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Measurements of Born Cross Section of $e^+e^- \to D_s D_{s1}(2460)$ and $e^+e^- \to D_s^* D_{s1}(2460)$

TianYu Qi

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Motivation

1. $D_{s1}(2460)$, first observed in 2003 by CLEO[1] and Belle[2] Collaborations via $D_s \pi^0 \gamma$, and subsequently confirmed by BaBar Collaboration[3].
2. Could be one of the missing $c\bar{s}$ 1^+ state.
3. However, its mass is (2459.5 ± 0.6) MeV$/c^2$, lower than the prediction, and its width is unexpectedly narrow.
4. Also, can be a good candidate for D^*K molecule state[4, 5, 6], or a mixture of $c\bar{s}$ and D^*K state[7].

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2. Could be one of the missing $c\bar{s}$ 1^+ state.
3. However, its mass is (2459.5 ± 0.6) MeV$/c^2$, lower than the prediction, and its width is unexpectedly narrow.
4. Also, can be a good candidate for D^*K molecule state[4, 5, 6], or a mixture of $c\bar{s}$ and D^*K state[7].

Ref. [8] predicts that the cross section of two D_s channel should follow the excitation behavior for S wave production:

$$\sigma\left[e^+e^- \to D_{s0}^*(2317)D_s^*\right] = \sigma\left[e^+e^- \to D_sD_{s1}(2460)\right] \propto \sqrt{E_{cm} - E_0}$$

$E_{cm} = \sqrt{s}$, and $E_0 \approx 4.43$ GeV is the threshold of both channel. It also suggests to test it on BESIII.

Analysis Strategy

In this analysis, We can reconstruct $D_s^\pm$ from $D_s^\pm \to K^+K^-\pi^\pm$, and reconstruct $D_s^{*\pm}$ from $D_s^{*\pm} \to \gamma D_s^\pm$. Then, we will observe $D_{s1}(2460)$ in the D_s and D_s^* recoil spectrum.

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For the study of $e^+e^- \to D_s^+D_{s1}^-(2460)$, in order to lower the background, we divide the D_s recoil spectrum into bins, and fit the D_s invariant mass spectrum in each bin. Then, we use the event count from the fit result to form and fit a D_s recoil spectrum from what we considered as real D_s event, and then get the $D_{s1}(2460)$ count.

Dataset

Data Point

$e^+e^- \to D_sD_{s1}(2460)$ at four data points above $\sqrt{s} \geq 4.467$ GeV.
$e^+e^- \to D_s^*D_{s1}(2460)$ at $\sqrt{s} = 4.575, 4.600$ GeV.

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BOSS version 7.0.3

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BOSS version 7.0.3

MC simulations

Create MC samples of these two channels, with $D_s^{*+} \to \gamma D_s^+$, $D_s^+ \to K^+K^-\pi^+$.
$D_{s1}^-(2460)$ decays inclusively.
The sixth comes from $\Gamma(D_{s1}(2460) \to \gamma D_s)/\Gamma(D_{s1}(2460) \to \gamma D_s^*)$ in Ref.[9].
ISR by KKMC.
Inclusive MC at $\sqrt{s} = 4.575, 4.600$ GeV under BOSS 6.6.5p01 are used.

$$
\begin{aligned}
D_{s1}^-(2460) &\to \pi^0 D_s^{*-} && B = 0.638 \\
&\to \gamma D_s^- && B = 0.18 \\
&\to \pi^+\pi^- D_s && B = 0.043 \\
&\to \gamma D_{s0}^{*-}(2317) && B = 0.037 \\
&\to \pi^0\pi^0 D_s^- && B = 0.022 \\
&\to \gamma D_s^{*-} && B = 0.08 \\
D_{s0}^*(2317) &\to \pi^0 D_s && B = 1.0
\end{aligned} \quad (1)
$$

Dataset

The cross section inputted is shown below, comes from rough measurement of cross section at four points. Use Gaussian for interpolation.

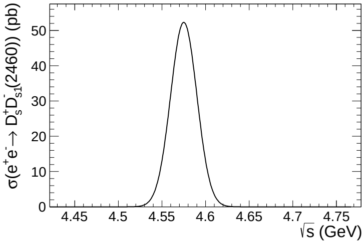

Figure: Cross section inputted for computing Initial State Radiation(ISR)

Selection Criteria

Basic selection

1. Charged Track: Begin from the interaction point, $V_{xy} < 1\text{cm}, |V_z| < 10\text{cm}$, and lie in $|\cos\theta| < 0.93$.
2. Neutral track:
    1. Deposit energy > 25 MeV in barrel EMC ($|\cos\theta| < 0.8$), > 50 MeV in end-cap EMC($0.86 < |\cos\theta| < 0.92$).
    2. Angle between this track and the nearest charged track larger than 20 degree.
    3. Time information from EMC:$0 < t < 14$ (50ns).
3. Use PID to separate Kaon and pion: If $Prob(K) > Prob(\pi)$ and $Prob(K) > 0.001$, it is considered as Kaon. On the contrary, it is considered as pion.

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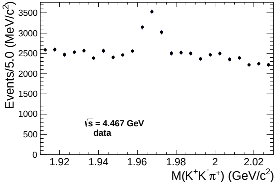
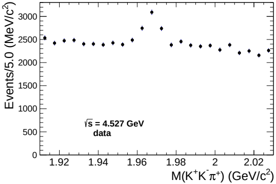
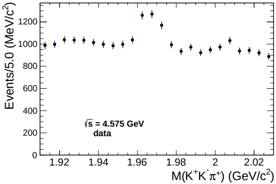
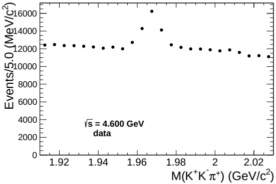
$e^+e^- \to D_s^+D_{s1}^-(2460) + c.c.$

Require at least three good charged tracks. Perform a vertex fit.

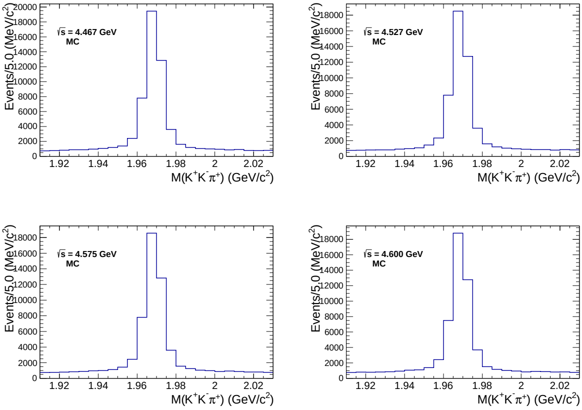








$e^+e^- \to D_s^+ D_{s1}^-(2460) + c.c.$



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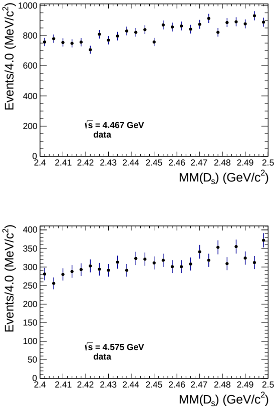

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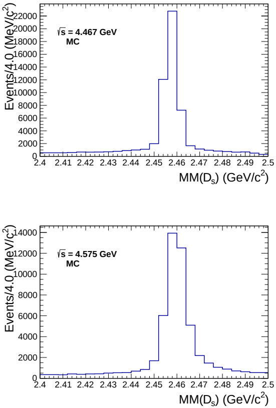

Inclusive MC sample

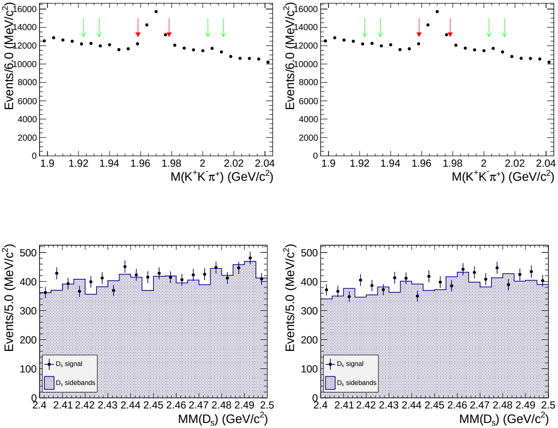

Figure: The D_s recoil mass spectrum only with D_s mass window cut, along with D_s sidebands.

Inclusive MC sample

We use the method stated before, fit entire D_s invariant mass spectrum, fix the signal shape, and fit the $M(D_s)$ in each bin.

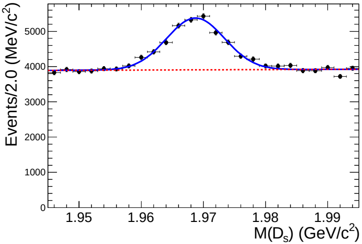

Figure: Fit the entire D_s invariant mass spectrum, for inclusive MC simulation at 4.575 GeV(left) and 4.600 GeV(right).

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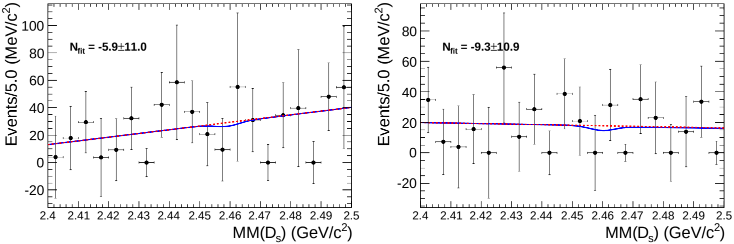


Figure: Divide the D_s recoil mass spectrum into bins, fit D_s invariant mass spectrum in each bin to get the real D_s event count, and then fit the D_s recoil mass spectrum, for inclusive MC simulation at 4.575 GeV(left) and 4.600 GeV(right).

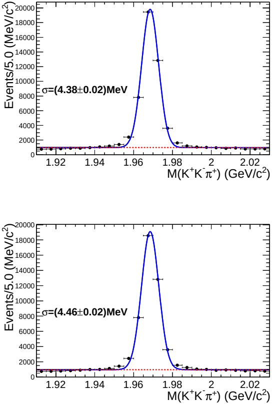
Background for $e^+e^- \to D_s^+D_{s1}^-(2460)$

Potential backgrounds are listed below:

index	event tree	nEvts
1	$e^+e^- \to \pi^+D^-D^{*0}, D^-\to\pi^-\pi^-K^+, D^{*0}\to\pi^0D^0, D^0\to\pi^0\pi^+K^-$	10
2	$e^+e^- \to \pi^+\bar{D}^{*-}D^{*0}, \bar{D}^{*-}\to\pi^-\bar{D}^0, D^{*0}\to\pi^0D^0, \bar{D}^0\to\pi^0\pi^-K^+, D^0\to\pi^0\pi^+K^-$	9
3	$e^+e^- \to \pi^-D^{*+}\bar{D}^0, D^{*+}\to\pi^+D^0, \bar{D}^0\to\pi^0\pi^-K^+, D^0\to\pi^0\pi^+K^-$	8
4	$e^+e^- \to \pi^-D^+\bar{D}^{*0}, D^+\to\pi^+\pi^+K^-, \bar{D}^{*0}\to\pi^0\bar{D}^0, \bar{D}^0\to\pi^0\pi^-K^+$	8
5	$e^+e^- \to \pi^-D^{*+}\bar{D}^0, D^{*+}\to\pi^+D^0, \bar{D}^0\to\pi^0\pi^-K^+, D^0\to K^-a_1^+, a_1^+\to\rho^0\pi^+,$ $\rho^0\to\pi^+\pi^-$	8
6	$e^+e^- \to \bar{D}^0D^{*0}, \bar{D}^0\to\pi^0\pi^-K^+, D^{*0}\to D^0\gamma, D^0\to\pi^0\pi^+K^-$	8
7	$e^+e^- \to \pi^+D^-D^{*0}, D^-\to\pi^-\pi^-K^+, D^{*0}\to D^0\gamma, D^0\to\pi^0\pi^+K^-$	7
8	$e^+e^- \to D^0\bar{D}^{*0}, D^0\to\pi^0\pi^+K^-, \bar{D}^{*0}\to\pi^0\bar{D}^0, \bar{D}^0\to\pi^0\pi^-K^+$	7
9	$e^+e^- \to D^+\bar{D}^{*-}, D^+\to\mu^+\nu_\mu\bar{K}^*, \bar{D}^{*-}\to\pi^-\bar{D}^0, \bar{K}^*\to\pi^+K^-, \bar{D}^0\to\pi^0\pi^-K^+$	7
10	$e^+e^- \to \pi^-D^{*+}\bar{D}^0, D^{*+}\to\pi^+D^0, \bar{D}^0\to e^-\bar{\nu}_eK^+, D^0\to K^-a_1^+, a_1^+\to\rho^0\pi^+,$ $\rho^0\to\pi^+\pi^-$	7
11	$e^+e^- \to \pi^-D^+\bar{D}^{*0}, D^+\to\pi^+\pi^+K^-, \bar{D}^{*0}\to\pi^0\bar{D}^0, \bar{D}^0\to K^+a_1^-, a_1^-\to\rho^0\pi^-,$ $\rho^0\to\pi^+\pi^-$	6
12	$e^+e^- \to \pi^+\bar{D}^{*-}D^0, \bar{D}^{*-}\to\pi^-\bar{D}^0, D^0\to\pi^0\pi^+K^-, \bar{D}^0\to\pi^0\pi^-K^+$	6
13	$e^+e^- \to \pi^0D^-D^{*+}, D^-\to\pi^-\pi^-K^+, D^{*+}\to\pi^+D^0, D^0\to\pi^0\pi^+K^-$	6
14	$e^+e^- \to \pi^-D^+\bar{D}^{*0}, D^+\to\pi^+\pi^+K^-, \bar{D}^{*0}\to\pi^0\bar{D}^0, \bar{D}^0\to e^-\bar{\nu}_eK^+$	6
15	$e^+e^- \to D_s^+D_s^{*-}, D_s^+\to\pi^+K^+K^-, D_s^{*-}\to D_s^-\gamma, D_s^-\to\pi^-K^+K^-$	6
16	$e^+e^- \to \pi^-D^+\bar{D}^{*0}, D^+\to\pi^+\pi^+K^-, \bar{D}^{*0}\to\bar{D}^0\gamma, \bar{D}^0\to\pi^0\pi^-K^+$	6

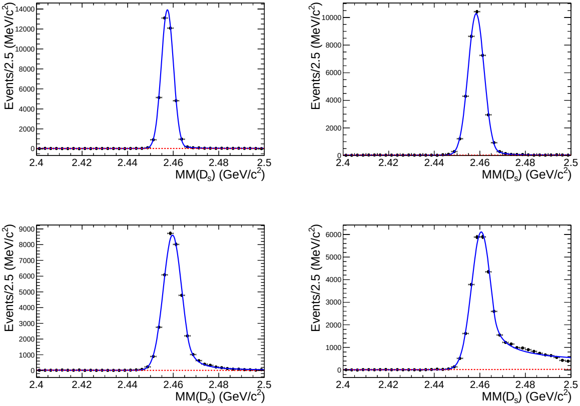
Fit of MC Simulation

First, fit the entire D_s invariant mass spectrum. Gaussian for signal, and 1st order polynomial for background. Then, fix the signal shape and fit the D_s invariant mass spectrum in each bin.



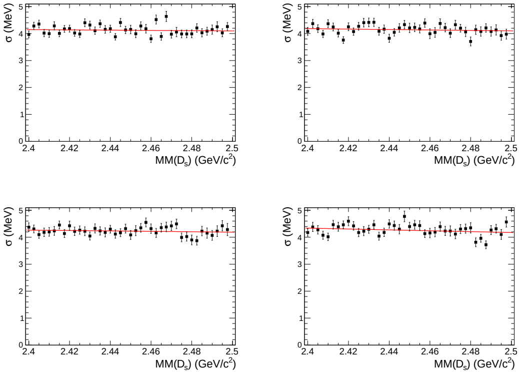
Fit of MC Simulation

After that, fit D_s recoil mass spectrum. Crystal ball for signal, 1st order polynomial for background.



Test Whether Resolution Varies

We perform a special MC simulation, where the width of $D_{s1}^-(2460)$ is set to 500 MeV, to ensure that we get enough events in each $MM(D_s)$ bin. Decay chain unchanged. Then, use the technique above to fit this sample; plot and linear fit the $\sigma - MM(D_s)$ spectrum from the fitting in each bin.



Fit of Data

After fitting the MC simulation, we perform the same fit for data.

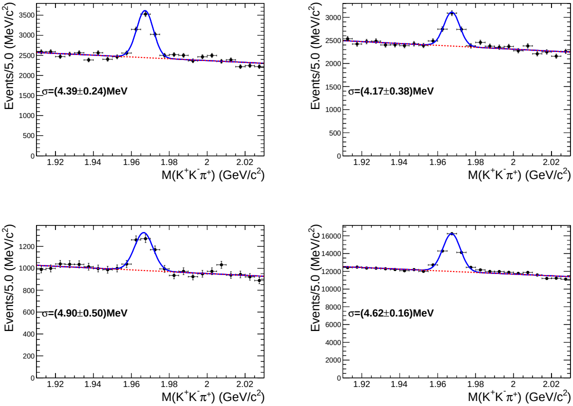
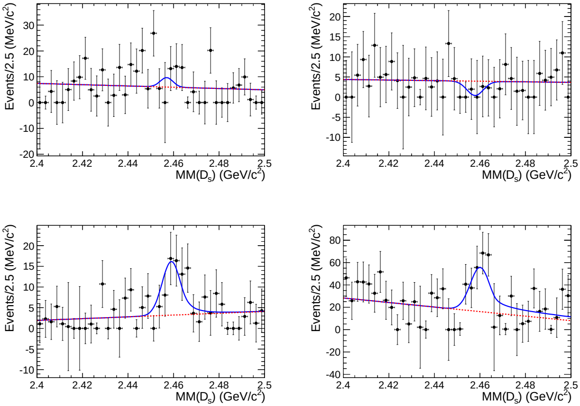


Figure: Fit the entire D_s invariant mass spectrum.

Fit of Data

Crystal ball convolve Gaussian for signal, where the Gaussian function represents the difference between data and MC on resolution and its σ is fixed to 0.9MeV. The shape of the Crystal ball function is fixed to the MC sample.



Fit Result

center-of-mass energy	efficiency	N_{event}	$(1+\delta)^{ISR}$	significance
4.467	37.4%	10.4 ± 7.4	1.035	1.5σ
4.527	36.4%	-13.0 ± 2.6	0.687	—
4.575	38.6%	49.3 ± 9.0	0.715	7.5σ
4.600	35.3%	218.6 ± 24.6	1.053	11.9σ

Table: N_{event} come from data fitting and efficiency come from MC simulation. Errors here are statistical only.

Born Cross Section

$$\sigma = \frac{N_{obs}}{(1+\delta)^{VP} * \varepsilon_{D_s} * B(D_s \to K^+K^-\pi) * L * (1+\delta)^{ISR}} \quad (2)$$

- N_{obs} stands for the number of events come from fitting data;
- ε_{D_s} stands for the D_s detect efficiency;
- $B(D_s \to K^+K^-\pi)$ stands for the branch fraction of $D_s^\pm \to K^+K^-\pi^\pm$, which equals to 5.45% according to PDG[10];
- L stands for the integrated luminosity at each energy point;
- $(1+\delta)^{VP}$ stands for vacuum polarization factor, which equals to 1.055 at all four energy point[11];
- $(1+\delta)^{ISR}$ stands for initial state radiation correction factor, which can be read from KKMC.

Born Cross Section

energy point	σ
4.467	4.2 ± 3.0pb
4.527	-8.1 ± 1.6pb
4.575	65.37 ± 11.9pb
4.600	17.4 ± 2.0pb

Table: Born cross section of $e^+e^- \to D_s D_{s1}(2460)$ calculated at four energy point

It will be plotted later.

π^0 Tag

To decrease the background, we try tagging π^0 in the $D_{s1}(2460)$ decay product, which is actually, measuring the cross section of $e^+e^- \to D_s D_{s1}(2460), D_{s1}(2460) \to \pi^0 + anything$.

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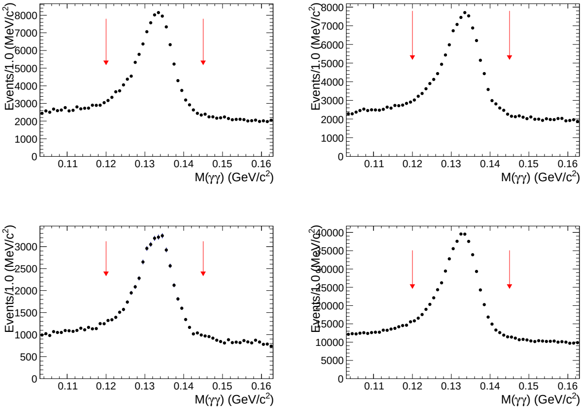

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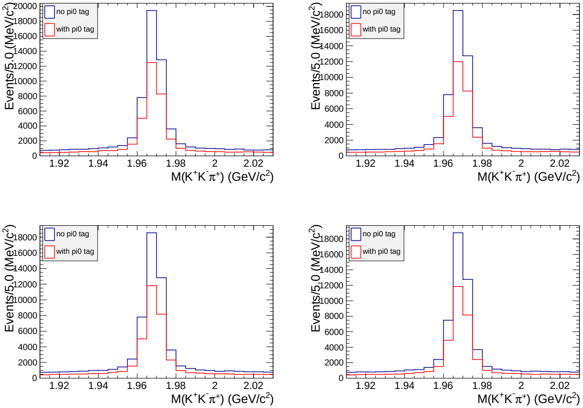


Figure: The entire D_s invariant mass spectrum with and without π^0 tag, for MC at 4.467 GeV(upper left), 4.527 GeV(upper right), 4.575 GeV(lower left) and 4.600 GeV(lower right).

π^0 Tag

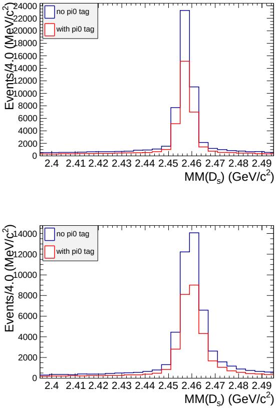


Figure: The D_s recoil mass spectrum with and without π^0 tag, for MC at 4.467 GeV(upper left), 4.527 GeV(upper right), 4.575 GeV(lower left) and 4.600 GeV(lower right).

π^0 Tag

The $D_{s1}^-(2460)$ in the signal MC sample here decays to products which only contains π^0, and the respective ratio of each channel is not changed.

$$\begin{aligned} D_{s1}^-(2460) &\to \pi^0 D_s^{*-} \quad B = 0.96 \\ &\to \pi^0\pi^0 D_s^- B = 0.04 \end{aligned} \tag{3}$$

π^0 Tag

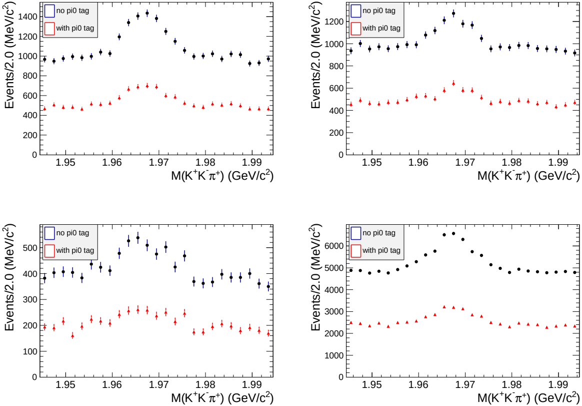


Figure: The entire D_s invariant mass spectrum with and without π^0 tag, for data at 4.467 GeV(upper left), 4.527 GeV(upper right), 4.575 GeV(lower left) and 4.600 GeV(lower right).

π^0 Tag

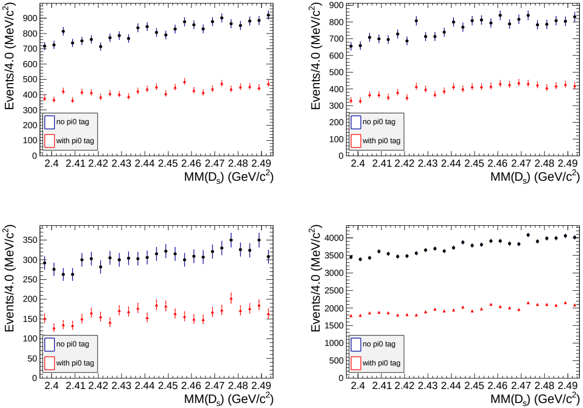
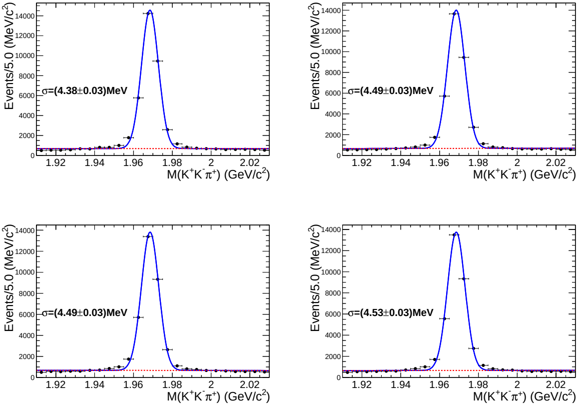


Figure: The D_s recoil mass spectrum with and without π^0 tag, for data at 4.467 GeV(upper left), 4.527 GeV(upper right), 4.575 GeV(lower left) and 4.600 GeV(lower right).

Fit of MC with π^0 Tag

Use the same procedure as we did without π^0 tag. First, Fit the entire D_s invariant mass spectrum.



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Fit of MC with π^0 Tag

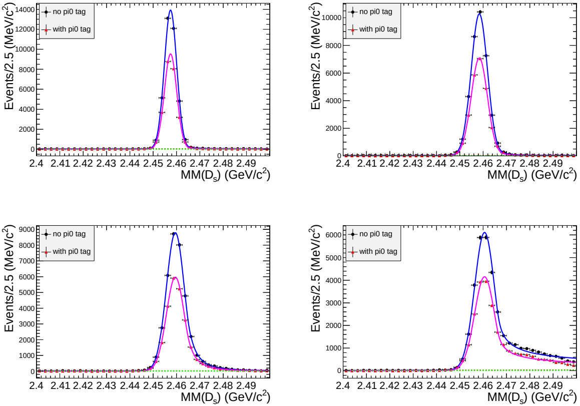
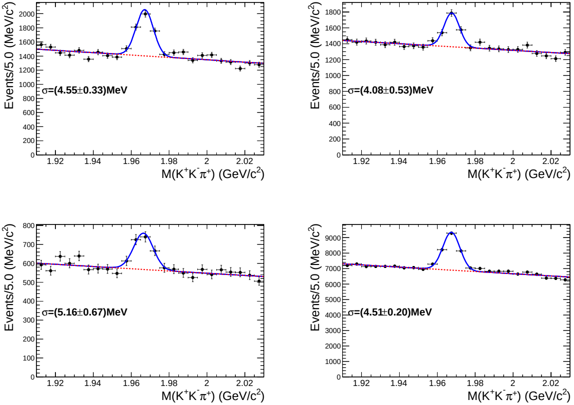


Figure: Fit in each bin to get the real D_s event count, and then fit the D_s recoil mass spectrum, with and without π^0 tag.

Fit of Data with π^0 Tag

Then, we perform the same fit for data.



Fit of Data with π^0 Tag

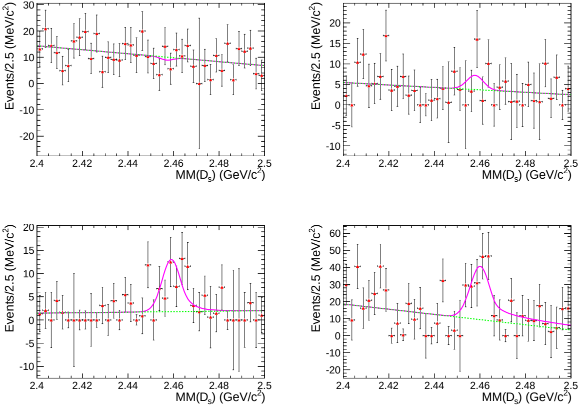


Figure: Fit in each bin to get the real D_s event count, and then fit the D_s recoil mass spectrum, with and without π^0 tag.

Fit Result

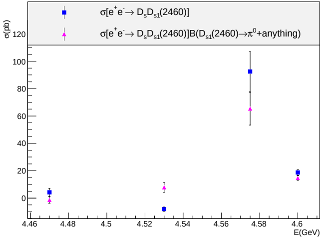
center-of-mass energy	efficiency	N_{event}	$(1+\delta)^{ISR}$	significance
4.467	28.9%	-3.3 ± 6.1	1.035	—
4.527	28.6%	12.7 ± 5.9	0.684	2.5σ
4.575	24.6%	49.3 ± 9.0	0.706	7.3σ
4.600	27.0%	185.39 ± 21.1	1.061	11.1σ

Table: N_{event} come from data fitting and efficiency come from MC simulation. Errors here are statistical only.

Born Cross Section

energy point	σ
4.467	-1.3 ± 2.5pb
4.527	7.9 ± 3.7pb
4.575	65.4 ± 11.9pb
4.600	14.7 ± 1.7pb

Table: Born cross section of $e^+e^- \to D_sD_{s1}(2460), D_{s1}(2460) \to \pi^0 + anything$ calculated at four energy point



Branch Fraction

So, we can obtain $B(D_{s1}(2460) \to \pi^0 + anything)$ by dividing $\sigma[e^+e^- \to D_sD_{s1}(2460), D_{s1}(2460) \to \pi^0 + anything]$ by $\sigma[e^+e^- \to D_sD_{s1}(2460)]$.

energy point	$B(D_{s1}(2460) \to \pi^0 + anything)$
4.575	$(70.7 \pm 17.0)\%$
4.600	$(78.3 \pm 12.0)\%$

$e^+e^- \to D_s^{*+}D_{s1}^-(2460) + c.c.$

Special Event Selection

Require at least three good charged tracks and one good photon. Perform a vertex fit on $K^+K^-\pi^+$, then a two-constraint (2C) kinematic fit, with the mass constraints of D_s and D_s^* .

$e^+e^- \to D_s^{*+} D_{s1}^-(2460) + c.c.$

Special Event Selection

Require at least three good charged tracks and one good photon. Perform a vertex fit on $K^+K^-\pi^+$, then a two-constraint (2C) kinematic fit, with the mass constraints of D_s and D_s^* .

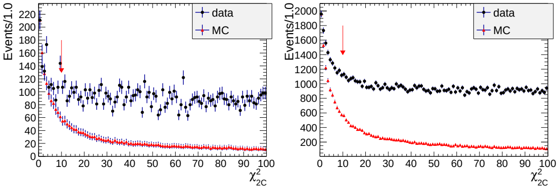
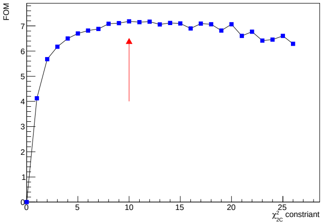


Figure: 4.575 GeV(left) and 4.6 GeV(right).

Here MC simulation is normalized to data with event in the first bin being the same.

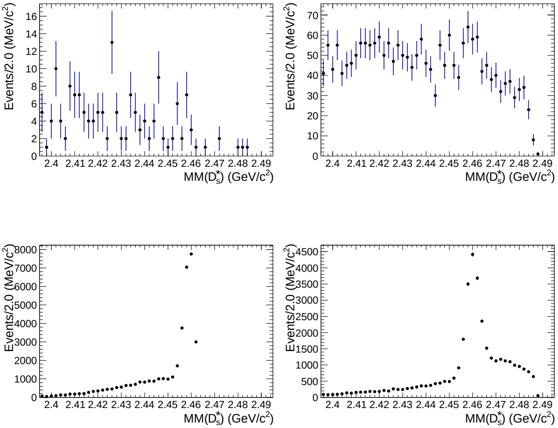
Optimize the χ^2 cut

Optimized by FOM value: $\frac{s}{\sqrt{s+B}}$
s: expected observed event,
$s = \sigma * (1+\delta)^{VP} * \varepsilon_{D_s^*} * B(D_s^* \to \gamma D_s) * B(D_s \to K^+K^-\pi) * L * (1+\delta)^{ISR}$
the σ comes from rough measurement of the cross section at $\sqrt{s} = 4.575$ GeV: $24pb$;
$\varepsilon_{D_s^*}$: the efficiency under variant χ^2_{2C} constraint.
B: the background event count from inclusive MC sample in the D_s^* signal range.



Distribution

The distribution of $MM(D_s^*)$ for data(above) and MC(below), at 4.575 GeV(left) and 4.6 GeV(right).



Inclusive MC sample

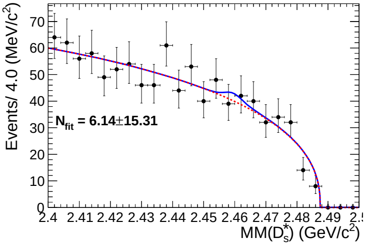


Figure: The distribution of $MM(D_s^*)$ for inclusive MC sample at $\sqrt{s} = 4.6$ GeV.

Background for $e^+e^- \to D_s^+ D_{s1}^-(2460)$

Potential backgrounds are listed below:

index	event tree	nEvts
1	$e^+e^- \to \pi^+ D^- D^{*0}, D^- \to \pi^0\pi^- K^+ K^-, D^{*0} \to D^0\gamma, D^0 \to \pi^0\pi^+ K^-$	2
2	$e^+e^- \to \pi^+\bar{D}^{*-}D^0, \bar{D}^{*-} \to \pi^-\bar{D}^0, D^0 \to \pi^0\pi^+K^-, \bar{D}^0 \to K^+ a_1^-, a_1^- \to \pi^0\rho^-,$ $\rho^- \to \pi^0\pi^-$	2
3	$e^+e^- \to \pi^- D^+ \bar{D}^{*0}, D^+ \to \pi^+\pi^+K^-, \bar{D}^{*0} \to \pi^0\bar{D}^0, \bar{D}^0 \to \pi^-\omega K^+, \omega \to \pi^0\pi^+\pi^-$	2
4	$e^+e^- \to \pi^+\bar{D}^{*-}D^0, \bar{D}^{*-} \to \pi^-\bar{D}^0, D^0 \to K^- a_1^+, \bar{D}^0 \to e^-\bar{\nu}_e K^{*+}, a_1^+ \to \rho^0\pi^+,$ $K^{*+} \to \pi^0 K^+, \rho^0 \to \pi^+\pi^-$	2
5	$e^+e^- \to \pi^0 D^{*0}\bar{D}^{*0}, D^{*0} \to \pi^0 D^0, \bar{D}^{*0} \to \bar{D}^0\gamma, D^0 \to K^- a_1^+, \bar{D}^0 \to K^+ a_1^-,$ $a_1^+ \to \rho^0\pi^+, a_1^- \to \pi^0\rho^-, \rho^0 \to \pi^+\pi^-, \rho^- \to \pi^0\pi^-$	2
6	$e^+e^- \to D^- D^{*+}, D^- \to \pi^-\pi^-K^+, D^{*+} \to \pi^+ D^0, D^0 \to \pi^0\pi^+K^-$	2
7	$e^+e^- \to D^{*0}\bar{D}^{*0}, D^{*0} \to D^0\gamma, \bar{D}^{*0} \to \pi^0\bar{D}^0, D^0 \to K^- a_1^+, \bar{D}^0 \to K^0\phi,$ $a_1^+ \to \rho^0\pi^+, K^0 \to K_L, \phi \to K^+K^-, \rho^0 \to \pi^+\pi^-$	2
8	$e^+e^- \to \pi^0 D^{*0}\bar{D}^{*0}, D^{*0} \to D^0\gamma, \bar{D}^{*0} \to \bar{D}^0\gamma, D^0 \to K^- a_1^+, \bar{D}^0 \to K^+ a_1^-,$ $a_1^+ \to \pi^0\rho^+, a_1^- \to \rho^0\pi^-, \rho^+ \to \pi^0\pi^+, \rho^0 \to \pi^+\pi^-$	1
9	$e^+e^- \to \bar{D}^0 D^{*0}, \bar{D}^0 \to \mu^-\bar{\nu}_\mu K^{*+}, D^{*0} \to \pi^0 D^0, K^{*+} \to \pi^0 K^+, D^0 \to K^- a_1^+,$ $a_1^+ \to \rho^0\pi^+, \rho^0 \to \pi^+\pi^-$	1
10	$e^+e^- \to \pi^- D^{*+}\bar{D}^{*0}, D^{*+} \to \pi^+ D^0, \bar{D}^{*0} \to \bar{D}^0\gamma, D^0 \to K^- a_0^+, \bar{D}^0 \to \rho^0 K^*,$ $a_0^+ \to \pi^+\eta, \rho^0 \to \pi^+\pi^-, K^* \to \pi^- K^+, \eta \to \pi^0\pi^0\pi^0$	1
11	$e^+e^- \to D^{*0}\bar{D}^{*0}, D^{*0} \to \pi^0 D^0, \bar{D}^{*0} \to \pi^0\bar{D}^0, D^0 \to \pi^0\pi^0K^+K^-, \bar{D}^0 \to \pi^0\pi^+\pi^-K^*,$ $K^* \to \pi^0 K^0, K^0 \to K_S, K_S \to \pi^+\pi^-$	1
12	$e^+e^- \to D^{*0}\bar{D}^{*0}, D^{*0} \to \pi^0 D^0, \bar{D}^{*0} \to \bar{D}^0\gamma, D^0 \to \pi^0\pi^+K^-, \bar{D}^0 \to \pi^-\bar{K}^0K^+,$ $\bar{K}^0 \to K_S, K_S \to \pi^+\pi^-$	1
13	$e^+e^- \to \pi^+\bar{D}^{*-}D^{*0}, \bar{D}^{*-} \to \pi^-\bar{D}^0, D^{*0} \to \pi^0 D^0, \bar{D}^0 \to \pi^0\pi^-K^+, D^0 \to \pi^0\pi^+K^0K^-,$ $K^0 \to K_L$	1

Fit of MC

Argus for background, Crystal ball for signal.
The cross section used for computing Initial State Radiation(ISR) is the same as that in $e^+e^- \to D_s^+ D_{s1}^-(2460)$.

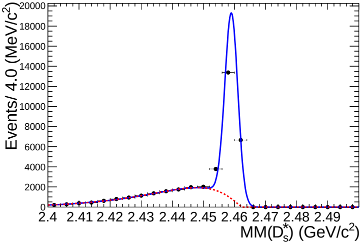


Figure: Fit of the recoil mass distribution of D_s^* for MC simulation, at 4.575 GeV(left) and 4.6 GeV(right).

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Fit of Data

Crystal ball convolve Gaussian for signal, where the Gaussian function represents the difference between data and MC on resolution and its σ is fixed to 0.9MeV.

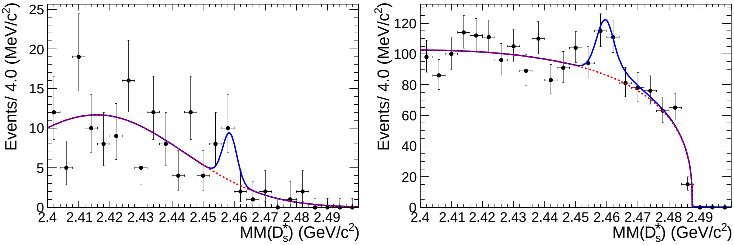


Figure: Fit of the recoil mass distribution of D_s^* for data at 4.575 GeV(left) and 4.6 GeV(right).

Fit Result

center-of-mass energy	efficiency	N_{event}	$(1+\delta)$	significance
4.575	19.7%	9.07 ± 3.91	0.709	2.8σ
4.600	15.8%	77.7 ± 22.8	1.060	3.4σ

Table: N_{event} come from data fitting and efficiency come from MC simulation. Errors here are statistical only.

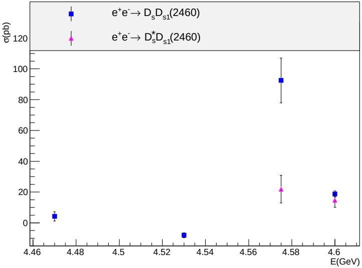
Born Cross Section

$$\sigma = \frac{N_{obs}}{(1+\delta)^{VP} * \varepsilon_{D_s^*} * B(D_s^* \to \gamma D_s) * B(D_s \to K^+ K^- \pi) * L * (1+\delta)^{ISR}} \quad (4)$$

energy point	σ
4.575	24.6 ± 10.6pb
4.600	14.7 ± 4.5pb

Summary

1. Measured the born cross section of $e^+e^- \to D_sD_{s1}(2460)$ at 4 energy points, and $e^+e^- \to D_s^*D_{s1}(2460)$ at 2 energy points.
2. Systematic uncertainty in progress.
3. Not consistent with the prediction[8].



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$e^+e^- \to D_s^+ D_{s1}^-(2460)$

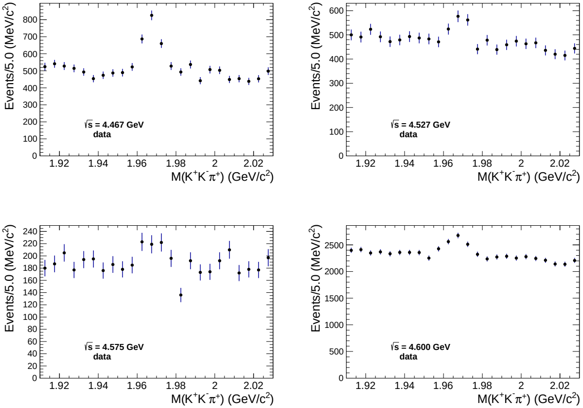

Figure: The distribution of $M(K^+K^-\pi^+)$ with the constraint of $MM(D_s)$ in the range of $[2.4, 2.5]$, for data.

Background for $e^+e^- \rightarrow D_s^+ D_{s1}^-(2460)$

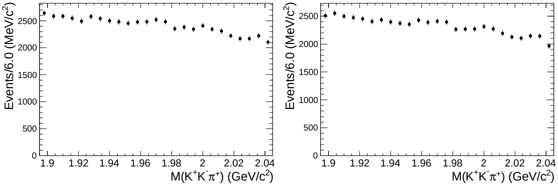

Figure: The D_s spectrum with $MM(D_s)$ in range [2.4, 2.5], for inclusive MC simulation at 4.575 GeV(left) and 4.600 GeV(right).