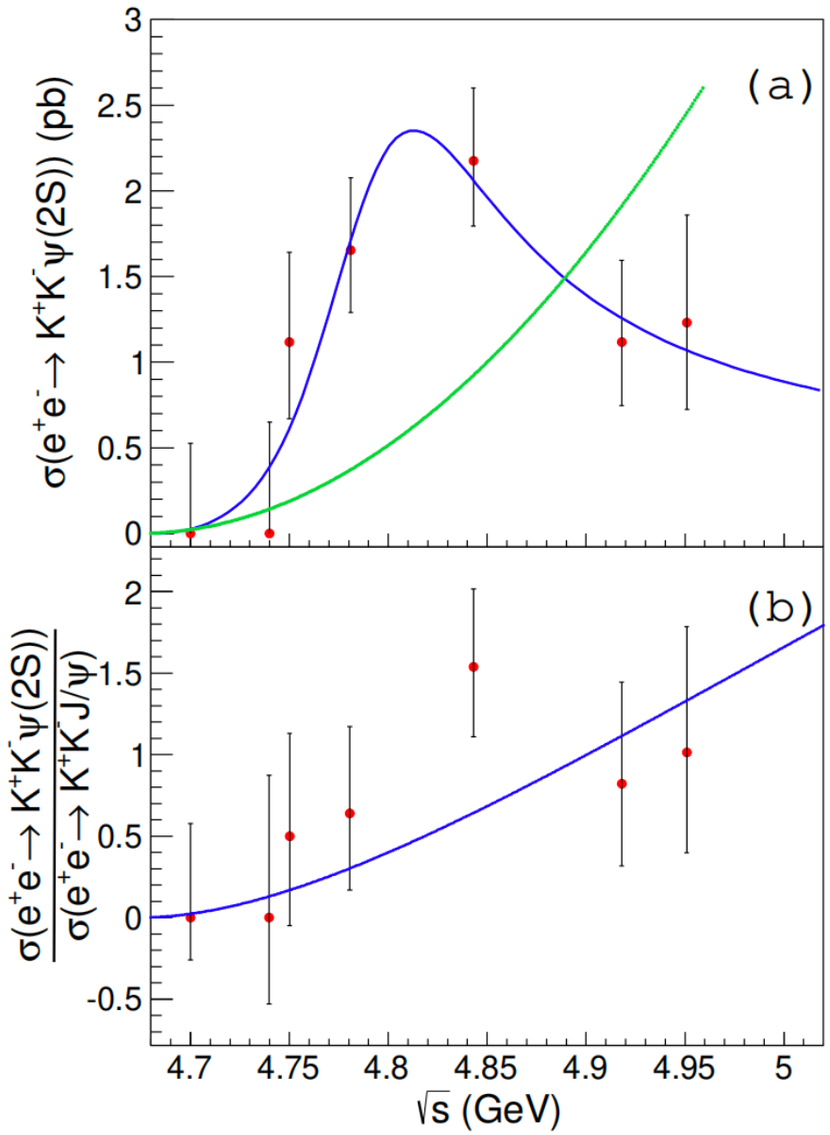




$$\sqrt{s} = 4.843 \text{ GeV}$$

$e^+e^- \to KK\psi(2S)$

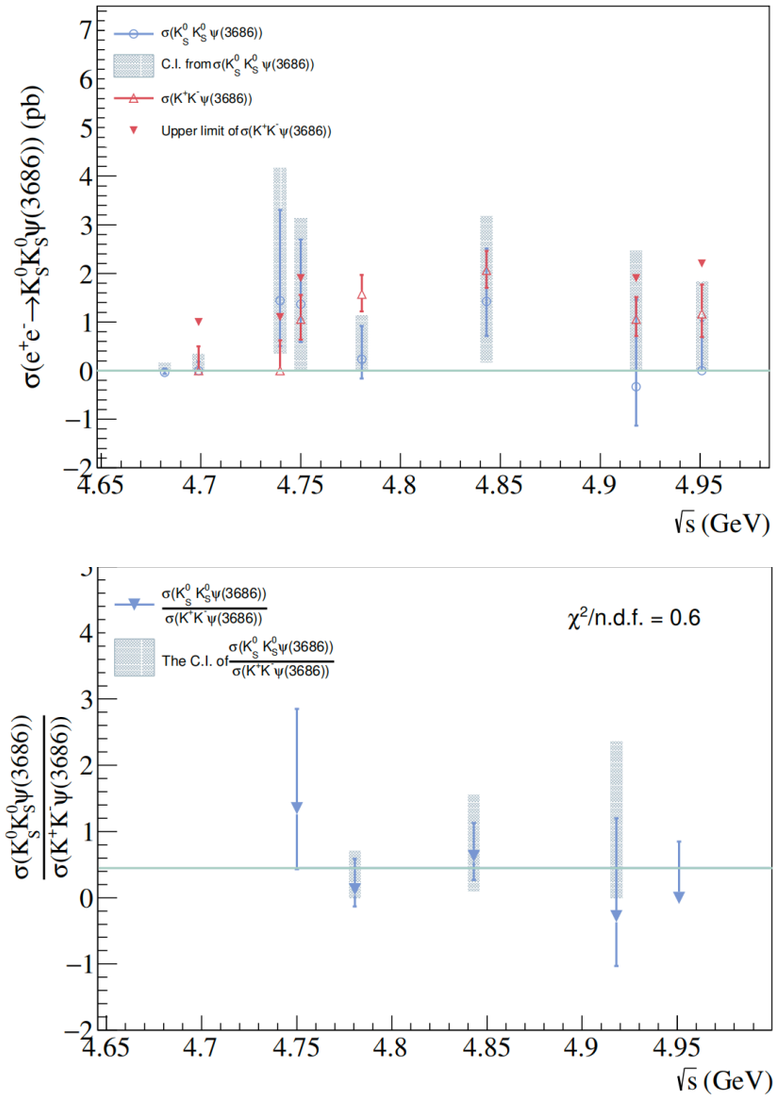
$K^+K^-\psi(2S)$



Fit with a BW function

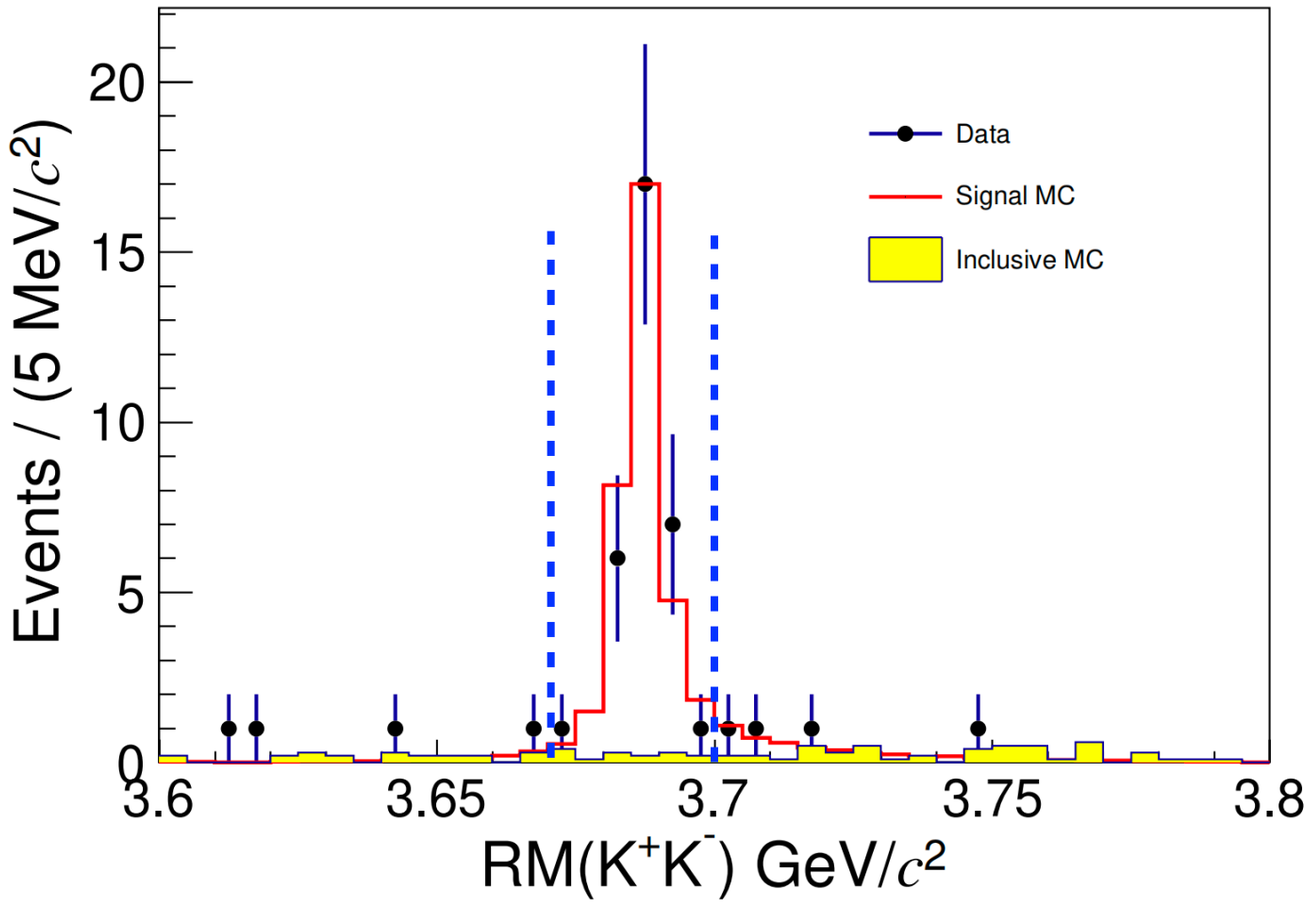
$M = 4787.7 \pm 17.7\,\mathrm{MeV}/c^2, \Gamma = 110.3 \pm 33.9\,\mathrm{MeV}$

$K_sK_s\psi(2S)$



$$\frac{\sigma(e^+e^-\to K^0_S K^0_S \psi(3686))}{\sigma(e^+e^-\to K^+K^-\psi(3686))} = 0.45 \pm 0.25$$

Search for Z_{cs} in KKψ(2S) System



$$\sqrt{s} = 4.843 \text{ GeV}$$

Search for Z_{cs} in KKψ(2S) System

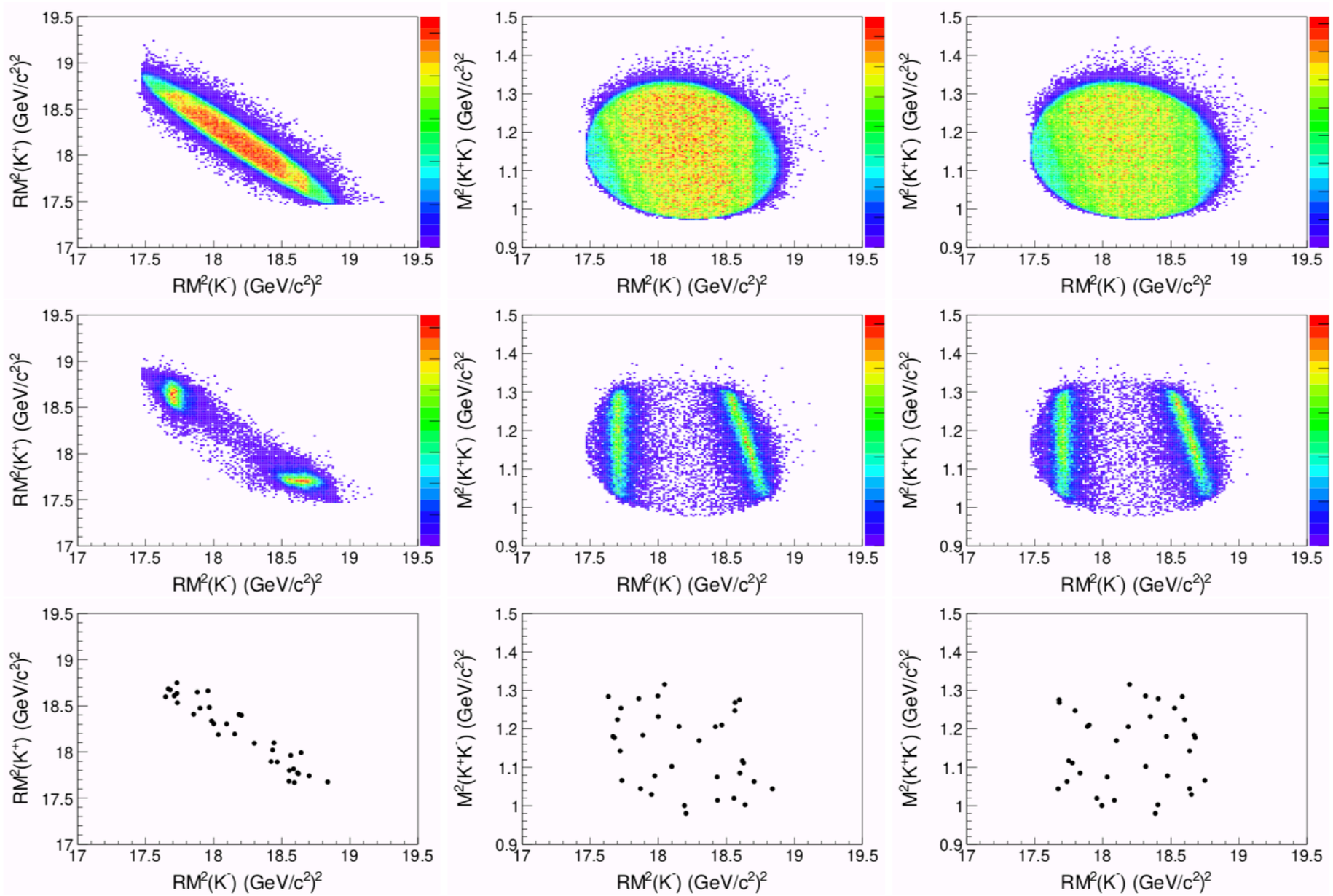
Dalitz plots

PHSP MC

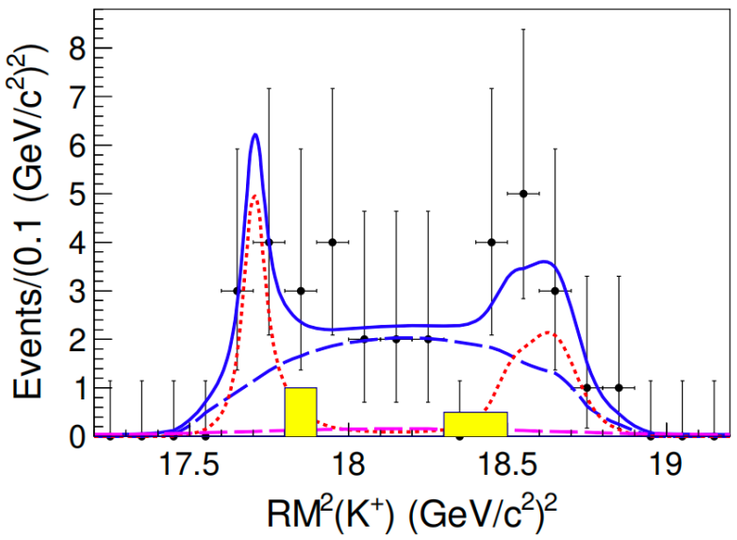
Z_{cs} MC

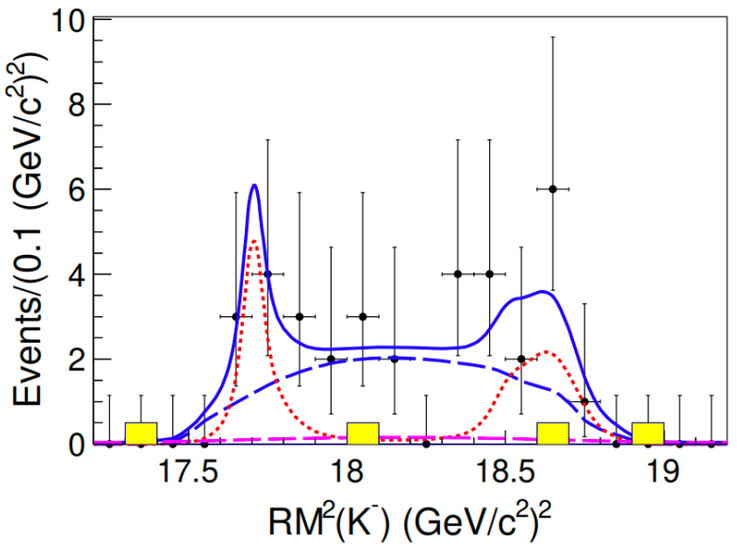
$M(Z_{cs})$=4.208 GeV
Γ=7 MeV

Data



Search for Z_{cs} in KKψ(2S) System

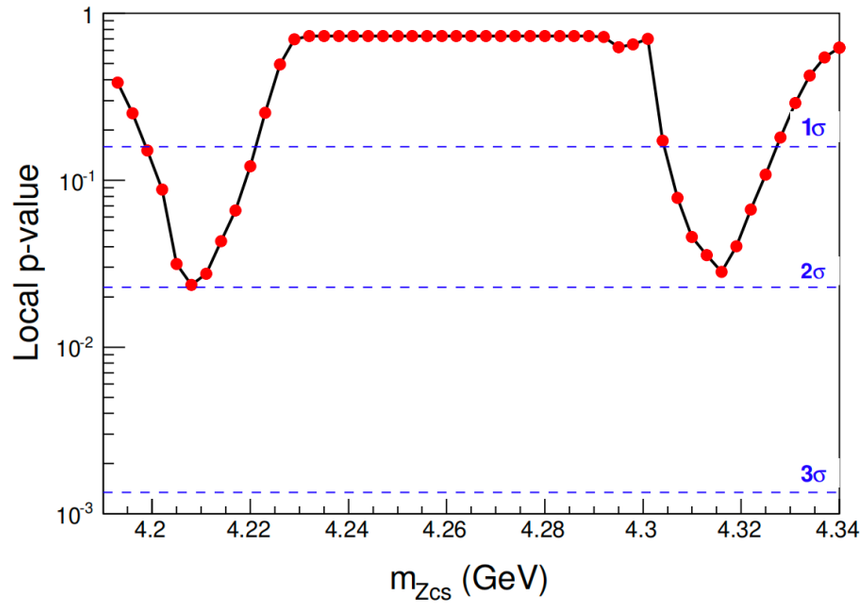




- Perform a simultaneous fit on $RM^2(K^+)$ and $RM^2(K^-)$

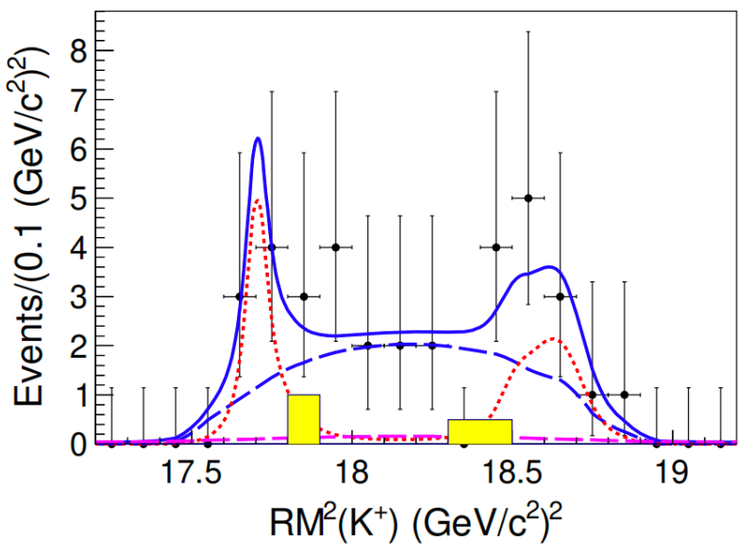
$$F(X,Y) = PHSP \cdot (|\frac{1}{X - M^2 - iM\Gamma}|^2 + |\frac{1}{Y - M^2 - iM\Gamma}|^2) \quad \Rightarrow \quad f(X) = \sigma(X) \otimes \int F(X,Y)dY$$

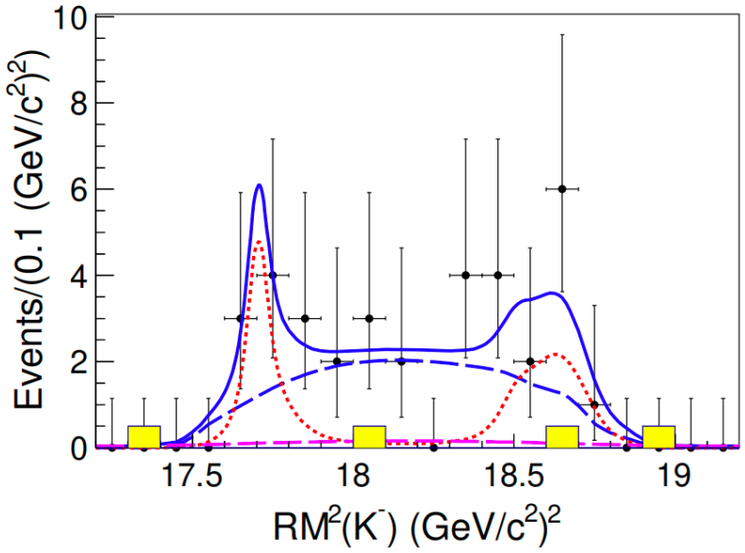
- Implement a series of fit to localize the Z_{cs} position.
- Two fits
  - Fit I, the mass around 4.205 GeV with a reflection at higher mass
  - Fit II, the mass around 4.315 GeV with a reflection at lower mass



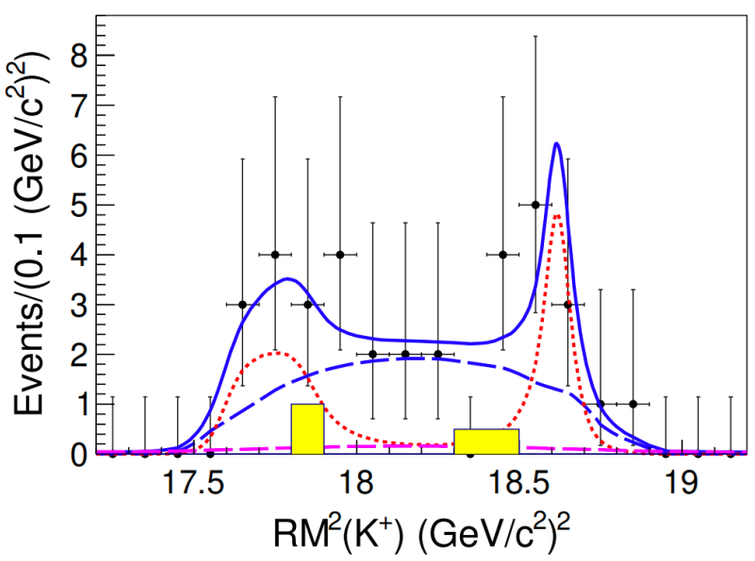
Search for Z_{cs} in KKψ(2S) System

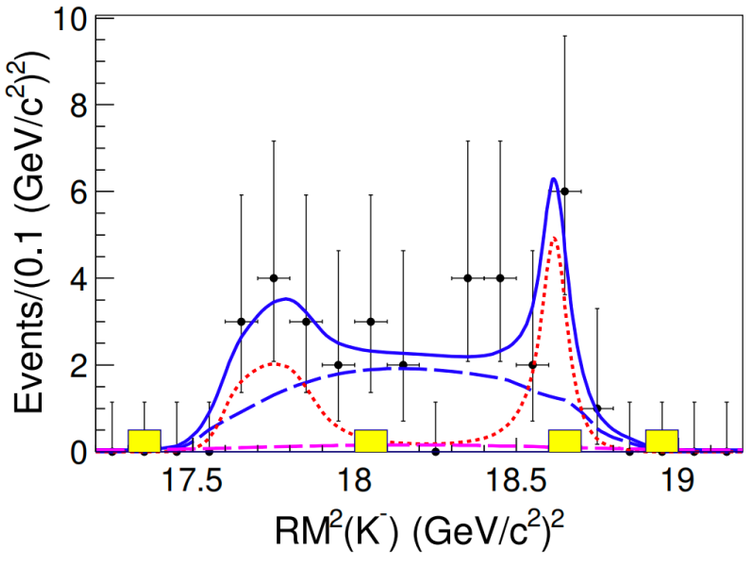
Fit I





Fit II



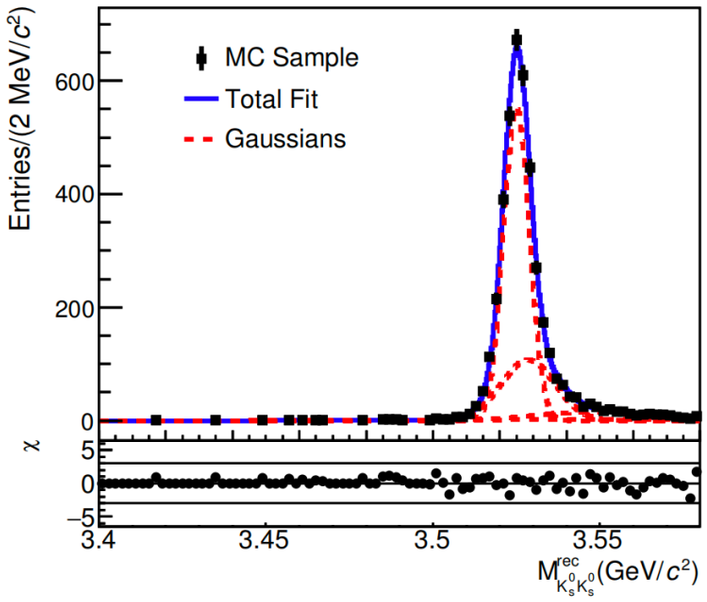


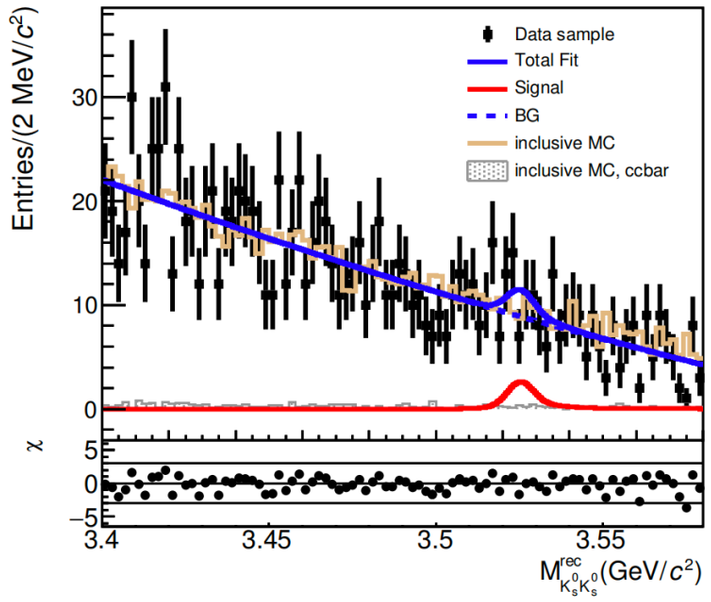
	M (MeV)	Γ (MeV)	$N_{\rm sig}$	N_{phsp}	$-\ln\mathcal{L}$	significance
Fit I	4208.4 ± 3.1	6.1 ± 5.7	12.3 ± 5.0	20.1 ± 5.4	-112.1	1.2σ
Fit II	4316.0 ± 2.7	9.0 ± 8.6	13.4 ± 6.5	19.0 ± 6.7	-111.8	1.1σ

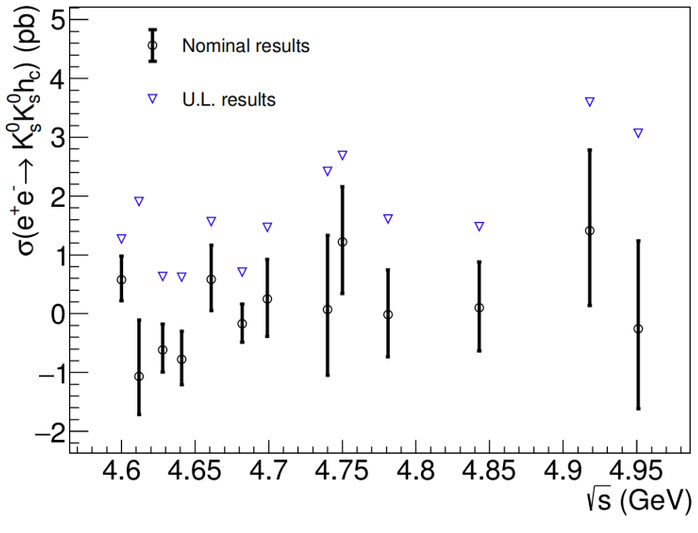
$e^+e^- \to K_S K_S h_c(1P)$

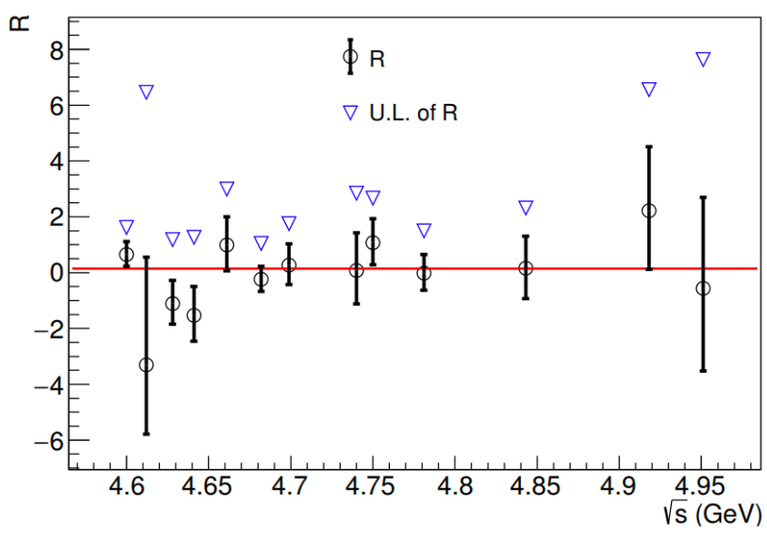
arXiv: 2502.07406

- 4.6-4.95 GeV
- $e^+e^- \to K_S K_S hc \to K_S K_S \gamma \eta_c$
- No significant signals









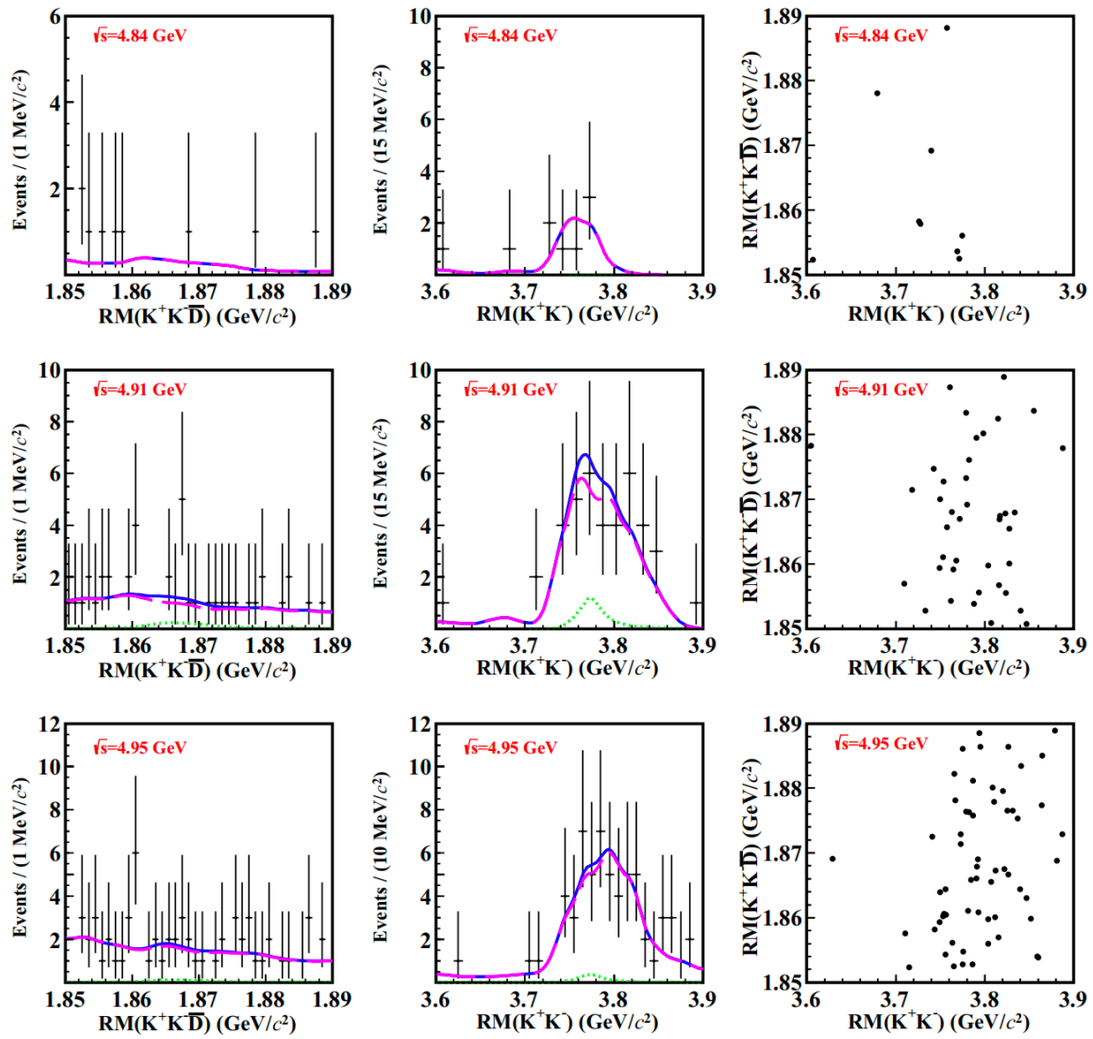
$$R = \frac{\sigma(e^+e^- \to K^0_S K^0_S h_c)}{\sigma(e^+e^- \to K^0_S K^0_S J/\psi)} = 0.15 \pm 0.22$$

$e^+e^- \to K^+K^-\psi(3770)$

PRD 109, 112019 (2024)

- 4.843-4.951 GeV
- $e^+e^- \to K^+K^-\psi(3770) \to K^+K^-D\bar{D}$
- No significant signals

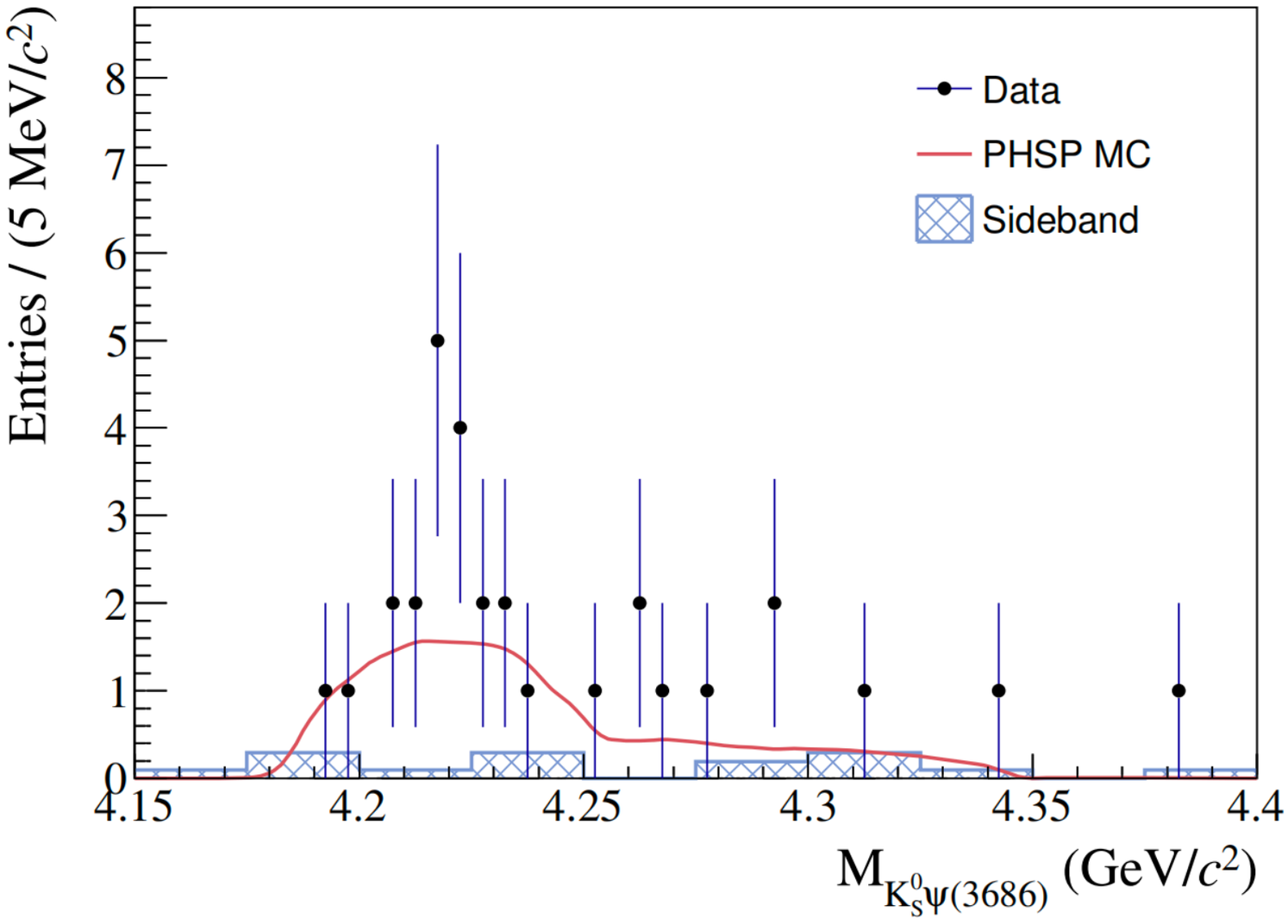
$$D^0 \to K^-\pi^+$$
$$D^0 \to K^-\pi^+\pi^0$$
$$D^0 \to K^-\pi^+\pi^+\pi^-$$
$$D^+ \to K^-\pi^+\pi^+$$
$$D^+ \to K_S^0\pi^+$$
$$D^+ \to K_S^0\pi^+\pi^0$$
$$D^+ \to K^-\pi^+\pi^+\pi^0$$
$$D^+ \to K_S^0\pi^+\pi^+\pi^-$$
$$D^+ \to K^+K^-\pi^-$$



$\sqrt{s}$ (GeV)	$\mathcal{L}_{\rm int}$ (pb^{-1})	$N_{\rm sig}$	$N^{\rm upper}$	$\epsilon_{\rm sig}$ (%)	σ^B (pb)
4.84	525.16 ± 2.78	$0.00^{+0.56}_{-0.54}$	<4.7	0.487 ± 0.015	<1.2
4.91	207.82 ± 1.10	$3.0^{+4.2}_{-5.2}$	<14.6	1.473 ± 0.027	<3.0
4.95	159.28 ± 0.84	$0.8^{+6.1}_{-5.0}$	<14.2	1.736 ± 0.028	<3.1

Summary

- The measurements of $e^+e^- \rightarrow KK+(cc)$ at BESIII.
  - $e^+e^- \rightarrow KKJ/\psi$
  - $e^+e^- \rightarrow KK\psi(2S)$
  - $e^+e^- \rightarrow KsKs\ h_c(1P)$
  - $e^+e^- \rightarrow K^+K^-\psi(3770)$
- See some interesting hints.
- More data is needed to obtain robust conclusions, and the upgrade BEPCII is an opportunity.


Entries / (5 MeV/c^2)
0
1
2
3
4
5
6
7
8
4.15
4.2
4.25
4.3
4.35
4.4
$M_{K^0_S\psi(3686)}$ (GeV/c^2)
Data
PHSP MC
Sideband

$e^+e^- \to KK\psi(2S)$

$\sqrt{s}$ (GeV)	$\mathcal{L}_{\rm int}(\rm pb^{-1})$	$N_{\rm sdb}$	$N_{\rm obs}$	$N_{\rm s}$	$\epsilon_{\rm iv}$	$\epsilon_{\rm iii}$	$\epsilon_{\rm ii}$	$\epsilon_{\rm i}$	$(1+\delta)$	$\sigma^{\rm B}$ (pb)	$\sigma^{\rm B}_{\rm up}$ (pb)	Significance
4.699	536.45	1	0	$0.0^{+0.5}_{-0.0}$	4.24	0.00	3.10	0.00	0.901	$0.00^{+0.50}_{-0.00} \pm 0.00$	1.0	-
4.740	164.27	1	1	$0.0^{+1.7}_{-0.0}$	25.35	5.51	19.80	5.56	0.851	$0.00^{+0.62}_{-0.00} \pm 0.00$	1.1	-
4.750	367.21	1	8	$7.0^{+3.3}_{-2.8}$	26.25	8.12	20.79	8.26	0.847	$1.06^{+0.50}_{-0.42} \pm 0.08$	1.9	2.1σ
4.781	512.78	1	19	$18.5^{+4.7}_{-4.1}$	25.86	14.21	20.94	14.44	0.850	$1.57^{+0.40}_{-0.35} \pm 0.12$	-	5.4σ
4.843	527.29	4	34	$32.0^{+6.2}_{-5.6}$	22.05	20.43	19.10	20.49	0.938	$2.06^{+0.40}_{-0.36} \pm 0.14$	-	7.1σ
4.918	208.11	0	7	$7.0^{+3.0}_{-2.3}$	17.49	22.26	15.63	22.49	1.027	$1.06^{+0.45}_{-0.35} \pm 0.07$	1.9	3.3σ
4.951	160.37	2	7	$6.0^{+3.1}_{-2.5}$	16.46	22.69	14.62	22.89	1.045	$1.17^{+0.60}_{-0.48} \pm 0.08$	2.2	2.4σ