Selected Recent Results on Charm Hadronic Decays from BESIII

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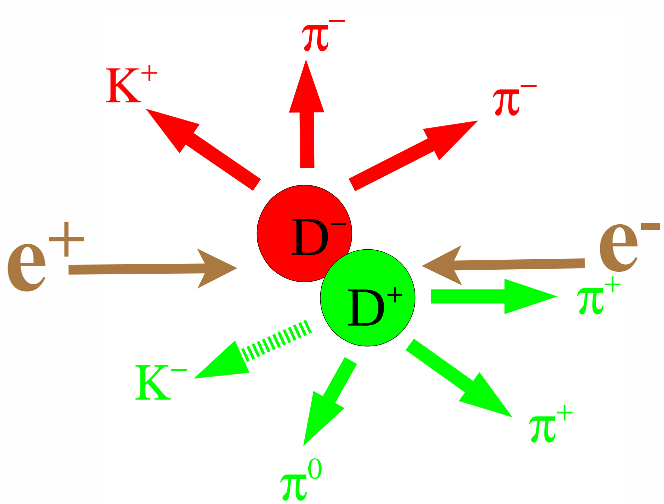
Outline

- A pair production of $D\bar{D}$ ($D_S^+D_S^-$) at mass threshold
- $\sigma(e^+e^- \rightarrow D\bar{D})$ at E_{cm} = 3.773 GeV
- Line shape of $\sigma(e^+e^- \rightarrow D\bar{D})$ around E_{cm} ~ 3.770 GeV
- 1st observation of SCSD, $D \rightarrow \omega\pi$
- $D_S^+ \rightarrow \eta' X$ and $D_S^+ \rightarrow \eta'\rho^+$

Charm @ mass threshold

- Around E_{cm} ~ 3.770 GeV , $e^+e^- \rightarrow \gamma^* \rightarrow D\bar{D}$
- Typical main backgrounds from
  $e^+e^- \rightarrow \gamma^* \rightarrow q\bar{q} \rightarrow$ light hadrons (q = u, d, and s).
  $\sigma(e^+e^- \rightarrow \gamma^* \rightarrow q\bar{q})$ is ~ 17 nb, while $\sigma(e^+e^- \rightarrow D\bar{D})$ ~ 6.5 nb.
- Typically, two ways to obtain the D yields:
  - ❖ Single Tag (ST) : Find only one D.
    - ➡Larger backgrounds
    - ➡Higher efficiencies
  - ❖ Double Tag (DT): Find both of them.
    - ➡Smaller backgrounds
    - ➡Smaller efficiencies



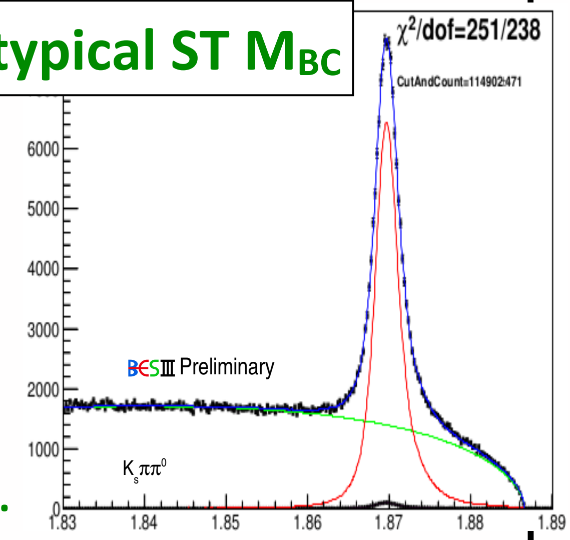
Two popular variables

- Beam-Constrained-Mass; $M_{BC} = \sqrt{(E_{beam}^2 - |\vec{p}_D|^2)}$

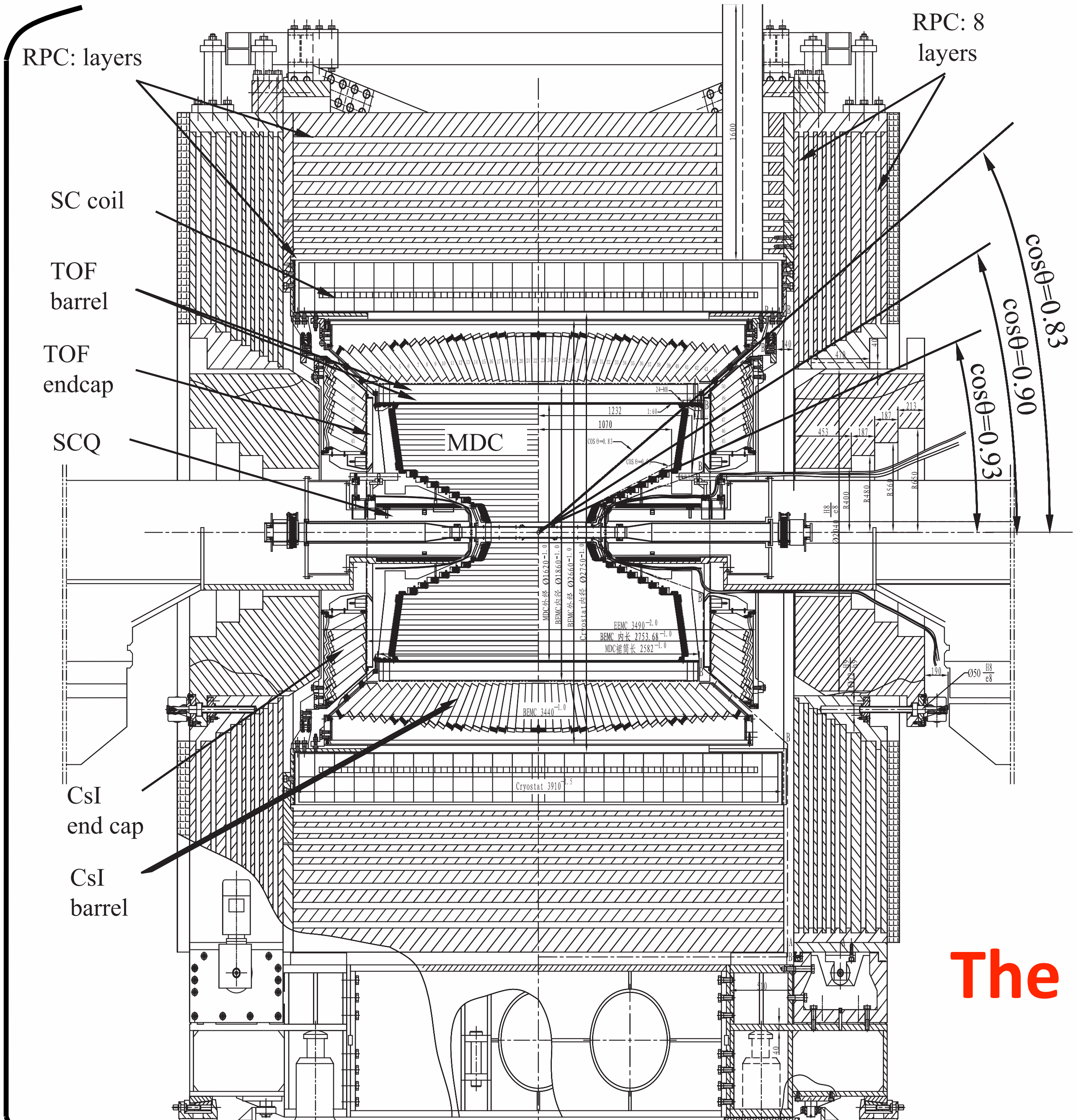
  $\vec{p}_D$ is a reconstructed D 3-momentum.

  - Its resolution is dominated by the spread in E_{beam}
  - The signal has asymmetric shape (longer tail on its high side) due to the ISR effect ($|\vec{p}_D|$ gets smaller)

A typical ST M_{BC}



- $\Delta E = E_D - E_{beam}$
  - Almost independent of the measured M_{BC}.



The BESIII detector

3 e^+e^- annihilation samples in this talk

1. At E_{cm} = 3.773 GeV. Accumulated luminosity = 2920 pb^{-1}.
2. 3.745 ≤ E_{cm} ≤ 3.854 GeV with 22 different E_{cm} values.
   - For each E_{cm}, the accumulated luminosity ~ 1~8 pb^{-1}.
   - The total accumulated luminosity ~ 70 pb^{-1}.

   (For more detail, please see Yi Fang's talk given at yesterday's parallel session.)
3. At E_{cm} = 4.009 GeV. Accumulated luminosity = 482 pb^{-1}.
   This sample produces;

$$e^+e^- \rightarrow \gamma^* \rightarrow D_S^+ D_S^-,$$

   where the paris of $D_S^+D_S^-$ come from decays of ψ(4040).
   Thus, M_{BC} and ΔE are useful again.

Measurement of $\sigma(e^+e^- \rightarrow D\bar{D})$ at E_{cm} = 3.773 GeV

An interesting topic in the context of $\sigma(e^+e^- \rightarrow \psi(3770) \rightarrow \text{non-}D\bar{D})$

Useful information to normalize a measured ST BF along with the accumulated luminosity

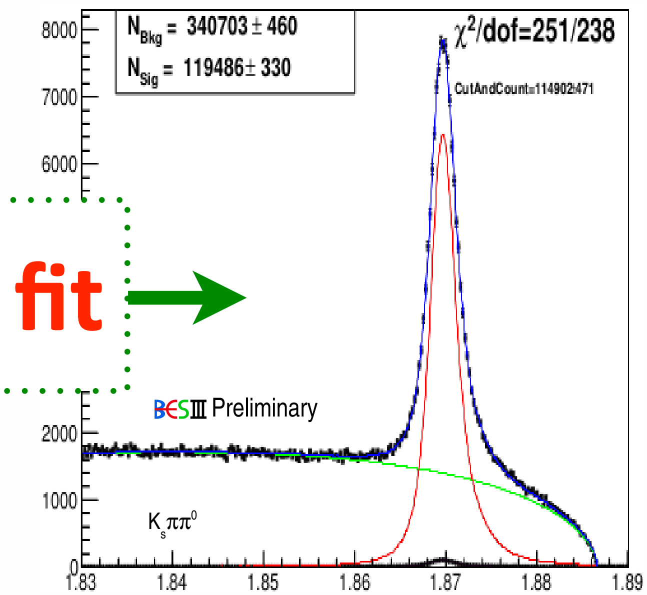
DT method

- Reconstruct (charge conjugate modes are implied)
  $D^0 \to$ 3 modes: $K^-\pi^+$, $K^-\pi^+\pi^0$, $K^-\pi^+\pi^-\pi^+$
  $D^+ \to$ 6 modes: $K^-\pi^+\pi^+$, $K^-\pi^+\pi^+\pi^0$, $K_S\pi^+$, $K_S\pi^+\pi^0$, $K_S\pi^+\pi^+\pi^-$, $K^-K^+\pi^+$
- In $e^+e^- \to D\bar{D}$ events, where $D \to X$ and $\bar{D} \to Y$,
  let $BF(D \to X) = N_X/(\varepsilon_X \cdot N_{D\bar{D}})$: Single Tag (ST)
  $BF(\bar{D} \to Y) = N_Y/(\varepsilon_Y \cdot N_{D\bar{D}})$: Single Tag (ST)
  $BF(D \to X) \times BF(\bar{D} \to Y) = N_{XY}/(\varepsilon_{XY} \cdot N_{D\bar{D}})$: Double Tag (DT)
  Then, $N_{D\bar{D}} = [N_X \cdot N_Y/N_{XY}] \times [\varepsilon_{XY}/(\varepsilon_X \cdot \varepsilon_Y)]$ and
  $\sigma = N_{D\bar{D}}/L$,
  $L = 2920\ fb^{-1}$ (Chin.Phys.C37, 123001 (2013)).
  (one can obtain the absolute BF from the DT/ST BFs ratio above)
- Extract N_X and N_Y by fitting to M_{BC} (with cut on ΔE)
- Extract N_{XY} by fitting to a 2D; M_{BC}^Y v.s. M_{BC}^X .

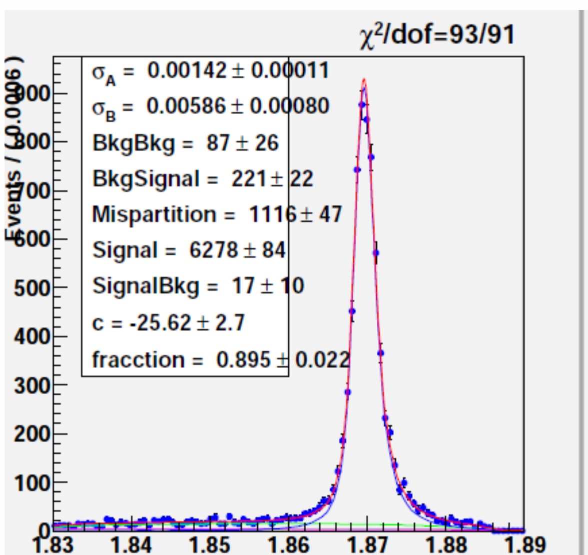
Fitting to M_{BC}

- Example fit to M_{BC} of $D^+ \to K_S\pi^+\pi^0$.
- MC-based signal shape w/ ARGUS background function.
- Small peaking backgrounds (~3%) are taken into account.

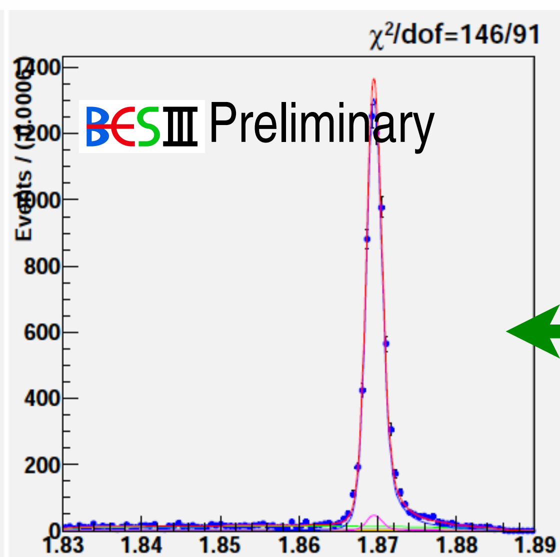
ST fit



$M_{BC}(K_S\pi^+\pi^0)$ in GeV/c^2



$M_{BC}(K^-\pi^+\pi^+\pi^0)$ in GeV/c^2



$M_{BC}(K^+\pi^-\pi^-)$ in GeV/c^2

DT fit

$K^-\pi^+\pi^+\pi^0$

vs

$K^+\pi^-\pi^-$

Preliminary results

- Averaging the resultant cross sections over different decay modes (X and Y), we have;

$$\sigma(e^+e^- \rightarrow D^0\overline{D}^0) = 3.641 \pm 0.010 \text{ (stat.) nb}$$
$$\sigma(e^+e^- \rightarrow D^+D^-) = 2.844 \pm 0.011 \text{ (stat.) nb}$$

at E_{cm} = 3.773 GeV based on 2920 pb^{-1}.

- Consistent with CLEO-c (PRD 89, 072002) at E_{cm} = 3.774 GeV based on 818 pb^{-1};

$$\sigma(e^+e^- \rightarrow D^0\overline{D}^0) = 3.607 \pm 0.017\text{(stat)} \pm 0.056 \text{ nb}$$
$$\sigma(e^+e^- \rightarrow D^+D^-) = 2.882 \pm 0.018\text{(stat)} \pm 0.042 \text{ nb}$$

How about in the vicinity of E_{cm}~ 3.770 GeV?

Line shape of $\sigma(e^+e^- \to D\bar{D})$

Does the highest $\sigma(e^+e^- \to D\bar{D})$ position correspond to the mass ψ(3770) measurement?
Or is there another source(s) that feeds $\sigma(e^+e^- \to D\bar{D})$ in this energy region?

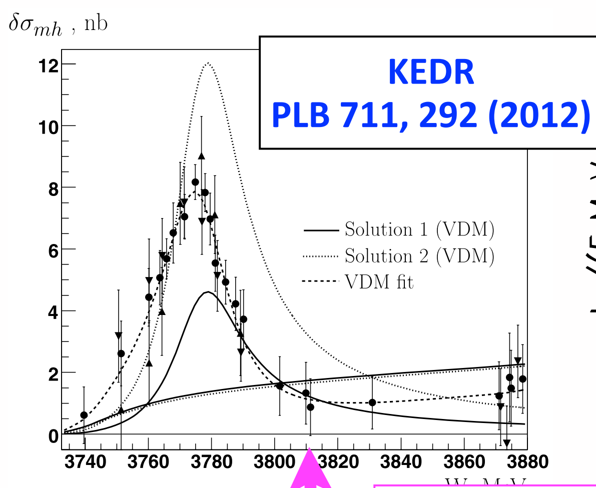
For more detail on this preliminary result,
Please see Yi Fang's talk given at yesterday's parallel session.

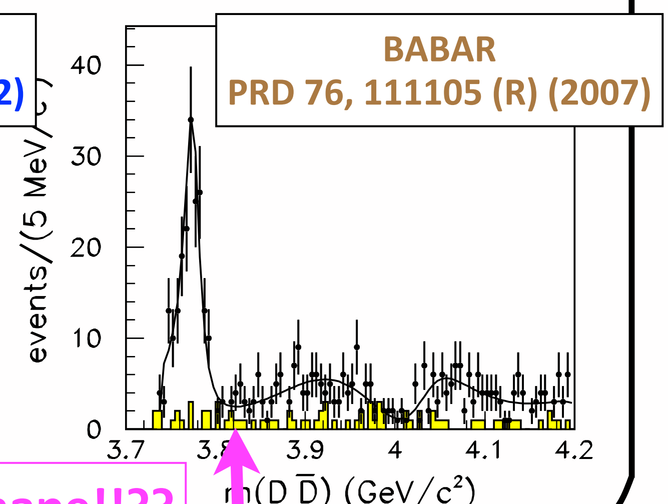
Production line shape of $D\bar{D}$
$\sigma(e^+e^- \to$ [not only ψ(3770) ?] $\to D\bar{D})$

- Recently, it has been claimed that a single BW may not be sufficient to describe the observed line shape of $D\bar{D}$.
  And some introduced an interference in the $D\bar{D}$ final states with $D\bar{D}$ from non-ψ(3770) decays (e.g., tails from other $c\bar{c}$ resonances).
- Consequently, there has been changes in ψ(3770) parameters, like MASS.
  The mass of the highest $\sigma(e^+e^- \to D\bar{D})$ does NOT change at ~3.773 GeV/c^2.

Experiment	$M_{\psi(3770)}$
BES-II [1]	3772.0 ± 1.9
Belle [2]	$3776.0 \pm 5.0 \pm 4.0$
BaBar [3]	$3775.5 \pm 2.4 \pm 0.5$
†BaBar [4]	$3778.8 \pm 1.9 \pm 0.9$
†KEDR [5]	$3779.2^{+1.8}_{-1.7}{}^{+0.5}_{-0.7}{}^{+0.3}_{-0.3}$

† includes interference





Dip in shape!!??

A brief description of analysis procedure

We primarily follow the KEDR procedure (PLB 711, 292 (2012)) in today's preliminary results.

- Define $\sigma_{born}(E_{cm}) \propto |A_{NR} + A_{Res} \cdot e^{i\phi}|^2$
  - $A_{Res}(E_{cm})$: ψ(3770) amplitude : $\propto \sqrt{[\Gamma_{ee}\Gamma_{D\bar{D}}(E_{cm})]} / [M^2 - E_{cm}^2 - iM\Gamma(E_{cm})]$
    where $\Gamma_{D\bar{D}}(E_{cm}) \propto \Gamma(E_{cm}) \times BF(\psi(3770) \to D\bar{D})$.
  - A_{NR} : Try two models for today (NOT the only choices)
    - ➡ Vector Dominance Model (VDM): use the above BW w/ M = 3.686 GeV.
    - ➡ An empirical approach: $A_{NR} \propto$ exponential form to probe the above model dependency.
- Procedure:
  - Fit to $\sigma_{obs}(E_{cm}) = N_D/[2 \cdot \varepsilon \cdot L(E_{cm})]$.
  - Obtain ψ(3770) shape parameters from $\sigma_{born}(E_{cm})$.
    We float $\Gamma_{ee}^{\psi(3770)}$, $\Gamma^{\psi(3770)}$, and ϕ with a fixed $BF(\psi(3770) \to D\bar{D}) = 100\%$.

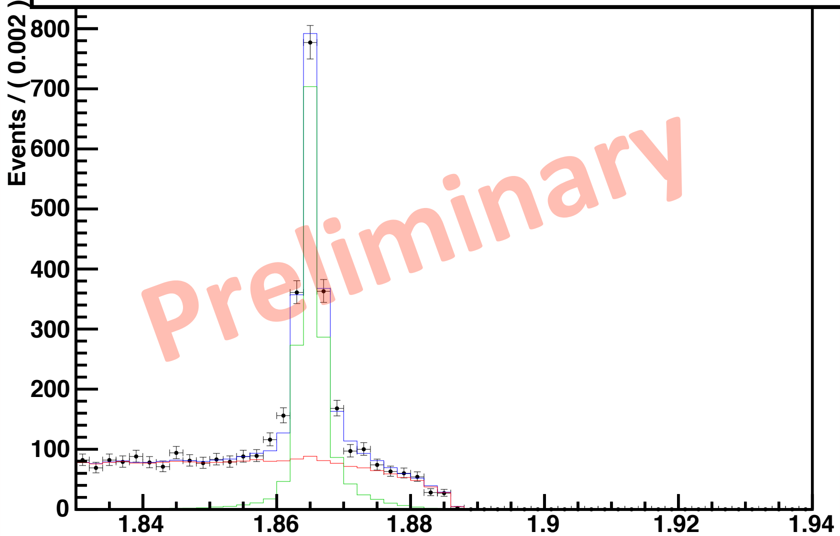
Fitting to "ΔE vs M_{BC}"

- Reconstruct (same as the previous analysis)
  $D^0 \rightarrow$ 3 modes: total reconstruction efficiency ~ 11% :
  $K^-\pi^+$, $K^-\pi^+\pi^0$, $K^-\pi^+\pi^-\pi^+$
  $D^+ \rightarrow$ 6 modes: total reconstruction efficiency ~ 10% :
  $K^-\pi^+\pi^+$, $K^-\pi^+\pi^+\pi^0$, $K_S\pi^+$, $K_S\pi^+\pi^0$, $K_S\pi^+\pi^+\pi^-$, $K^+K^-\pi^+$

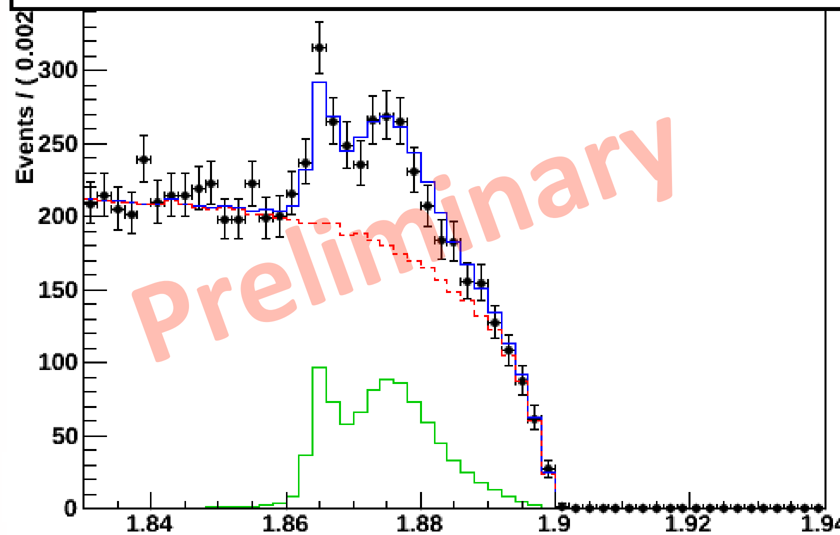
- SingleTag method:
  - Fit to 2D (ΔE vs M_{BC}) with MC shapes
    ➜ obtain yields, N_D, in each E_{cm} bins
  - Form $\sigma_{obs}(E_{cm}) = N_D/[2\cdot\varepsilon\cdot L(E_{cm})]$.
    $L(E_{cm})$ is the accumulated luminosity in E_{cm} bin.

Projections onto M_{BC} (in GeV/c^2)

Fit example at E_{cm} ~ 3.773 GeV



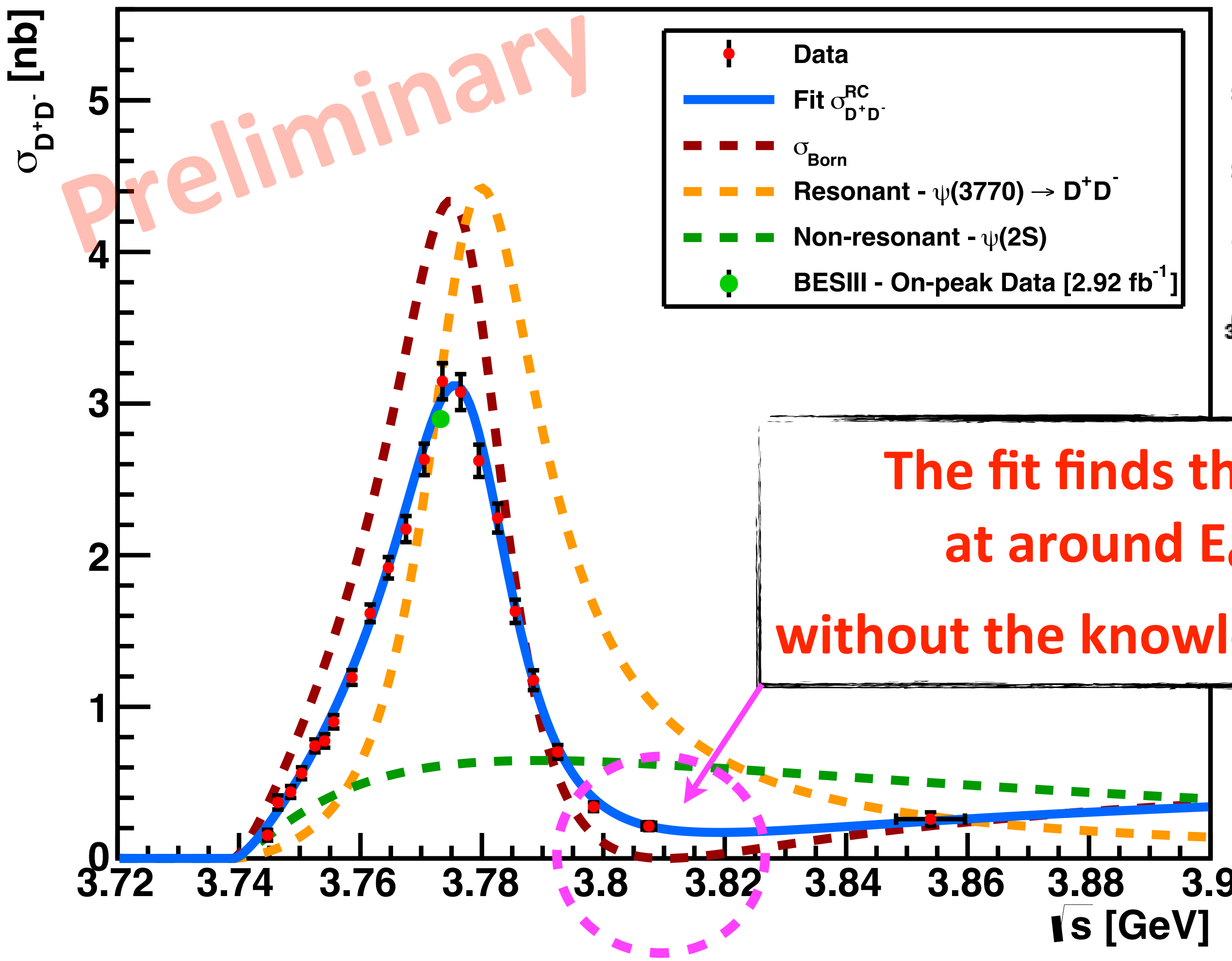
Fit example at E_{cm} ~ 3.800 GeV



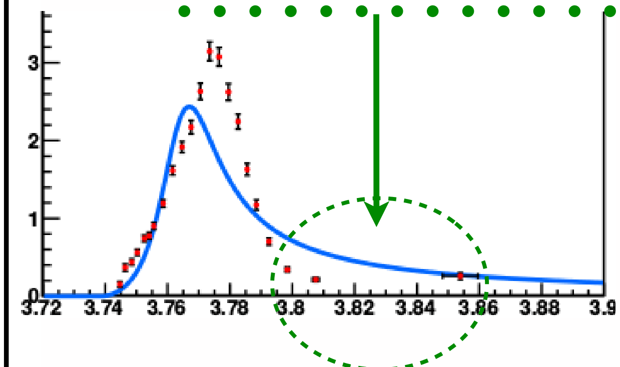
- At around E_{cm} ~ 3.773 GeV, the direct production dominates (not much the ISR tail on the high side of M_{BC}).
- At higher E_{cm}, the contribution from ISR dominates.
  Particularly,
  at E_{cm} ~ 3.810 GeV (not shown), the peak at 1.865 GeV/c^2 is gone!
  That is, the yield of D is entirely from the ISR tail!

Fitting to $\sigma_{obs}(E_{cm})$

- Simultaneously fit to $\sigma_{obs}(W)$ of $D^0\bar{D}^0$ and D^+D^-.
- Only $\sigma_{obs}(e^+e^- \to D^+D^-)$ with the VDM is shown here.



Not easy to fit with a single BW?



The fit finds the minimum σ_{born} at around E_{cm} = 3.810 GeV without the knowledge of the ISR effect

Results

We got only one solution from the fit

Preliminary

Source	$M^{\psi(3770)}$[MeV/c²]	$\Gamma^{\psi(3770)}$ [MeV]	$\Gamma_{ee}^{\psi(3770)}\times$ $B(\psi(3770)\to D\bar{D})$ [eV]
$BESIII_{VDM}$	3781.5±0.3	25.2±0.7	230±18
$BESIII_{Exponential}$	3783.0±0.3	27.5±0.9	270±24
KEDR	$3779.3^{+1.8}_{-1.7}$	$25.3^{+4.4}_{-3.9}$	160^{+78}_{-58}, 420^{+72}_{80}
PDG	3773.2±0.3	27.2±1.0	[262±18]× $B(\psi(3770)\to D\bar{D})$

Systematics,likely dominated by the NR model dependency

- Consistent with the KEDR's result (as they should).
- The shown errors are statistical errors only.
- We can only determine $\Gamma_{ee}^{\psi(3770)}\times BF(\psi(3770)\to D\bar{D})$ (this is essentially, our $D\bar{D}$ YIELDS).
  That is, IF $\Gamma_{ee}^{\psi(3770)}$ could be determined independently, THEN $BF(\psi(3770)\to D\bar{D})$ can be extracted from our fit!

The first observation of singly Cabibbo-suppressed decay

$D^+ \rightarrow \omega\pi^+$

and

the evidence in $D^0 \rightarrow \omega\pi^0$

For more detail on this preliminary result, Please see Peter Weidenkaff's talk given at yesterday's parallel session.

$D \to \omega\pi$ so far

The singly Cabibbo-suppressed decays $D^{+(0)} \to \omega\pi^{+(0)}$ have not been observed yet.
The most recent experimental search:
$BF(D^+ \to \omega\pi^+) < 3.0 \times 10^{-4}$ @90% C.L.
$BF(D^0 \to \omega\pi^0) < 2.6 \times 10^{-4}$ @90% C.L.
(CLEO-c; PRL96, 081802(2006); 281 pb^{-1})
was Singe Tag method ➜ continuum background dominates.

- H.Y. Cheng and C.W. Chiang predicts $BF(D^0 \to \omega\pi^0) \sim 1\times10^{-4}$ (PRD 81, 074021 (2010), due to destructive interference between color-suppressed diagrams.
- We'll go the Double Tag route: Reconstruct the same 3 and 6 decay modes for D^0 and D^+ as in the $D\bar{D}$ line shape study.

Double Tag: on the signal side

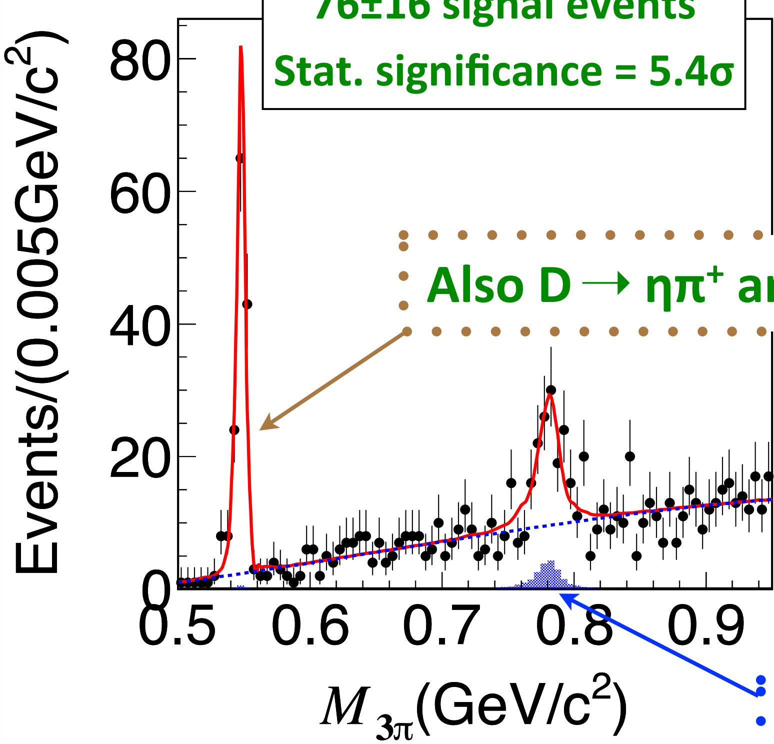
- Reconstruct $\omega \to \pi^+\pi^-\pi^0$, $\pi^0 \to \gamma\gamma$
- ω helicity angle:
  Require $|H_\omega| = |\cos\theta_{helicity}| > 0.54$ (0.51) for D^+(D^0):
  Expect the signal to have H_ω^2 shape.
- ω peaking backgrounds are estimated from 2D M_{BC} sidebands (both tag and signal side M_{BC}).
- Require M_{BC} and ΔE to be consistent with D on both signal and tag sides.

- Fit to $M_{3\pi}$ = invariant mass of $\pi^+\pi^-\pi^0$ with MC-based signal shapes and background polynomials.

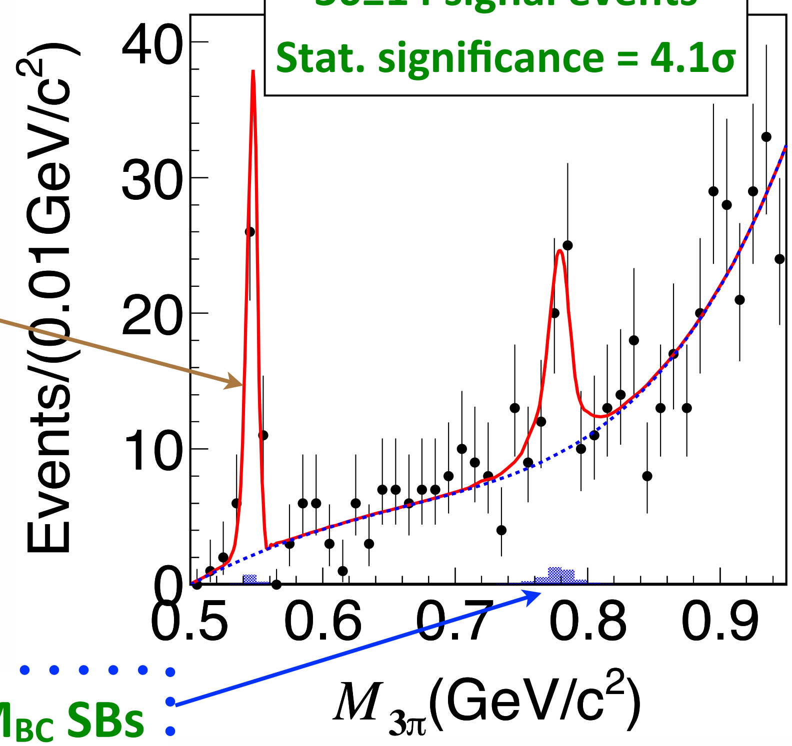
Preliminary

Fit to doubly tagged $M_{3\pi}$

$D^+ \rightarrow \omega\pi^+$
76±16 signal events
Stat. significance = 5.4σ

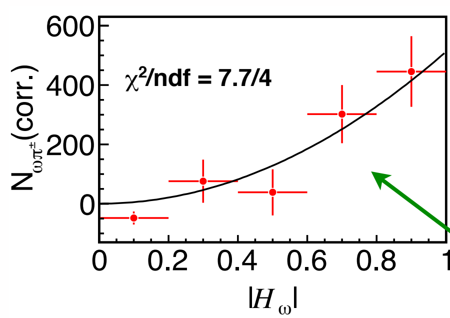


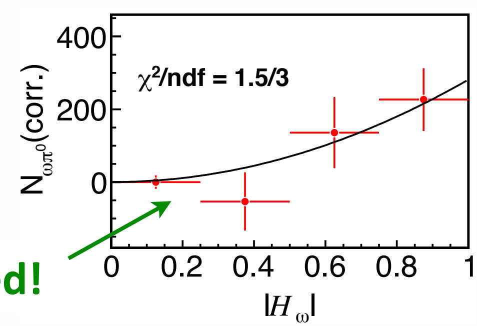
$D^0 \rightarrow \omega\pi^0$
36±14 signal events
Stat. significance = 4.1σ



Also D → $\eta\pi^+$ are see

From M_{BC} SBs

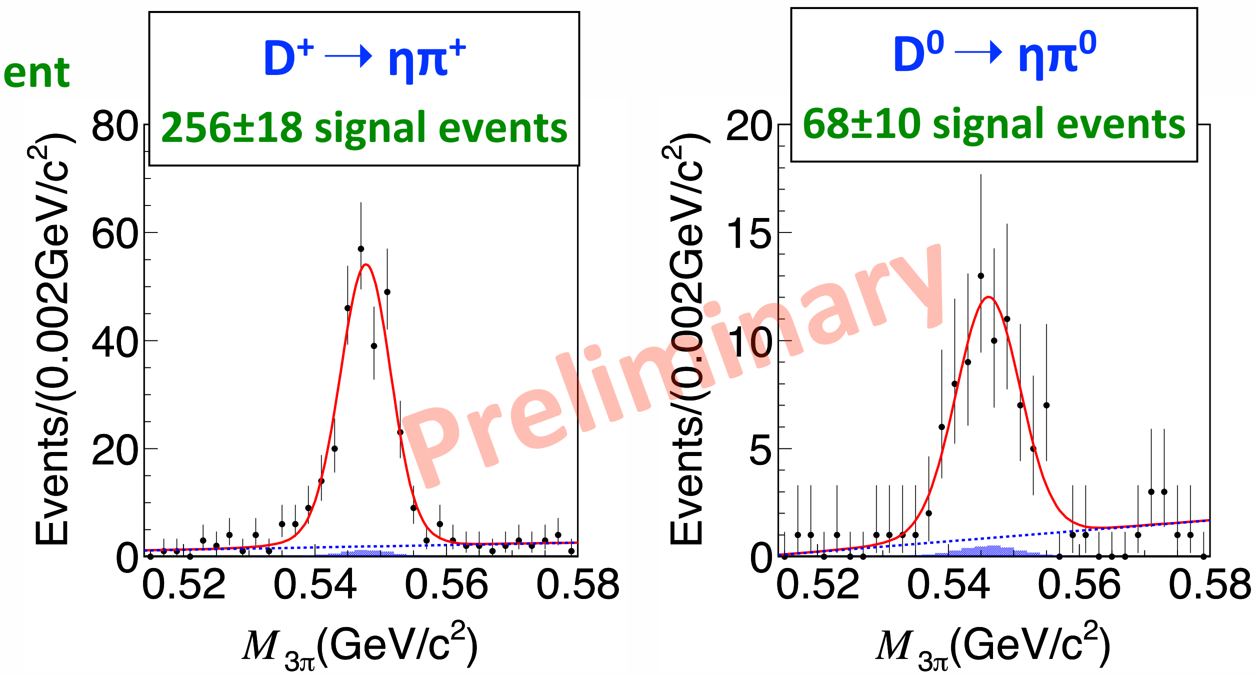




H_ω shapes are checked!

So we fit to the η region only as well

- but without the requirement on the $|H_\omega|$.



Decay mode	This work	PDG value
$D^+ \to \omega\pi^+$	$(2.74 \pm 0.58 \pm 0.17) \times 10^{-4}$	$< 3.4 \times 10^{-4}$ at 90% C.L.
$D^0 \to \omega\pi^0$	$(1.05 \pm 0.41 \pm 0.09) \times 10^{-4}$	$< 2.6 \times 10^{-4}$ at 90% C.L.
$D^+ \to \eta\pi^+$	$(3.13 \pm 0.22 \pm 0.19) \times 10^{-3}$	$(3.53 \pm 0.21) \times 10^{-3}$
$D^0 \to \eta\pi^0$	$(0.67 \pm 0.10 \pm 0.05) \times 10^{-3}$	$(0.68 \pm 0.07) \times 10^{-3}$

Results

D_S^+ hadronic decays

For today,

$D_S^+ \rightarrow \eta\, X$

and

$D_S^+ \rightarrow \eta\, \rho^+$

This is based on the sample taken at

$E_{cm} = 4.009$ GeV

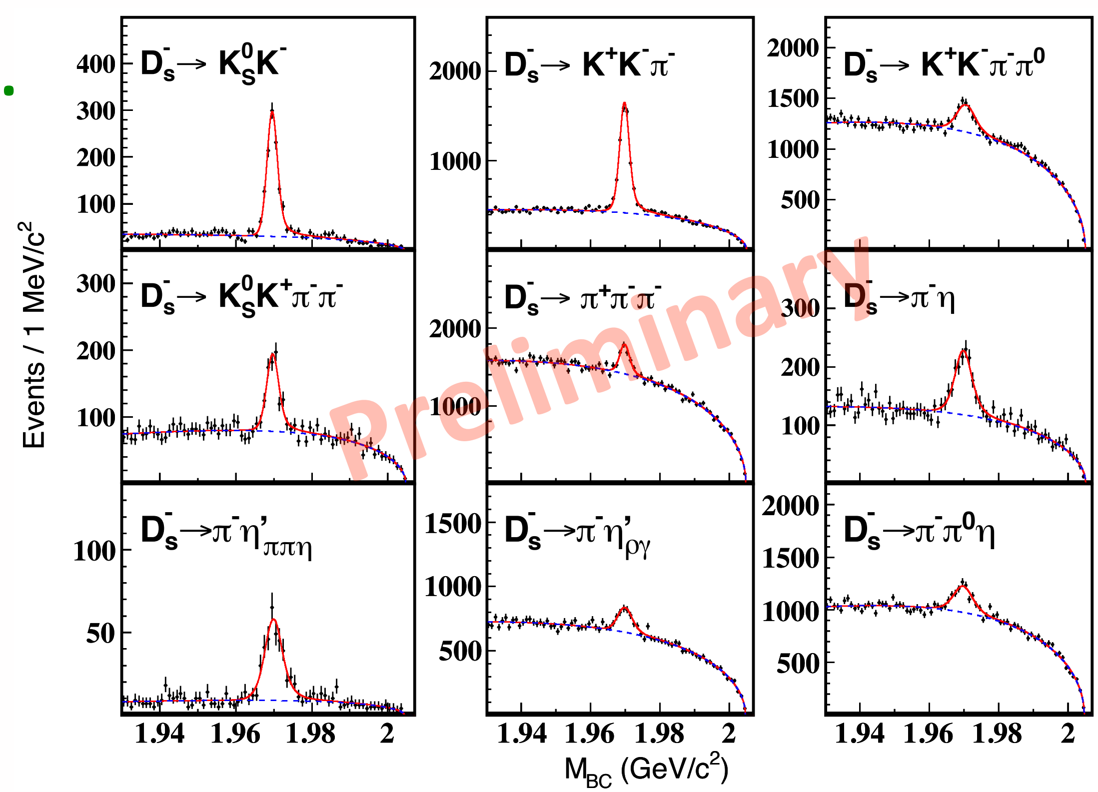
(Accumulated luminosity = 482 pb^{-1})

BF($D_S^+ \to \eta' X$) and BF($D_S^+ \to \eta' \rho^+$)

- The situation is rather interesting
  Sum[BF($D_S^+ \to \eta'$ + exclusive in PDG)] = (18.6±2.3)%, while
  BF($D_S^+ \to \eta' X$) = (11.7±1.8)% (CLEO-c @ E_{cm}~4.170 GeV PRD79, 112008).
- In the exclusives, the single largest BF is
  BF($D_S^+ \to \eta'\rho^+$) = (12.5±2.2)% (CLEO2 @ E_{cm}~$M_{Y(4S)}$,PRD58, 052002(1998)).
  However, CLEO-c reports (@ E_{cm}~4.170 GeV; PRD88,032009(2013))
  BF($D_S^+ \to \eta' \pi^+\pi^0$;inclusive) = (5.6±0.5±0.6)%.
- A factorization method predicts
  BF($D_S^+ \to \eta'\rho^+$) = (3.0±0.5)% (F.S. Yu, et al, PRD84, 074019 (2011)).
- We can use our "E_{cm} = 4.009 GeV" data to measure these BFs.
  We'll employ
  the Double Tag method for BF($D_S^+ \to \eta' X$) analysis
  and the Single Tag method for BF($D_S^+ \to \eta'\rho^+$) analysis.

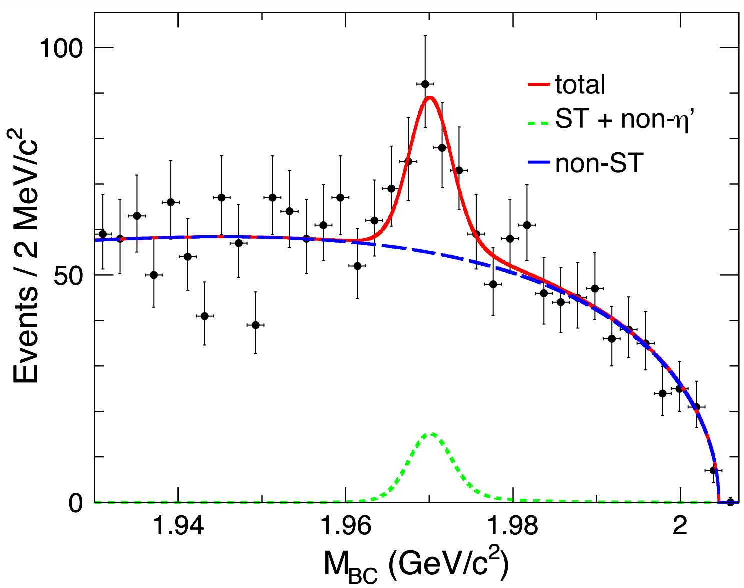
The tag side

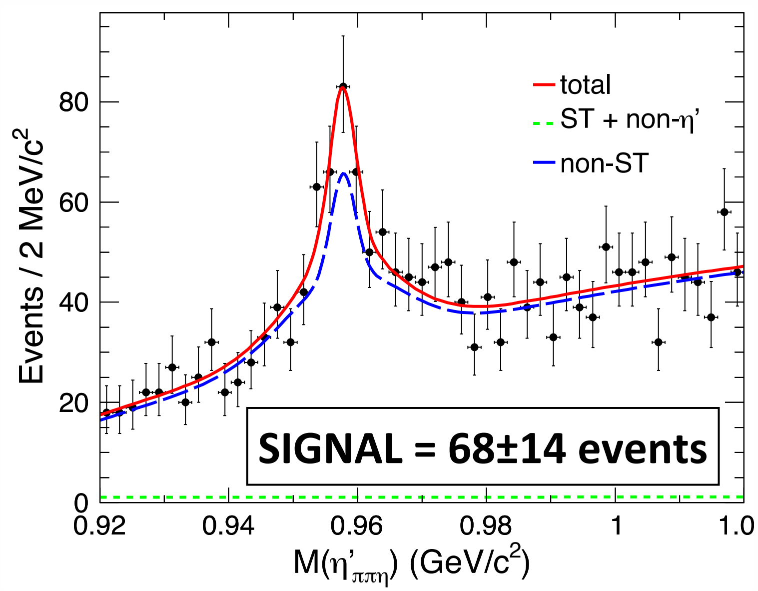
- Reconstruct these 9 tag modes.
- Cutting on ΔE and fit to M_{BC}.
- Fit with
  MC-based signal shapes
  and ARGUS bkg functions.



The signal side: $D_S^+ \to \eta' X$

- $\eta' \to \eta\pi^+\pi^-$, $\eta \to \gamma\gamma$
- Take the smallest $|M(\pi\pi\eta) - M(\eta')|$ if multiple candidates
  ➜ bkg in $M(\pi\pi\eta)$ tends to peak. It also peaks due to mis-reconstructed D_S.
- Fit to a 2D; $M(\pi\pi\eta)$ vs M_{BC}, where
  M_{bc} is the tag side beam-constrained mass.
- M_{BC} : MC-based signal shape and ARGUS background function.
  $M(\pi\pi\eta)$: MC-based signal shape
  BKG = polynomial + 2 Gaussians (center fixed at M(PDG)).





Single TAG: $D_S^+ \to \eta'\rho^+$

- Due to the limited statistics, we'll do the Singe Tag method.
- Require
  - $0.943 < M(\pi\pi\eta) < 0.973$ (roughly $\pm 3\sigma$)
  - $|M(\pi^+\pi^0) - M(\rho)| < 0.170$ GeV/c^2
  - $|\Delta E|$ be consistent with zero (~-4+3σ)
- Goal: obtain $BF(D_S^+ \to \eta'\rho^+)/BF(D_S^+ \to K^+K^-\pi^+)$
  And use $BF(D_S^+ \to K^+K^-\pi^+)$ as a reference mode.
- Use the helicity angle of ρ^+ to separate
  $D_S^+ \to \eta'\pi^+\pi^0$ (3 body) from $D_S^+ \to \eta'\rho^+$ (2 body).
  - ▸ $D_S^+ \to \eta'\rho^+$: $\cos^2\theta_{helicity}$
  - ▸ $D_S^+ \to \eta'\pi^+\pi^0$: independent of $\cos\theta_{helicity}$

2D fit : M_{BC} vs $\cos\theta_{helicity}$

M_{BC} : SIGNAL = MC-based shapes, BKG = ARGUS bkg function.

$\cos\theta_{helicity}$: SIGNAL = MC-based shapes,

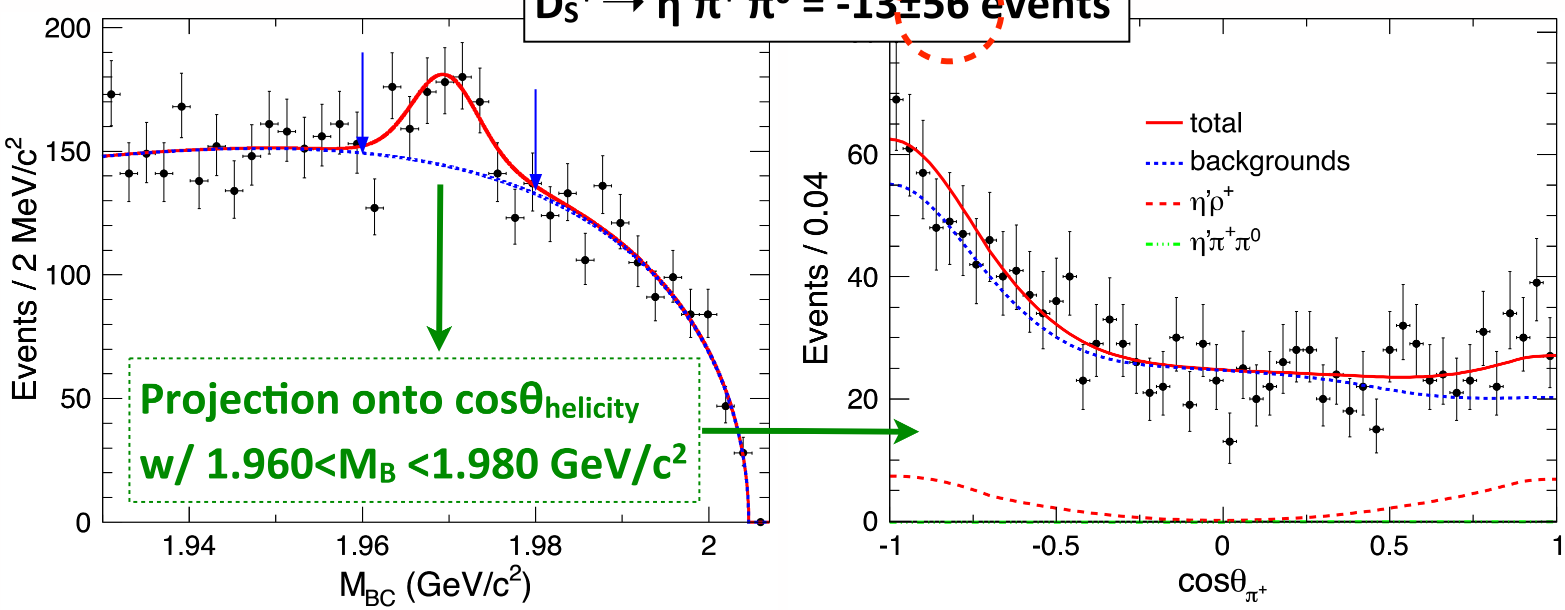
non-D_S Background = the shape is FIXed based on sidebands of M_{BC}

($1.932<M_{BC}<1.950$ and $1.988<M_{BC}<1.997$ GeV/c^2).

Large..
The DT method would be a help,
if we have more stat…

$D_S^+ \to \eta'\rho^+$ = 210±50 events

$D_S^+ \to \eta'\pi^+\pi^0$ = -13±56 events



Systematics

Source	$\mathcal{B}(D_s^+ \to \eta' X)$	$\mathcal{B}(D_s^+ \to \eta' \rho^+)$
MDC track reconstruction	2.0	
PID	2.0	3.0
π^0 detection		2.8
η detection	2.7	3.5
ΔE requirement	1.0	1.4
$M(\eta'_{\pi\pi\eta})$ requirement		2.0
$M(\eta'_{\pi\pi\eta})$ backgrounds	1.5	
Peaking backgrounds in ST	0.3	
$M_{\rm BC}$ signal shape	1.0	0.6
$M_{\rm BC}$ fit range	1.7	0.5
Uncertainty of efficiency	1.6	0.5
Quoted branching fractions	1.7	3.8
Total	5.3	7.1

Preliminary

- **π^0 reconstruction uncertainty is estimated from DT $D^0\bar{D}^0$, $D^0 \to K^-\pi^+\pi^0$ in each p bins. The disagreement between data/MC is assumed to be the same for η.**
- **BF($\eta'\rho$) error is dominated by BF($D_S^+ \to K^+K^-\pi^+$) from CLEO-c (PRD88, 032009(2013)).**
- **Also looked at sidebands of $M(\pi^+\pi^0)$ and $M(\pi^+\pi^-\eta)$ and saw no yields of "D_S^+" in M_{BC}.**
  ➜ indicates possible non-resonant processes like $D_S^+ \to \pi^+\pi^-\eta\rho^+$ is negligible.

Results

- $BF(D_S^+ \to \eta' X)$ = (8.8±1.8±0.5)%, consistent with
  PDG = (11.7±1.7±0.7)% within ~1σ.
- $BF(D_S^+ \to \eta'\rho^+)/BF(D_S^+ \to K^+K^-\pi^+)$ = 1.04±0.25±0.07 or
  $BF(D_S^+ \to \eta'\rho^+)$ = (5.8±1.4±0.4)%
  PDG = (12.5±2.2)% from PDG,
  confirming the CLEO-c result,
  $BF(D_S^+ \to \eta' \pi^+\pi^0$;inclusive) = (5.6±0.5±0.6)%
  (CLEO-c:PRD88,032009(2013)).
- Also set UL @ 90%CL:
  $BF(D_S^+ \to \eta'\pi^+\pi^0$; non-resonant) < 5.1%

Summary

- Our preliminary results on $\sigma_{obs}(e^+e^- \to D\bar{D})$ at E_{cm} = 3.773 GeV are consistent with the CLEO-c results.
- $\sigma_{obs}(e^+e^- \to D\bar{D})$ line shape in the vicinity of E_{cm} = 3.770 GeV is not a consistent with a single BW form.
  Followed the KEDR procedure and obtained a consistent result, the higher mass of ψ(3770).
- Presented the first observation of SCSD, $D \to \omega\pi$.
- Measured $BF(D_S^+ \to \eta' X)$ and $BF(D_S^+ \to \eta'\rho^+)$ which solved the self-consistent problem within the PDG and confirmed the latest CLEO-c measurements.

Other results from BESIII

- SCDS: $D^0 \to \pi^0\pi^0$ (arXiv:1505.03087)
- Quantum-Correlated analyses:
  (see Onur Albayrak's talk at this workshop)
  - $D^0 \to K_S\pi^+\pi^-$
  - the y_{CP} measurement
- Amplitude analysis in $D^0 \to K_S K^+ K^-$
  (see Peter Weidenkaff's talk at this workshop).
- Strong phase difference in $D^0 \to K^-\pi^+$ (PLB 734, 227 (2014))
- Amplitude analysis in $D^+ \to K_S\pi^+\pi^0$

Backups

- The observed cross section, $\sigma_{obs}(W)$ at $E_{cm} = W$ is given by;

$$\sigma_{obs}(W) = \int z_{DD}(W',x) \times \sigma_{born}(W',x) \times F_{ISR}(W'^2,x) \times G(W,W')\, dW' dx$$

  - $x = 1 - (W'/W)^2$
  - z_{DD} : Coulomb interaction (Sommerfeld-Sakharov factor)
  - $F_{ISR}(W'^2,x)$: The ISR radiator (E.A. Kuraev and V.S. Fadin)
  - $G(W,W')$: Beam energy spread (Gaussian)
  - $\sigma_{born}(W',x)$: Born level cross section of $D\bar{D}$

- $\Gamma_{D\bar{D}}(W) = (M/W) \times \Gamma^{\psi(3770)} \times BF(\psi(3770)\to D\bar{D}) \times [z_{D0\bar{D}0}(W)\cdot d_{D0\bar{D}0}(W) + z_{D+D-}(W)\cdot d_{D+D-}(W)] / [z_{D0\bar{D}0}(M)\cdot d_{D0\bar{D}0}(M) + z_{D+D-}(M)\cdot d_{D+D-}(M)]$,
  where $d \propto p_D^3$ in the $\psi(3770)$ center-of-mass system

  is the Blatt-Weisskopf damping factor.