Search for $e^+e^- \to \eta\psi(2S)$ above center-of-mass energy $\sqrt{s} = 4.26GeV$

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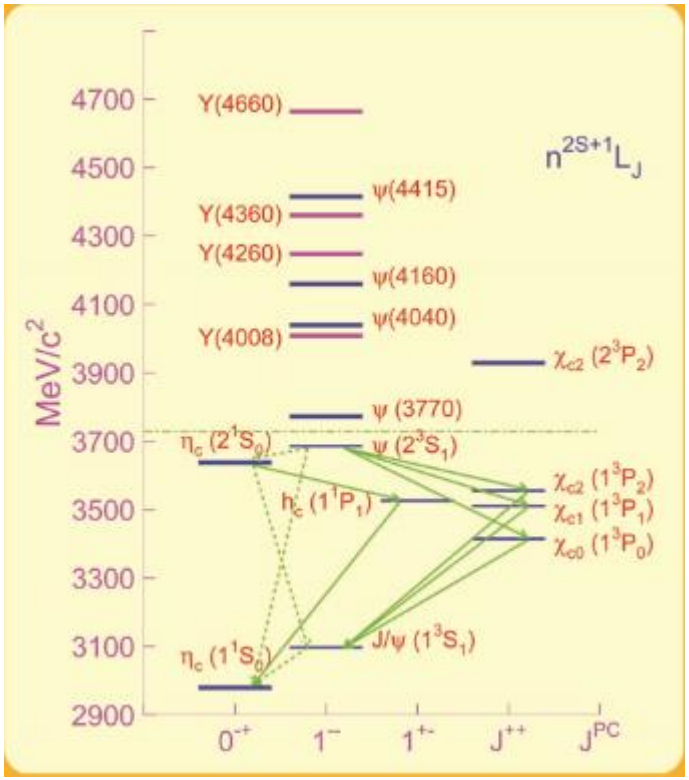
Motivation



Many exotic charmoniumlike states have been discovered around 4GeV, which means hidden charm coupling is also prominent for new states lying in this energy region. Thus, careful investigation of hidden charm cross section is necessary and will give us a chance to clarify new charmoniumlike states.

BESIII have collected ~4 fb^{-1} *data above 4.0GeV. It is a good opportunity to investigate hidden charm decays, such as* $e^+e^- \rightarrow \eta\psi(2S)$.

Data set

- *Decay channels:*

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

$\eta \to \gamma\gamma$, $\psi(2S) \to \pi^+\pi^- J/\psi$; $J/\psi \to e^+e^- / \mu^+\mu^-$;

- *Data sets:*

The threshold is 4.234GeV!

$\sqrt{s}$(GeV)	Luminosity(pb^{-1})	$\sqrt{s}$(GeV)	Luminosity(pb^{-1})	$\sqrt{s}$(GeV)	Luminosity(pb^{-1})
4.260	825.7	4.310	44.9	4.360	544.5
4.390	55.2	4.420	1023.3	4.470	110.7
4.530	110.5	4.575	47.7	4.600	567.7

- *Inclusive MC: ~500 pb $^{-1}$@4.26GeV;*
- *Signal MC: 10k events for each channel;*
- *BOSS version: 7.0.2*

Event selection

Charged tracks:

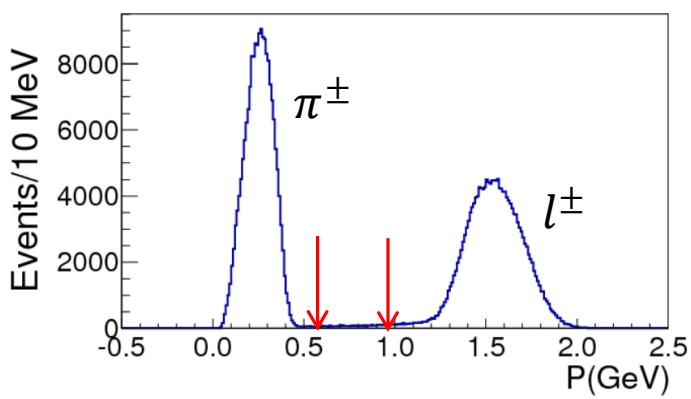
Rxy < 1cm, |Rz |< 10cm; $|cos\theta| < 0.93$;
$\sum Q=0$; $N_{good} = 4$.

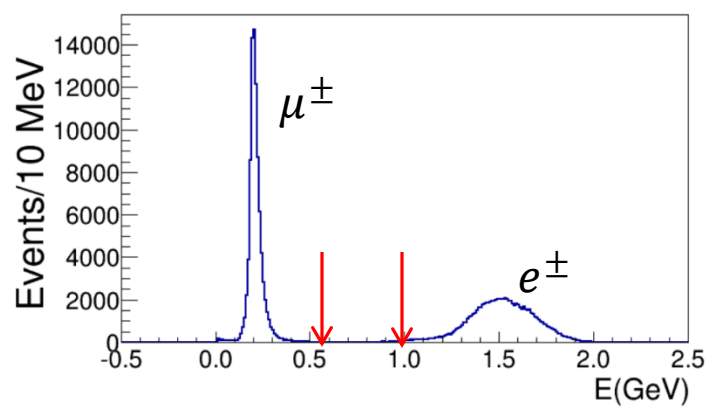
Good photon:

$0 \leq TDC \leq 14$;
Barrel: $E > 25MeV$, $|cos\theta| < 0.8$; *Endcap*: $E > 50MeV$, $0.86 < |cos\theta| < 0.92$;
$N_\gamma \geq 2$.

Particle identification:

$\pi^\pm : P_{mdc} < 0.6GeV$;
$e^\pm : P_{mdc} > 1.0GeV \& E_{emc} > 1.0GeV$; $\mu^\pm : P_{mdc} > 1.0GeV \& E_{emc} < 0.6GeV$;



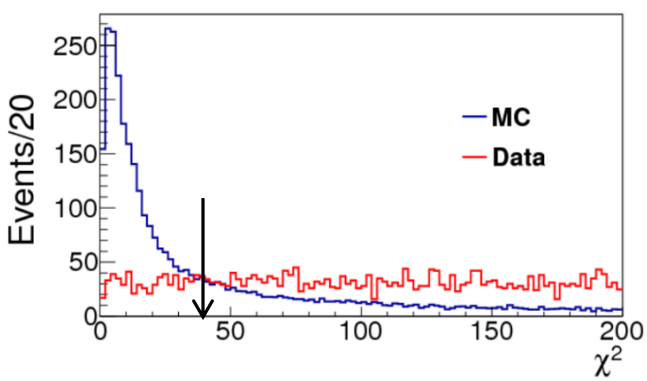


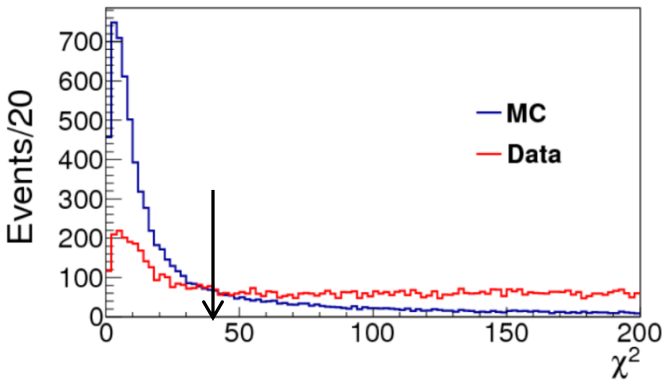
Event selection

4C kinematic fit:

$\chi^2_{4C} < 40$;

left: $J/\psi \rightarrow e^+e^-$
Right: $J/\psi \rightarrow \mu^+\mu^-$

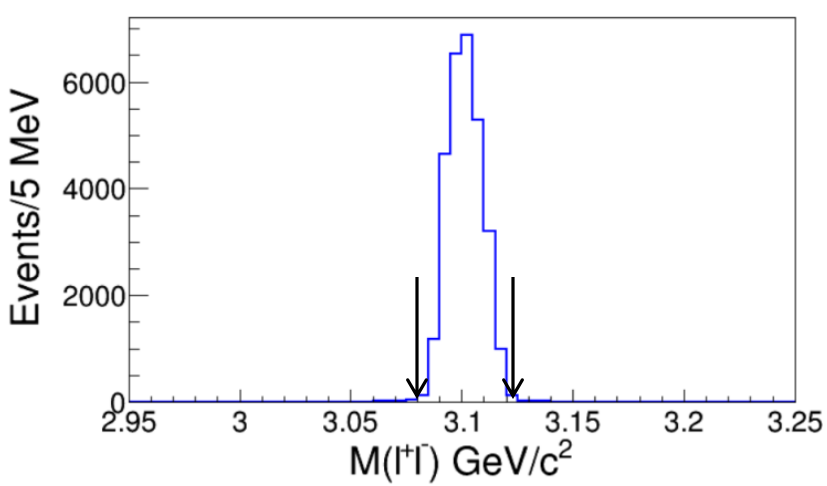


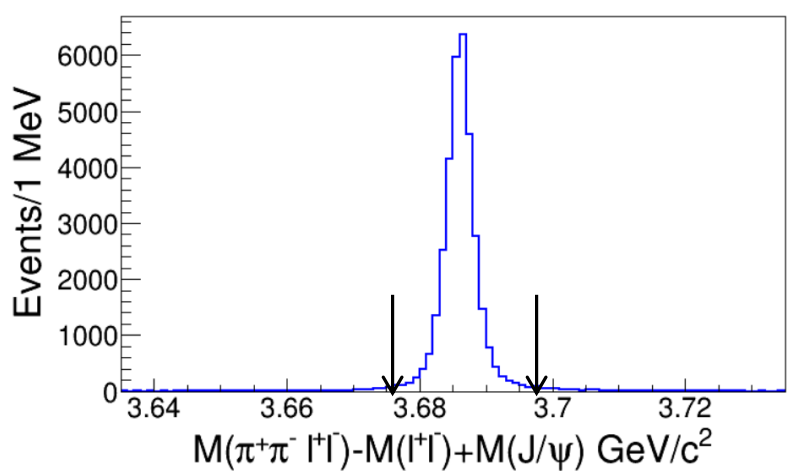


Other selections:

J/ψ *mass window*:
$[3.08 - 3.12] GeV$

$\psi(2S)$ *mass window*:
$[3.678 - 3.706] GeV$

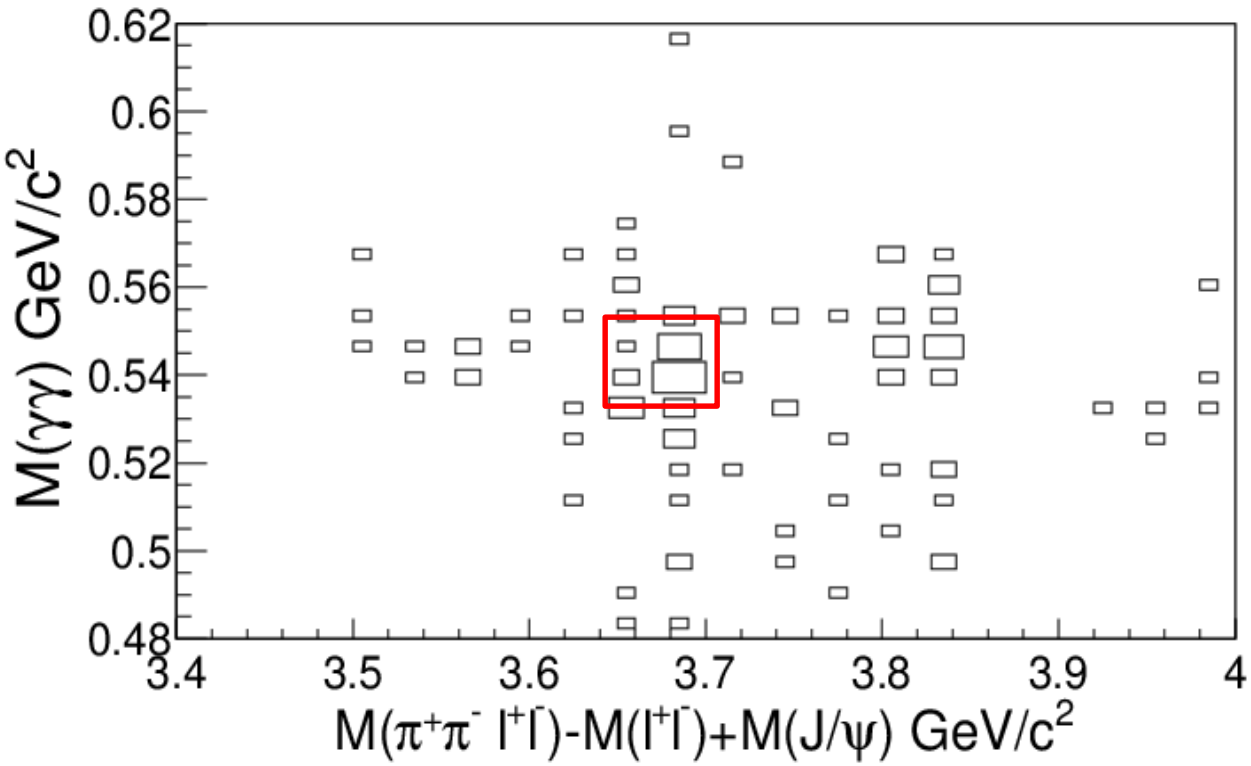




Data and background analysis

$M(\gamma\gamma)$ vs. $M(\pi^+\pi^- l^+l^-) - M(l^+l^-) + M(J/\psi)$

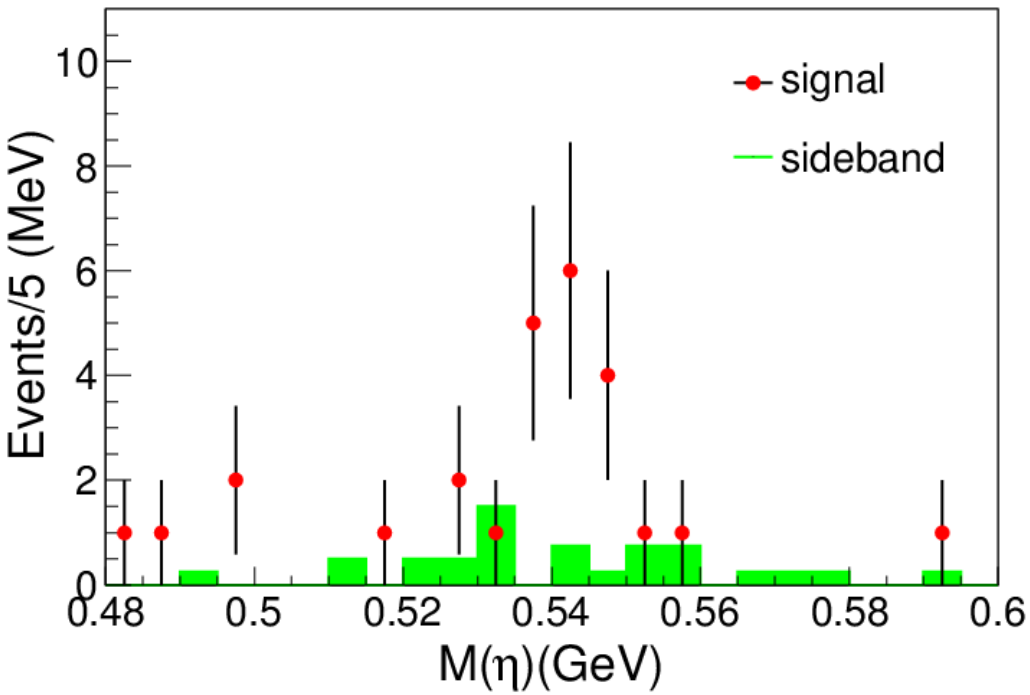
Full data samples



Background shape estimation (sideband)

$\psi(2S)\ signal\ range$: $[3.666, 3.706] GeV;$
$\psi(2S)\ sideband\ range$: $[3.626, 3.666] GeV\ and\ [3.706,\ 3.746] GeV.$

full



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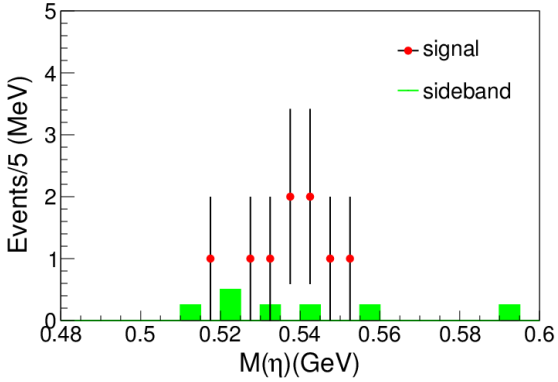
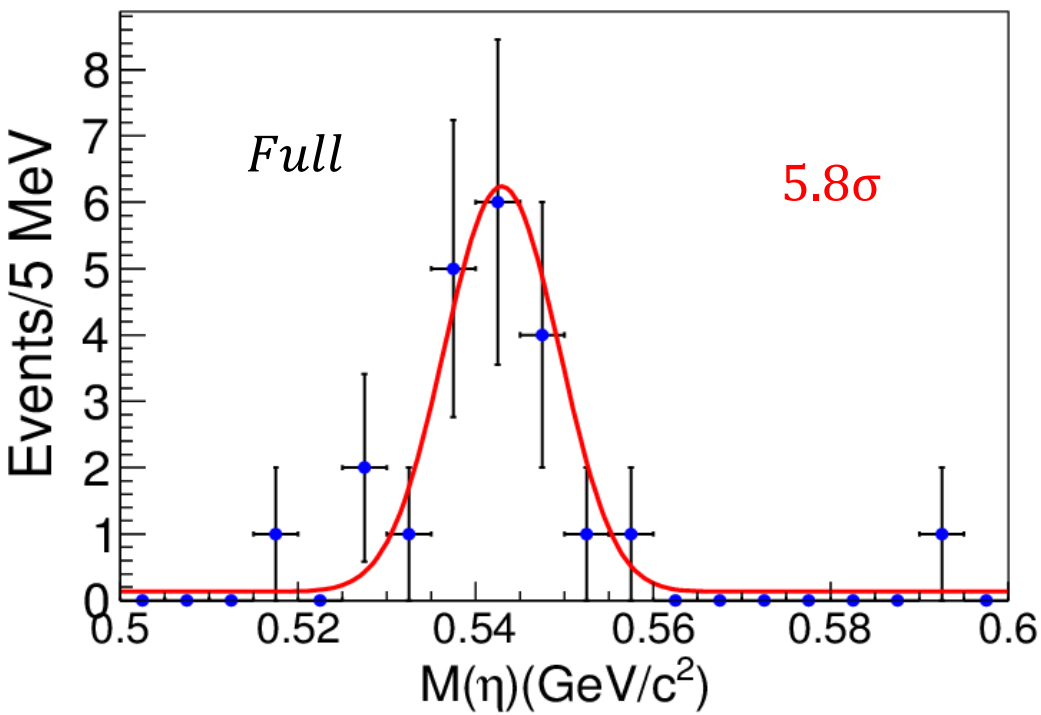


Signal extraction: Simultaneous fit

Signal shape: Double Gaussian function.

(Resolutions are determined by MC samples and the number of events of each channel is constrained by $\epsilon_i B_i$.)

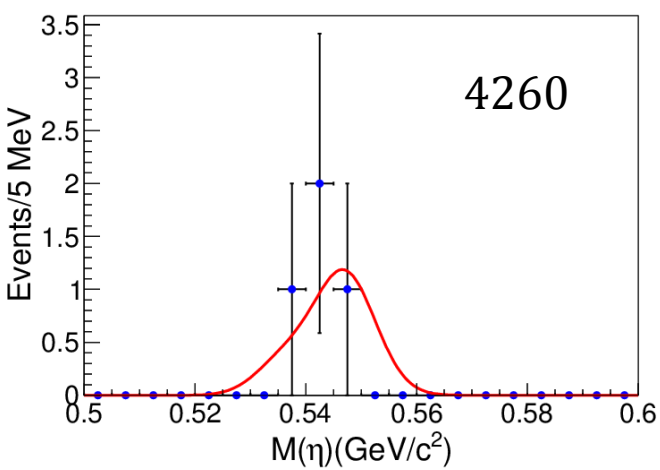
Background shape: Linear function at all energy points.

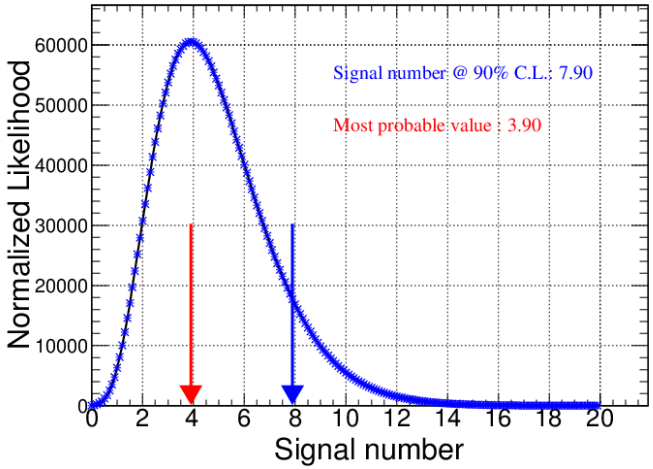


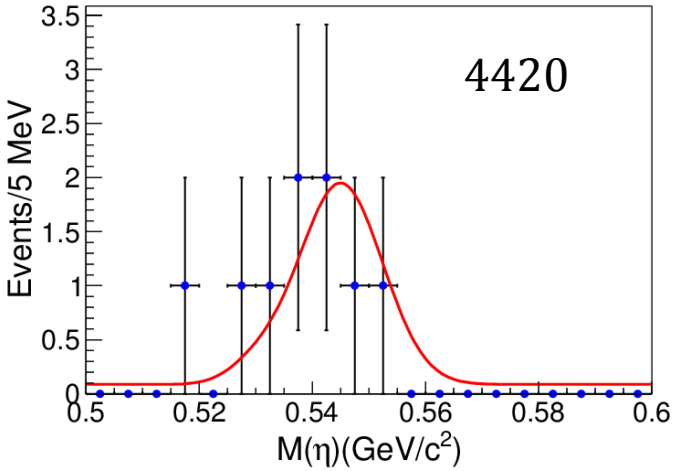
N^{obs} *is* 19 ± 6;

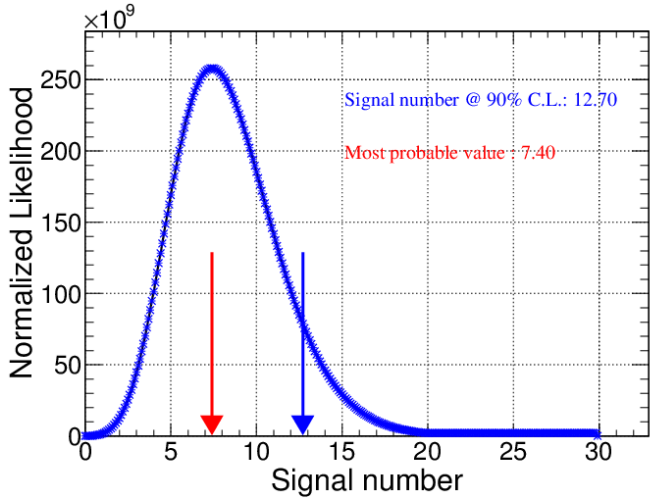
Statistical significance is less than 5σ *at other energy points, and the biggest one is* 3.1σ.

Signal extraction: Simultaneous fit

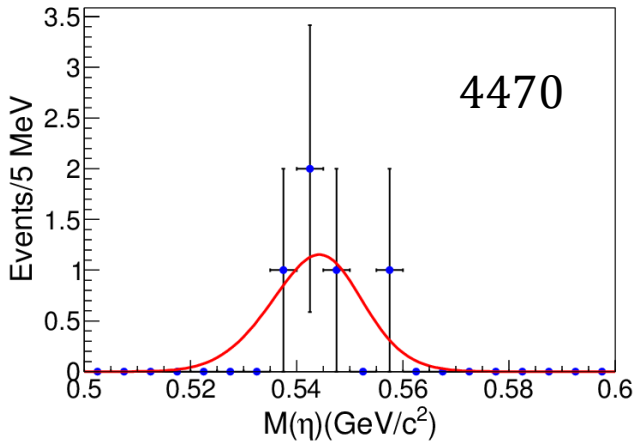


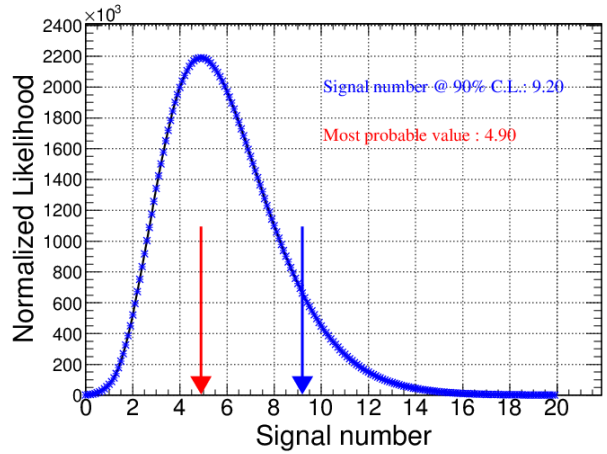


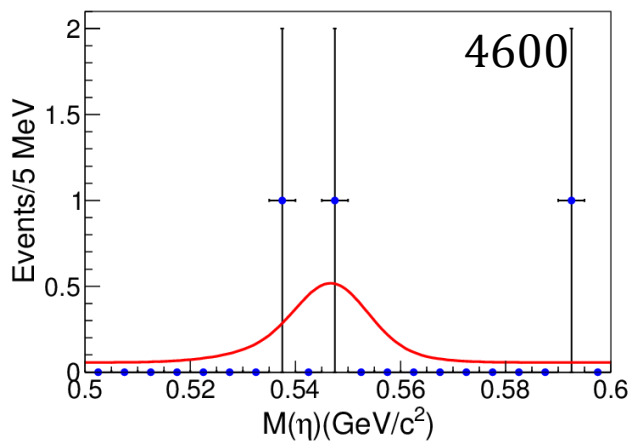


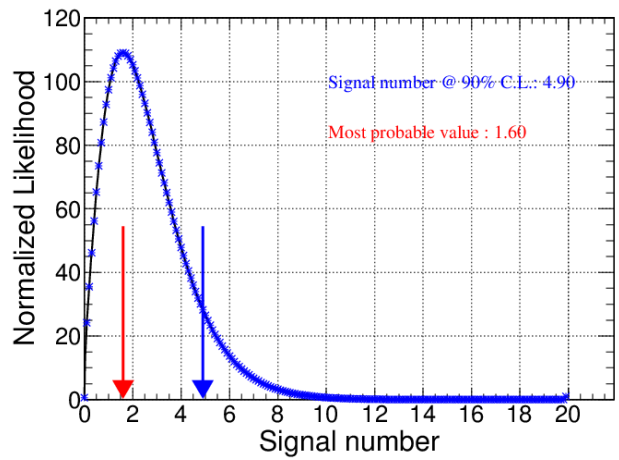


Signal extraction: Simultaneous fit









Cross section measurement

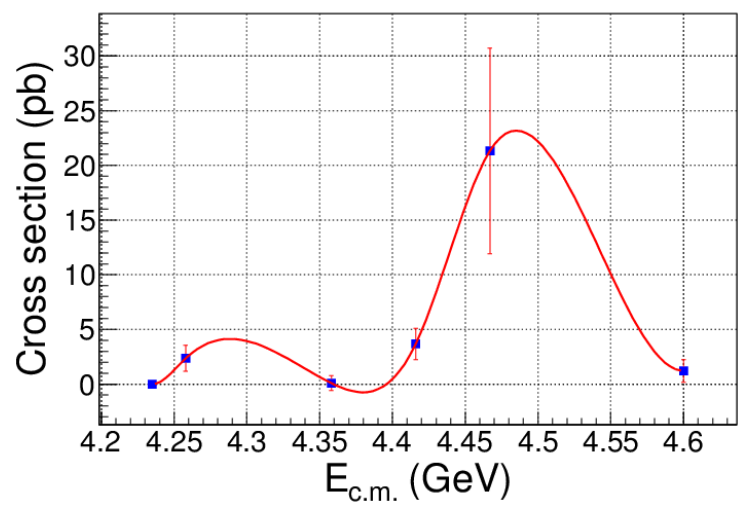
The Born cross section is calculated using the formula:

$$\sigma^{\mathrm{B}} = \frac{N^{\mathrm{obs}}}{L_{\mathrm{int}} \cdot (1+\delta) \cdot |1+\Pi|^2 \cdot \sum_{i=1}^{4} \epsilon_i \mathcal{B}_i}$$

Input this shape in generator!

$$1+\delta = \frac{\int_0^1 \sigma(s(1-x))F(x,s)dx}{\sigma(s)}$$

Cubic spline



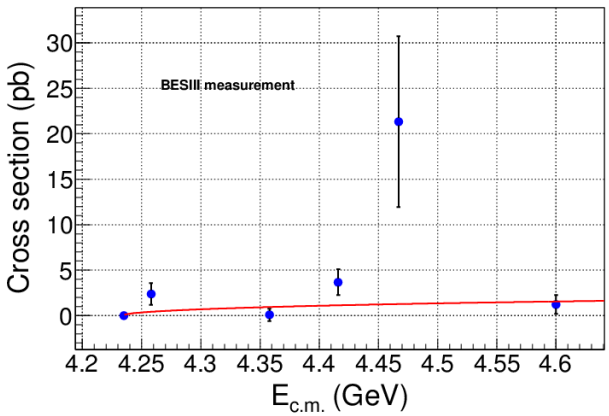
Cross section measurement

$\sqrt{s}$ (GeV)	N^{obs}	L_{int} (pb^{-1})	$1+\delta$	$\sum \epsilon_i \mathcal{B}_i$ (10^{-2})	$\lvert 1+\Pi \rvert^2$	σ^B (pb)
4.258	3.9 ± 2.0 (< 5.9)	825.7	0.674	0.28	1.054	$2.4 \pm 1.2 \pm 0.6$ (< 6.3)
4.416	7.4 ± 1.5 (< 5.9)	1028.9	0.807	0.23	1.053	$3.7 \pm 1.4 \pm 0.9$ (< 8.4)
4.467	4.9 ± 2.3 (< 7.9)	109.9	0.745	0.27	1.055	$21.3 \pm 9.4 \pm 4.9$(< 52.0)
4.600	1.6 ± 2.1 (< 8.3)	566.9	1.802	0.12	1.055	$1.2 \pm 1.1 \pm 0.4$ (< 5.6)
4.308	0.0 ± 0.8(< 15.9)	44.9	0.768	0.25	1.052	< 33.2
4.358	0.1 ± 0.7 (< 14.8)	539.8	0.899	0.23	1.051	< 3.9
4.387	0.0 ± 0.7 (< 5.3)	55.2	1.593	0.15	1.051	< 24.2
4.527	0.0 ± 0.7 (< 9.0)	110.0	0.863	0.24	1.055	< 12.8
4.575	0.0 ± 0.5 (< 7.9)	47.7	1.248	0.18	1.055	< 27.3

Systematic error estimation

$Sources$	$Method$
$Luminosity$	1.0% $using\ Bhabha\ events$
$Background\ shape$	$Try\ a\ 2^{nd}\ order\ polynomial$
$Fitting\ range$	$Vary\ the\ fitting\ range$
$ISR\ correction$	$Use\ different\ shapes\ of\ \sigma$
$Photon$	$1.0\%\ \ per\ photon$
$Tracking$	$1.0\%\ \ per\ charged\ track$
$J/\psi\ \ mass\ window$	$Use\ \gamma^{ISR}\psi(2S)\ contral\ sample\ to\ estimate$
$\psi(2S)\ \ mass\ window$	$Vary\ the\ mass\ range$
$Kinematic\ fit$	$Correct\ the\ track\ helix\ parameters\ and\ take\ the\ difference\ between\ MC\ with\ and\ without\ correction$
$Branching\ fraction$	$Taken\ from\ PDG$

ISR correction



two body phase space function

Energy(GeV)	$1+\delta$	$(1+\delta)\sum \epsilon_i B_i (10^{-3})$
4.258	0.712	1.907
4.308	0.777	1.896
4.358	0.807	1.918
4.387	0.819	1.940
4.416	0.830	1.890
4.467	0.844	1.921
4.527	0.859	1.939
4.575	0.867	2.041
4.600	0.872	2.010

Source/$\sqrt{s}$ (GeV)	4.258	4.416	4.467	4.600	4.308	4.358	4.387	4.527	4.575
Luminosity	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Background shape	0.2	9.7	0.1	21.9	9.7	9.7	9.7	9.7	9.7
Fitting range	7.0	1.2	0.1	8.7	1.2	1.2	1.2	1.2	1.2
ISR correction	1.1	1.5	3.1	9.5	2.9	8.0	17.3	7.5	10.9
Photon	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Tracking	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Kinematic fit	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
J/ψ mass window	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
$\psi(2S)$ mass window	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
Branching fraction	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Total	23.8	24.8	22.9	34.1	24.9	26.0	30.2	25.9	27.1

Summary and plans

- Observed the $e^+e^- \to \eta\psi(2S)$ process with a statistical significance of 5.8σ from full data sets.
- Born Cross sections are measured at 4.258, 4.416, 4.467 and 4.6 GeV with large statistical error.
- There seems enhancement around the threshold, new data will be very helpful.
- Systematic uncertainties are estimated.
- Include more decays of η and ψ(2S), $\eta \to 3\pi$, and $\psi(2S) \to l^+l^-$, by Song Jiaojiao
- Analyze the data at 4.237 GeV and the coming data.

Thanks for your attention.