Open charm B decays

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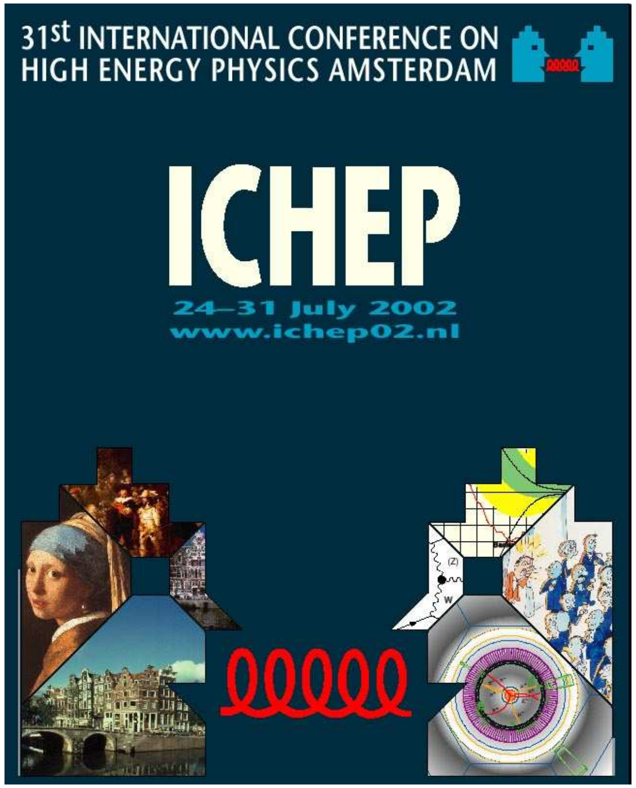
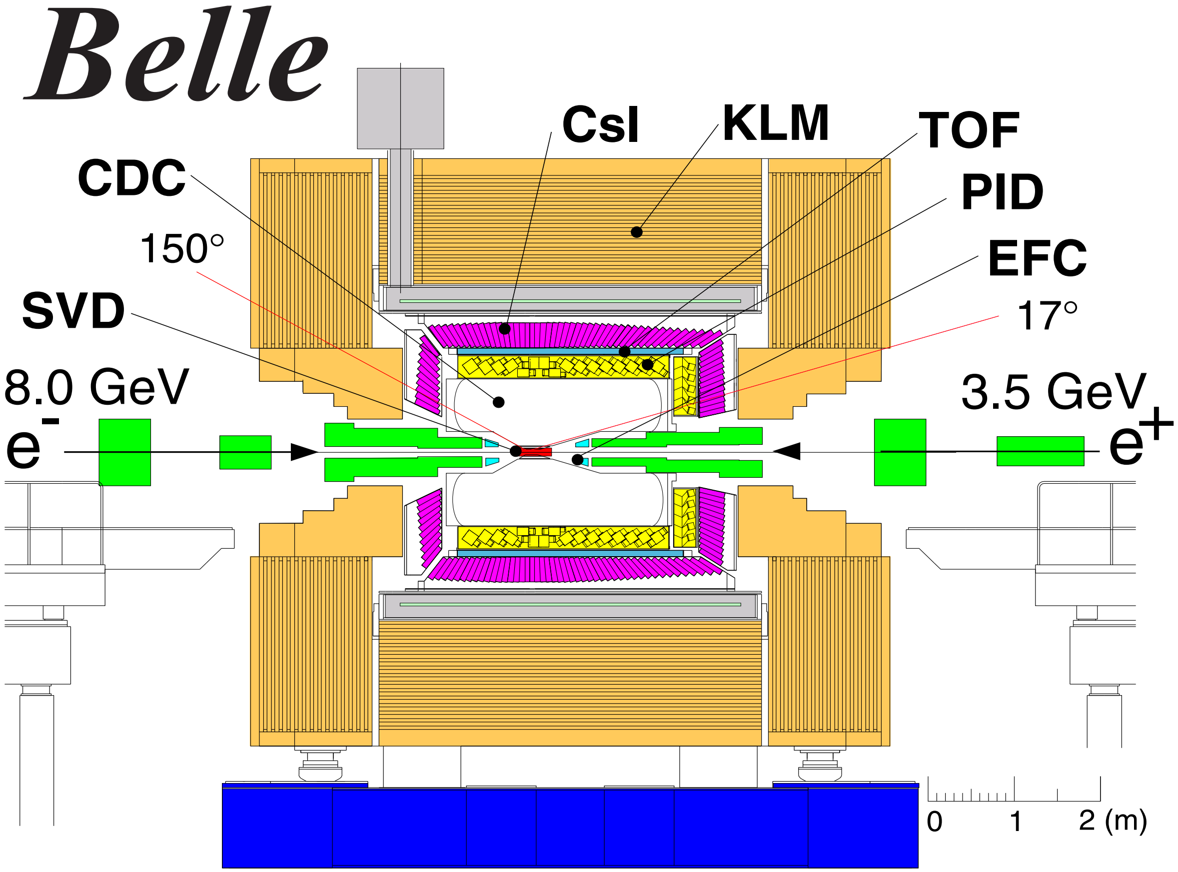
on behalf of the

Belle Collaboration



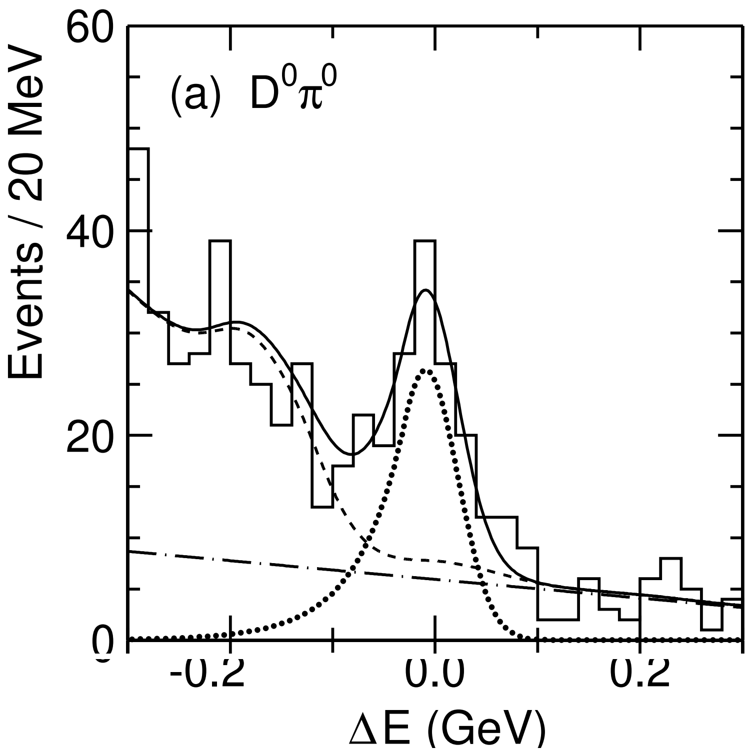
Outline:

- Introduction
- $B \to D\pi$ isospin analysis (CLEO)
- $B \to D_s\pi/K$
- D^{**} production
- $B \to D^{(*)}K^-K^{(*)0}$
- Conclusion



The Belle results are obtained with (30 - 85)$\times10^6$ $B\bar{B}$ pairs

Observation of color-suppressed B decays (Belle & CLEO)



$$\Delta E = \sum E_i - E_{CM}$$

Belle Results:

- ✓ $\mathcal{B}(\bar{B}^0 \to D^0\pi^0) = (3.1 \pm 0.4 \pm 0.5) \times 10^{-4}$,
- ✓ $\mathcal{B}(\bar{B}^0 \to D^{*0}\pi^0) = (2.7\,^{+0.8}_{-0.7}\,^{+0.5}_{-0.6}) \times 10^{-4}$,
- ✓ $\mathcal{B}(\bar{B}^0 \to D^0\eta) = (1.4\,^{+0.5}_{-0.4} \pm 0.3) \times 10^{-4}$,
- ✓ $\mathcal{B}(\bar{B}^0 \to D^0\omega) = (1.8 \pm 0.5\,^{+0.4}_{-0.3}) \times 10^{-4}$,
- ✓ $\mathcal{B}(\bar{B}^0 \to D^{*0}\eta) < 4.6 \times 10^{-4}$,
- ✓ $\mathcal{B}(\bar{B}^0 \to D^{*0}\omega) < 7.9 \times 10^{-4}$

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CLEO Results:

- ✓ $\mathcal{B}(\bar{B}^0 \to D^0\pi^0) = (2.74^{+0.36}_{-0.32} \pm 0.55) \times 10^{-4}$,
- ✓ $\mathcal{B}(\bar{B}^0 \to D^{*0}\pi^0) = (2.20^{+0.59}_{-0.52} \pm 0.79) \times 10^{-4}$

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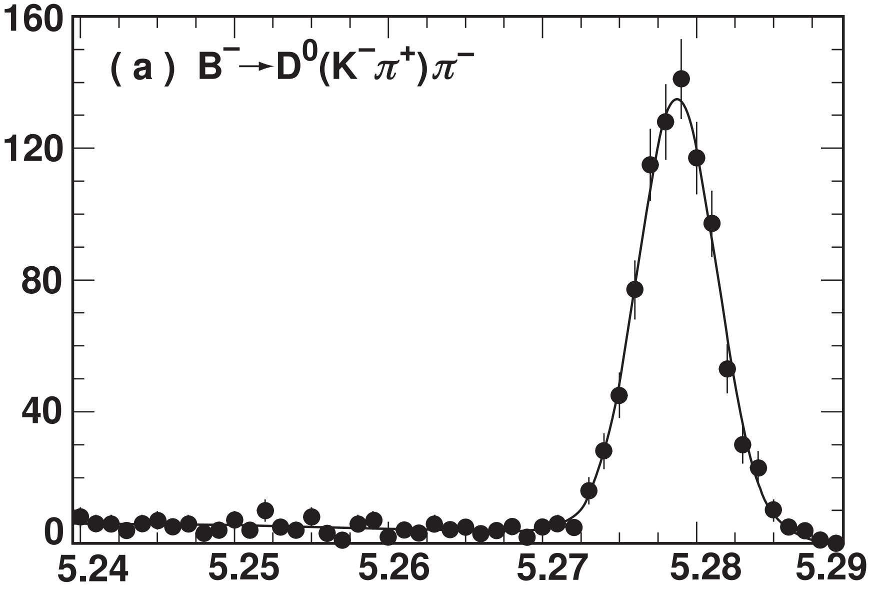
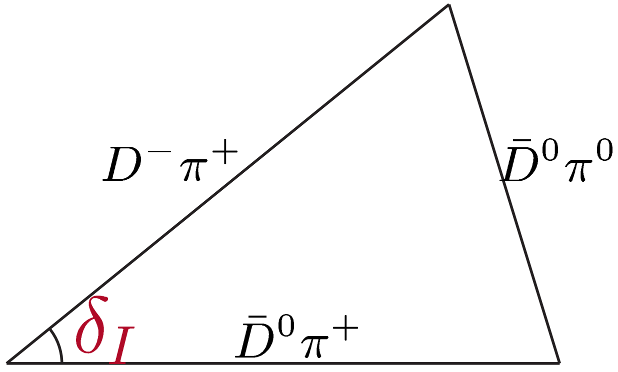
$\mathcal{B}(B \to D\pi)$ and isospin analysis (CLEO)



$$M_{bc} = \sqrt{E_b^2 - (\sum_i \vec{p}_i)^2}$$

Motivation:

- ✓ Strong phase δ_I
- ✓ Final state interactions



Results:

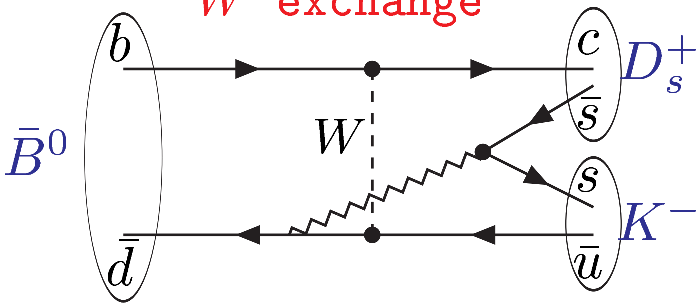
- ✓ $\mathcal{B}(B^- \to D^0\pi^-) = (49.7 \pm 1.2 \pm 2.9 \pm 2.2) \times 10^{-4}$
- ✓ $\mathcal{B}(\bar{B}^0 \to D^+\pi^-) = (26.8 \pm 1.2 \pm 2.4 \pm 1.2) \times 10^{-4}$
- ✓ $cos(\delta_I) = 0.863^{+0.024+0.036+0.038}_{-0.023-0.035-0.030}$ $\quad$ 2.3σ from $\delta_I = 0$

hep-ex/0206030

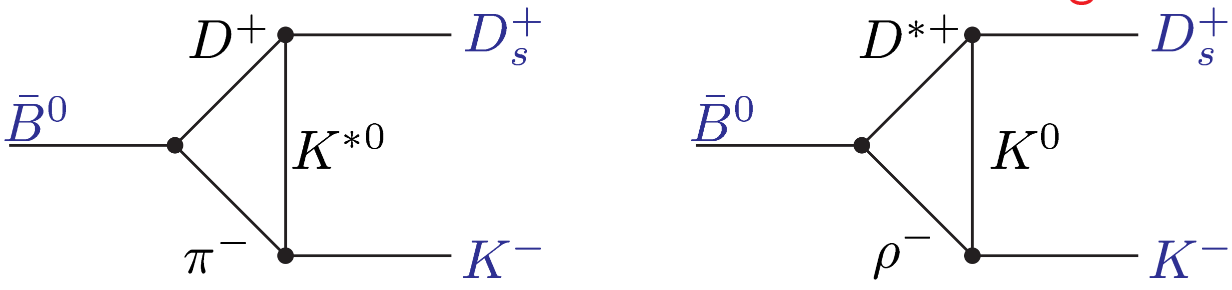
$\bar{B}^0 \to D_s^+ K^-$ motivation

- Decay mechanism: W-exchange or final state rescattering.
- Has not been observed so far.
- Predictions: $(0.3 - 6) \times 10^{-5}$.
- CLEO 90% UL: $< 24 \times 10^{-5}$.

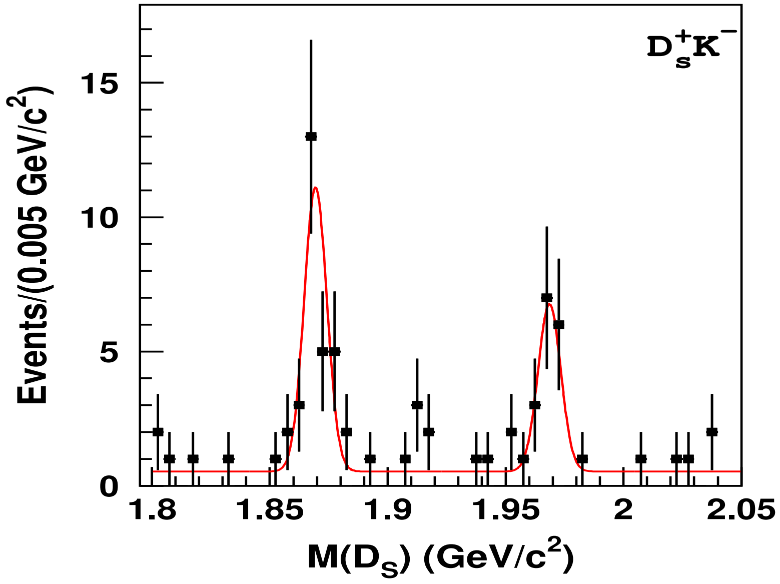
W exchange



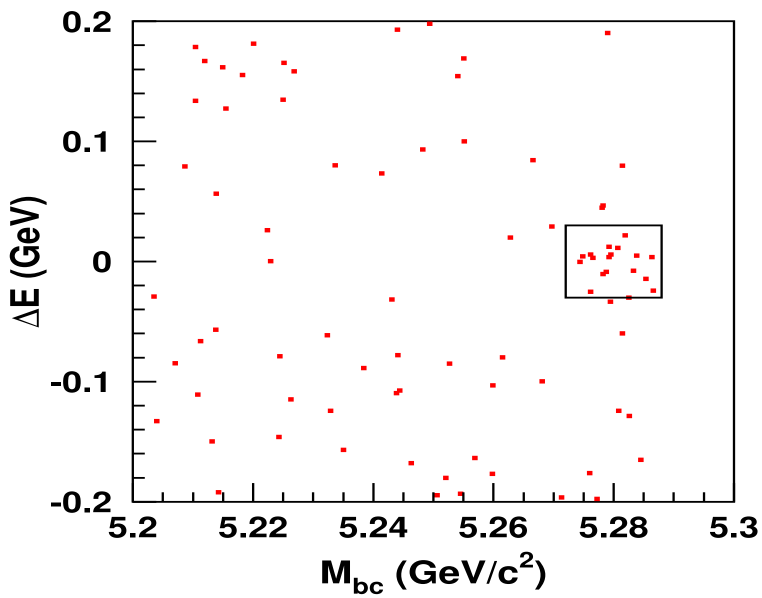
Final state rescattering

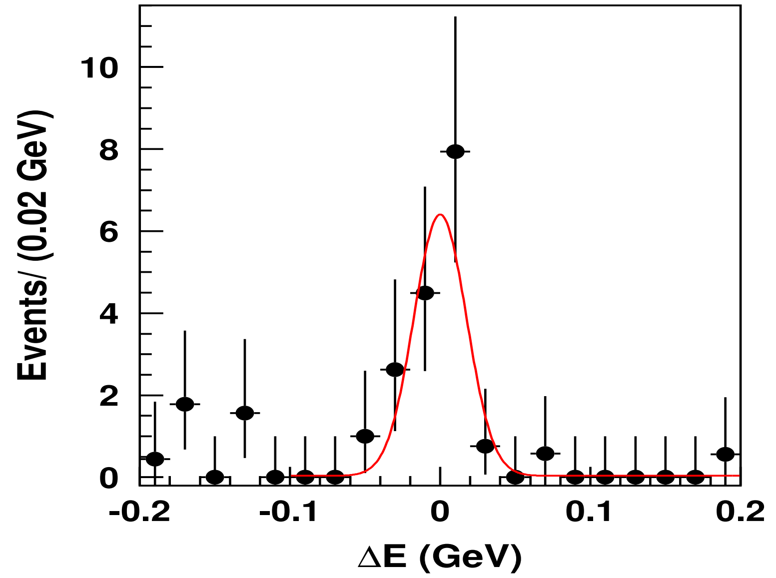


Results: $\bar{B}^0 \to D_s^+ K^-$ (Belle)



D_s^+ reconstruction: $\phi\pi^+$, $\bar{K}^{*0}K^+$, $K_S K^+$





First Observation

$$\mathcal{B}(\bar{B}^0 \to D_s^+ K^-) = (4.6^{+1.2}_{-1.1} \pm 1.3) \times 10^{-5}$$

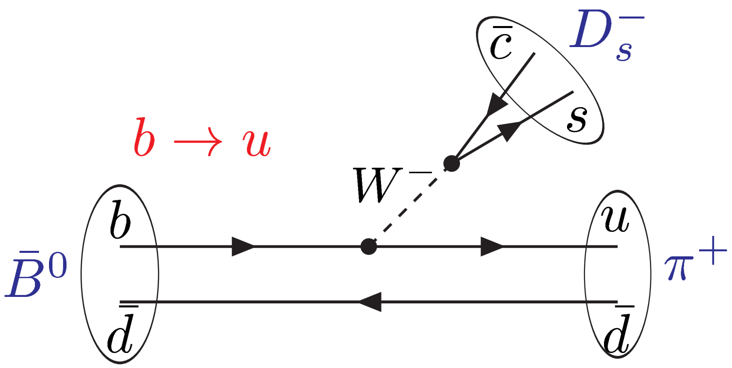
6.4σ

Preliminary

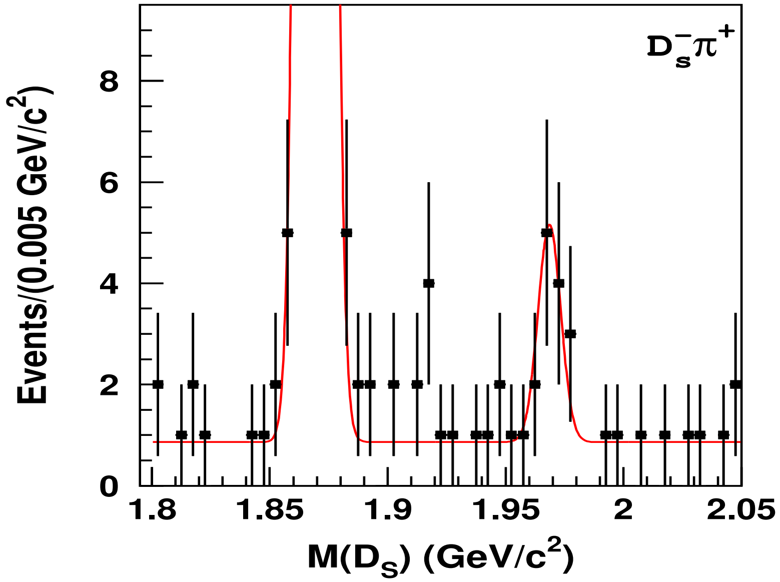
BELLE-CONF-0248

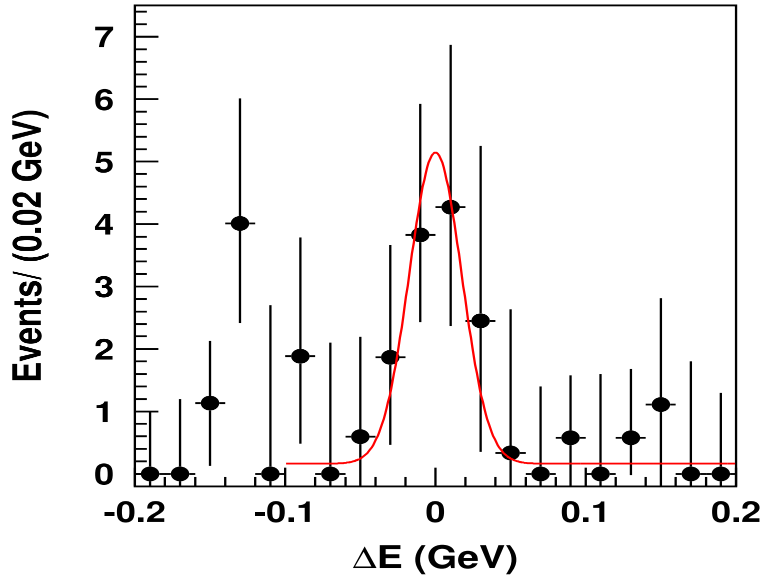
$B^0 \to D_s^+ \pi^-$ motivation

- √ Decay mechanism: $b \to u$ transition, no penguin contribution.
- √ Can be used to determine $|V_{ub}|$.
- √ Predictions: $(2-6) \times 10^{-5}$.
- √ CLEO 90% UL: $< 7.5 \times 10^{-5}$;
  BaBar evidence: $(3.1 \pm 1.0 \pm 1.0) \times 10^{-5}$ (hep-ex/0205102).



Results: $B^0 \to D_s^+ \pi^-$ (Belle)





Signal reconstruction:

- $\surd$ D_s^+: $\phi\pi^+$, $\bar{K}^{*0}K^+$, $K_S K^+$
- $\surd$ B: 2D fit to the ΔE and D_s mass

Evidence for:

$$\mathcal{B}(B^0 \to D_s^+ \pi^-) = (2.4^{+1.0}_{-0.8} \pm 0.7) \times 10^{-5}$$

3.6σ

BaBar (hep-ex/0205102):

$$\mathcal{B}(B^0 \to D_s^+ \pi^-) = (3.1 \pm 1.0 \pm 1.0) \times 10^{-5}$$

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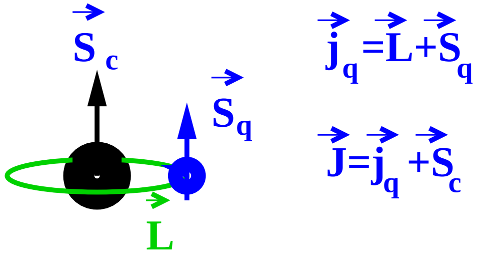
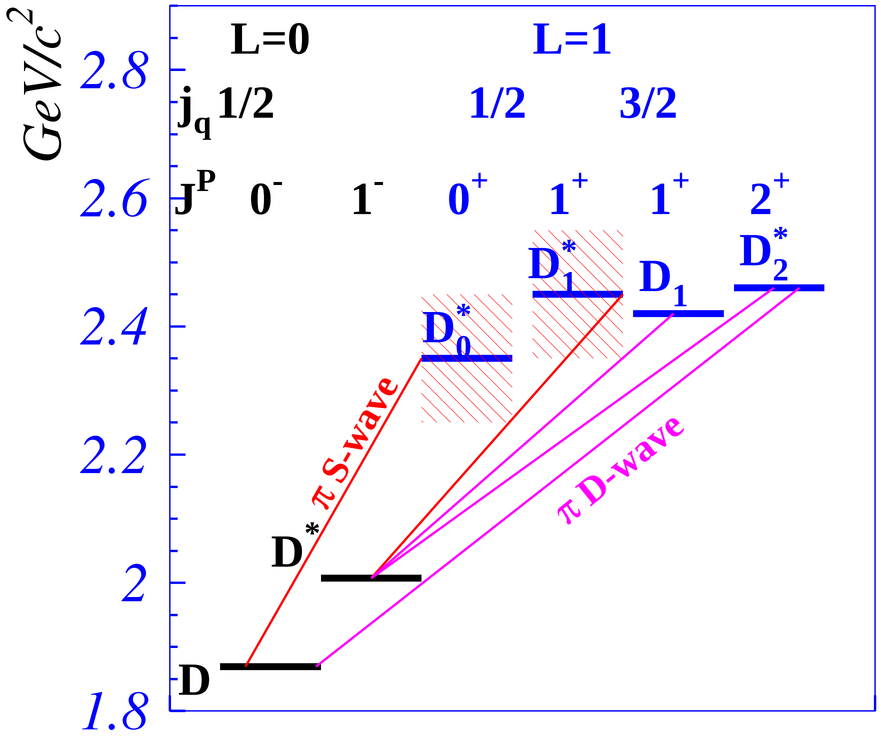
$B^- \to D^{**0}\pi^-(D^{**0} \to D^{(*)+}\pi^-)$





Motivation:

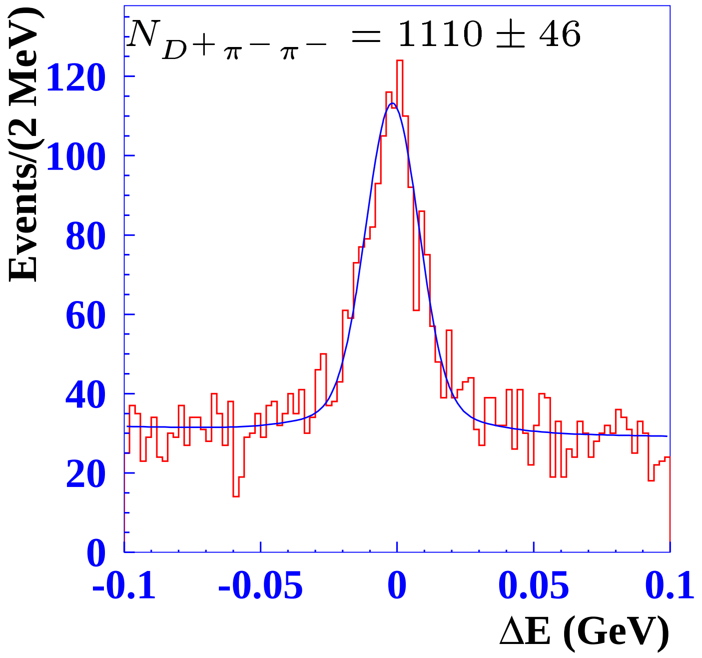
- **Factorization calculations:** (M. Neubert Phys. Lett. B418, 173)

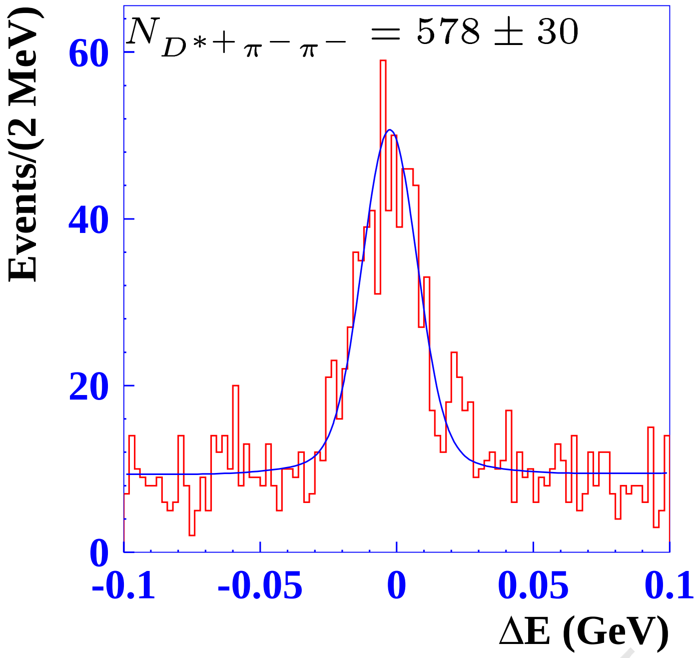
$$R = \frac{\mathcal{B}(B^- \to D_2^{*0}\pi^-)}{\mathcal{B}(B^- \to D_1^0\pi^-)} \approx 0.35$$

CLEO analysis gives 1.8 ± 0.8

- $B(B \to D^{(*)}\pi l^-\bar{\nu}) = (2.26 \pm 0.44)\%$ (ALEPH) indicates a large contribution of broad structure, the contribution of narrow resonances is $(0.86 \pm 0.34)\%$. QCD sum rules predict the dominance of the narrow D^{**} in $B \to D^{**}l\nu$.

$B^- \to D^{(*)+}\pi^-\pi^-$ (Belle)





Results:

$\mathcal{B}(B^- \to D^+\pi^-\pi^-) = (1.07 \pm 0.04 \pm 0.16) \times 10^{-3}$

$CLEO \quad < 1.4 \times 10^{-3}$ (Phys.Rev. D 50, 43)

$\mathcal{B}(B^- \to D^{*+}\pi^-\pi^-) = (1.24 \pm 0.07 \pm 0.22) \times 10^{-3}$

$CLEO \quad (1.9 \pm 0.7) \times 10^{-3}$ (Phys.Rev. D 50, 43)

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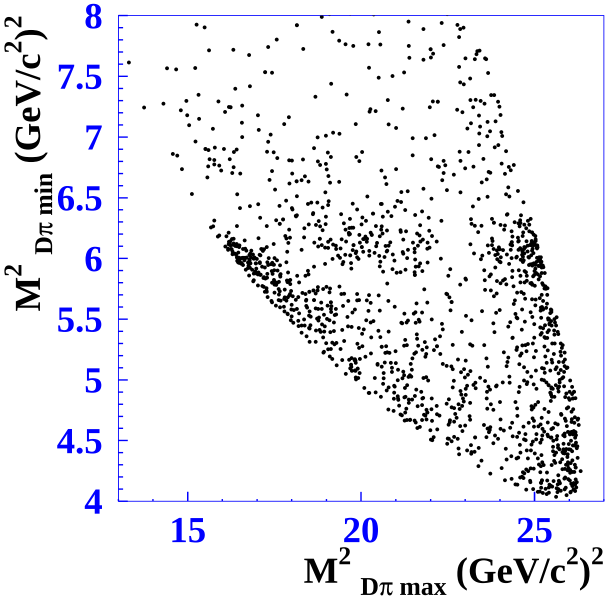
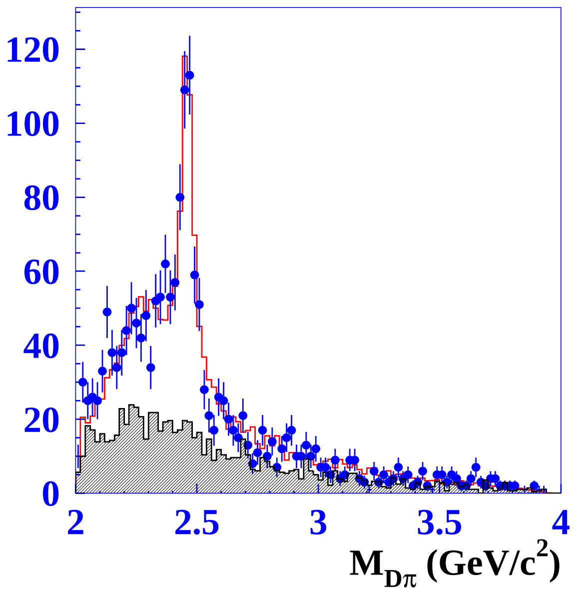
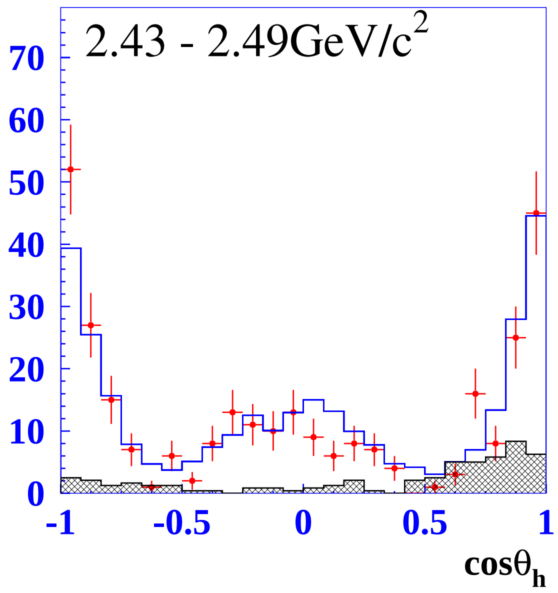
$D^+\pi^-\pi^-$ amplitude analysis (Belle)







Results:

$M_2 = (2461 \pm 2 \pm 3)$ MeV/c^2, $\quad\Gamma_2 = (46.4 \pm 4.4 \pm 3.1)$ MeV/c^2

$B(B^- \to D_2^{*0}\pi^-) \times B(D_2^{*0} \to D^+\pi^-) = (3.5 \pm 0.3 \pm 0.5) \times 10^{-4}$

$M_0 = (2290 \pm 22 \pm 20)$ MeV/c^2, $\quad\Gamma_0 = (300 \pm 30 \pm 30)$ MeV/c^2

$B(B^- \to D_0^{*0}\pi^-) \times B(D_0^{*0} \to D^+\pi^-) = (5.5 \pm 0.5 \pm 0.8) \times 10^{-4}$.

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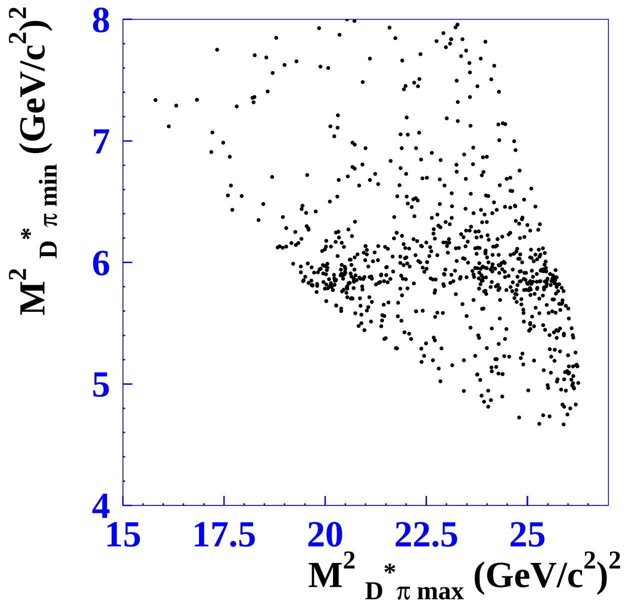
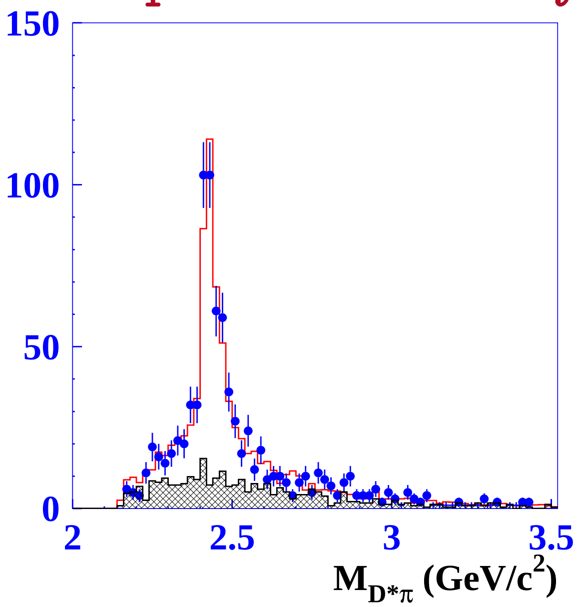
$D^{*+}\pi^-\pi^-$ amplitude analysis (Belle)





$$\frac{\mathcal{B}(B^- \to D_2^{*0}\pi^-)}{\mathcal{B}(B^- \to D_1^0\pi^-)} = 0.89 \pm 0.14$$

(Neubert: $R \approx 0.35$)

Fraction of $j_q = 3/2$:

$33 \pm 4\%$ of the $D\pi\pi$

$66 \pm 7\%$ of the $D^*\pi\pi$

Results:

$M_1 = (2424 \pm 2)\ \mathrm{MeV/c^2}$, $\quad \Gamma_1 = (26.7 \pm 3.1 \pm 2.2)\ \mathrm{MeV/c^2}$

$B(B^- \to D_1\pi^-) \times B(D_1 \to D^{*+}\pi^-) = (6.2 \pm 0.5 \pm 1.1) \times 10^{-4}$,

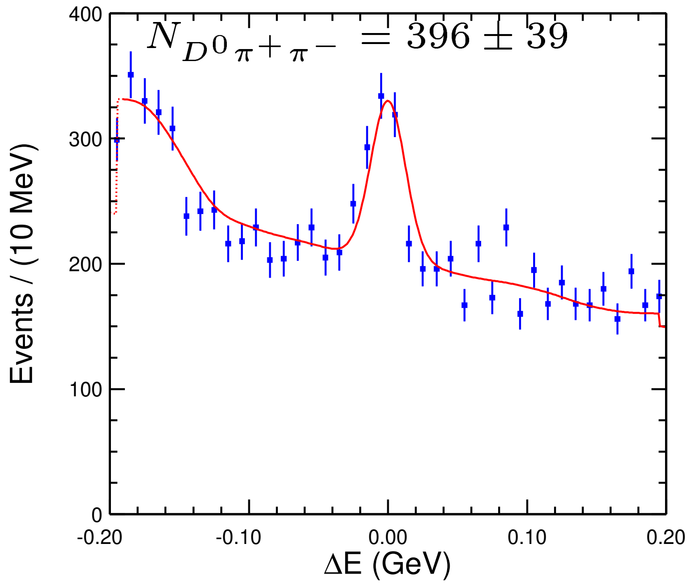
$B(B^- \to D_2^{*0}\pi^-) \times B(D_2^{*0} \to D^{*+}\pi^-) = (2.0 \pm 0.3 \pm 0.5) \times 10^{-4}$

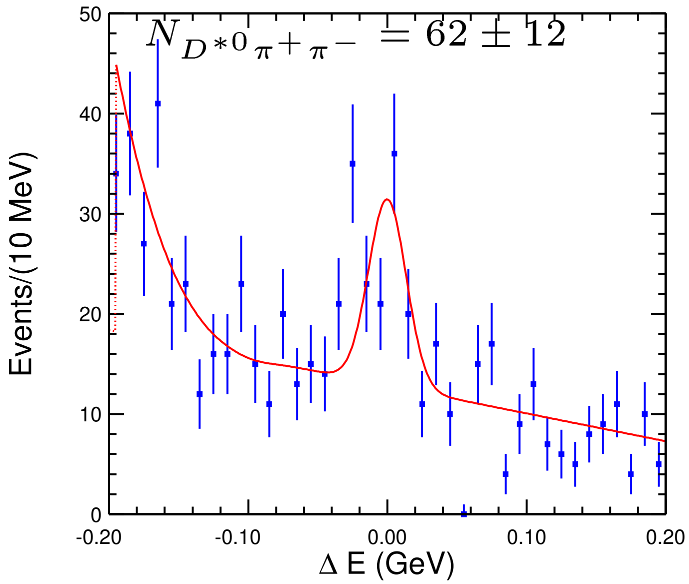
$M_{1w} = (2400 \pm 30 \pm 20)\ \mathrm{MeV/c^2}$, $\quad \Gamma_{1w} = (380 \pm 100 \pm 100)\ \mathrm{MeV/c^2}$.

$B(B^- \to D_1^{*0}\pi^-) \times B(D_1^{*0} \to D^{*+}\pi^-) = (4.1 \pm 0.5 \pm 0.8) \times 10^{-4}$.

BELLE-CONF-0235

$\bar{B}^0 \to D^{(*)0}\pi^+\pi^-$ (Belle)





Results:

$$B(\bar{B}^0 \to D^0\pi^+\pi^-) = (7.5 \pm 0.7 \pm 1.5) \times 10^{-4}$$

$CLEO \quad < 16 \times 10^{-4}$ (Phys.Rev. D 50, 43)

$$B(\bar{B}^0 \to D^{*0}\pi^+\pi^-) = (6.2 \pm 1.2 \pm 1.7) \times 10^{-4}$$

Preliminary

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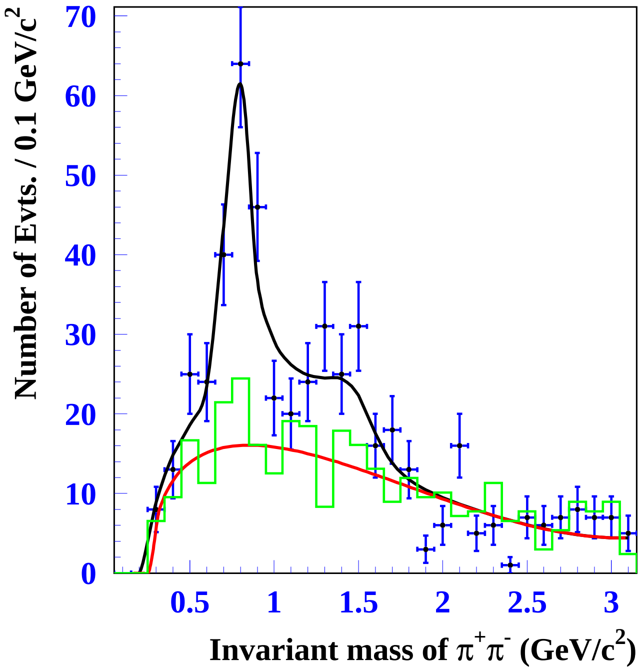
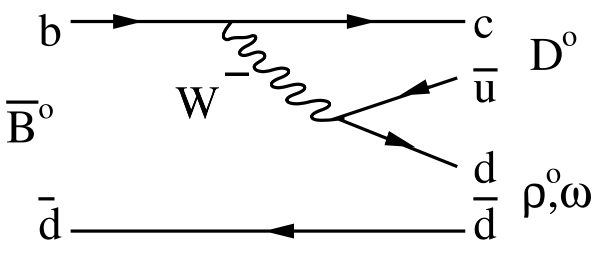
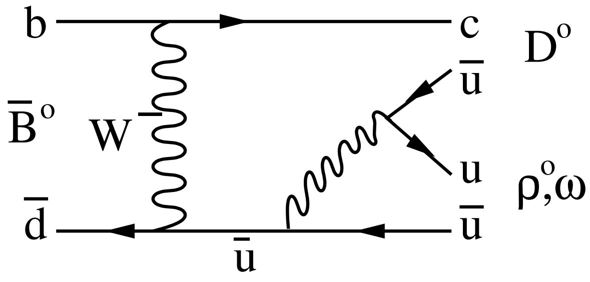
$\bar{B}^0 \to D^0 \rho$ (Belle)





Dominant Diagram



W−exchange Diagram

$$\frac{\mathcal{B}(\bar{B}^0 \to D^0 \rho)}{\mathcal{B}(\bar{B}^0 \to D^0 \omega)} \neq 1$$

in case of W exchange contribution

Results:

$$B(\bar{B}^0 \to D^0 \rho^0) = (3.0 \pm 1.3 \pm 0.4) \times 10^{-4}$$

$CLEO \quad < 3.9 \times 10^{-4}$ (Phys.Rev. D 50, 43)

$$\frac{B(\bar{B}^0 \to D^{*0} \rho^0)}{B(\bar{B}^0 \to D^{*0} \omega)} = 1.7 \pm 1.0$$

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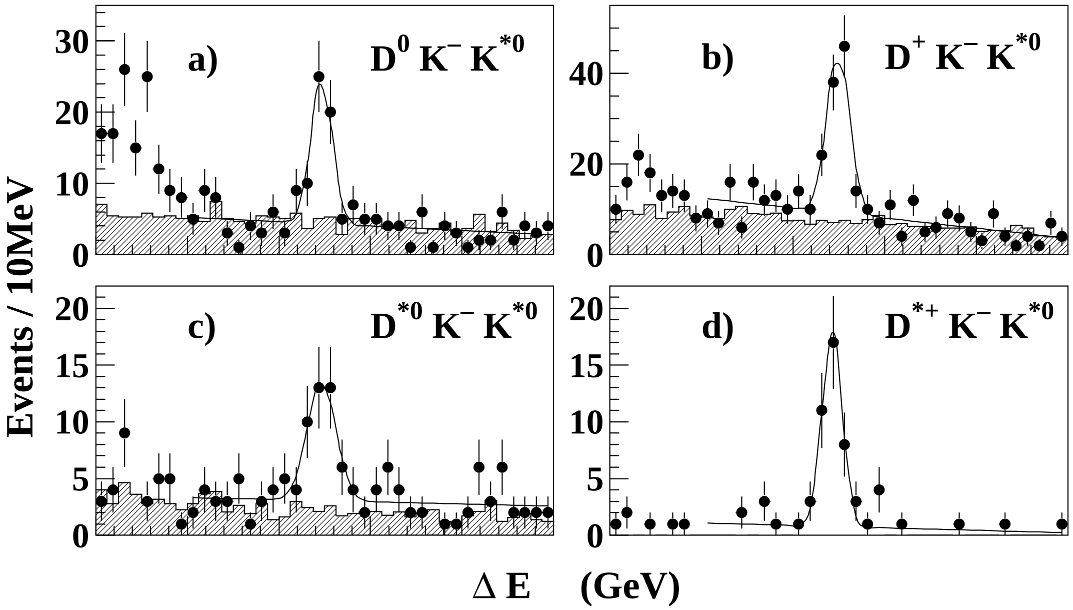
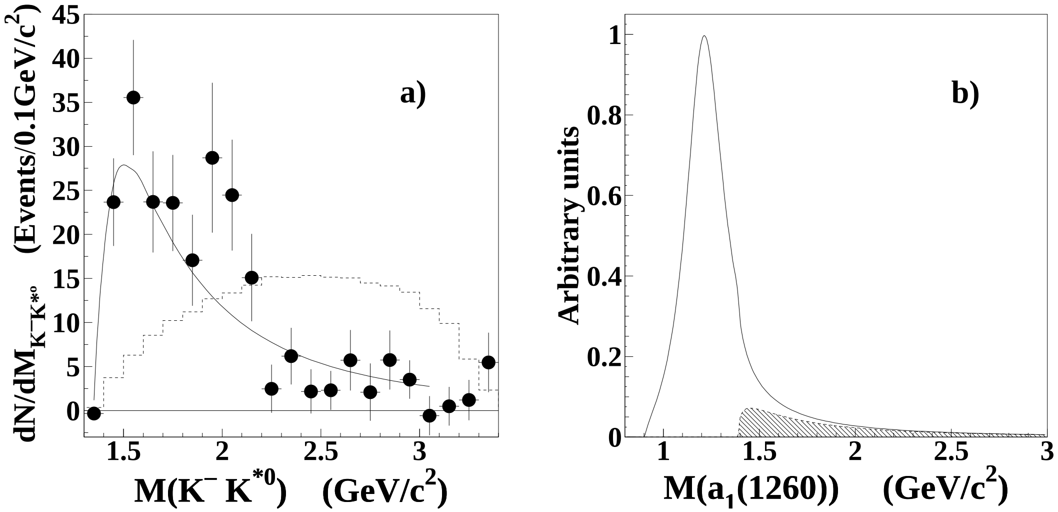
Results: $B \to D^{(*)} K K^{(*)}$ (Belle)





Motivation:

- ✓ $s\bar{s}$ production
- ✓ $B \to Da_1$, $B \to D\rho$

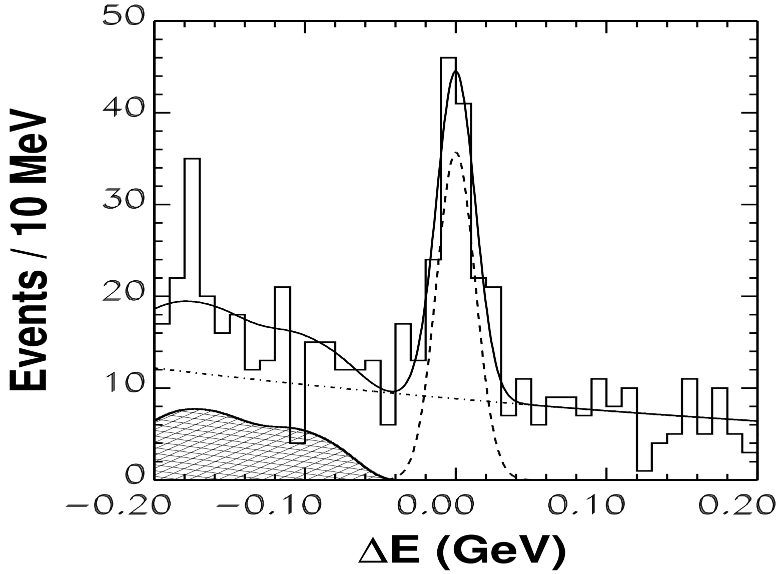
Fit Results:

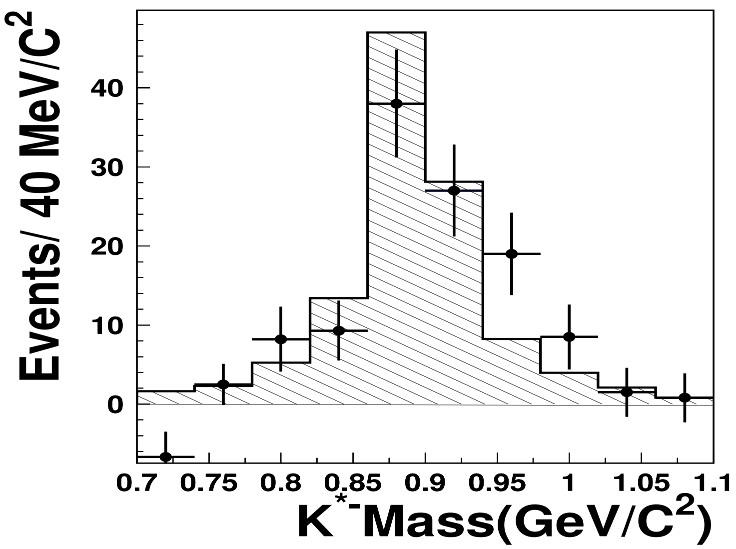
Mode	$\mathcal{B}(10^{-4})$
$D^0 K^- K^{*0}$	$7.5 \pm 1.3 \pm 1.1$
$D^+ K^- K^{*0}$	$8.8 \pm 1.1 \pm 1.5$
$D^{*0} K^- K^{*0}$	$15.3 \pm 3.1 \pm 2.9$
$D^{*+} K^- K^{*0}$	$12.9 \pm 2.2 \pm 2.5$
$D^0 K^- K^0$	$5.5 \pm 1.4 \pm 0.8$
$D^+ K^- K^0$	< 3.1
$D^{*0} K^- K^0$	< 10.6
$D^{*+} K^- K^0$	< 4.7

Evidence for $a_1(1260) \to K^* K$

BELLE-CONF-0234

Results: $B^- \to D^0 K^{*-}$ (Belle)





Motivation:

- ✓ $B^- \to D^0 K^-$
- ✓ $\phi_3(\gamma)$ CKM angle extraction

Signal reconstruction:

- ✓ D^0: $K^-\pi^+$, $K^-\pi^+\pi^0$, $K^-\pi^+\pi^+\pi^-$
- ✓ K^{*-}: $K_S\pi^-$

Fit Result:

$$\mathcal{B} = (5.4 \pm 0.6 \pm 0.8) \times 10^{-4}$$

CLEO (Phys. Rev. Lett. 88, 101803):

$$\mathcal{B} = (6.1 \pm 1.6 \pm 1.7) \times 10^{-4}$$

Preliminary

BELLE-CONF-0236

Conclusion

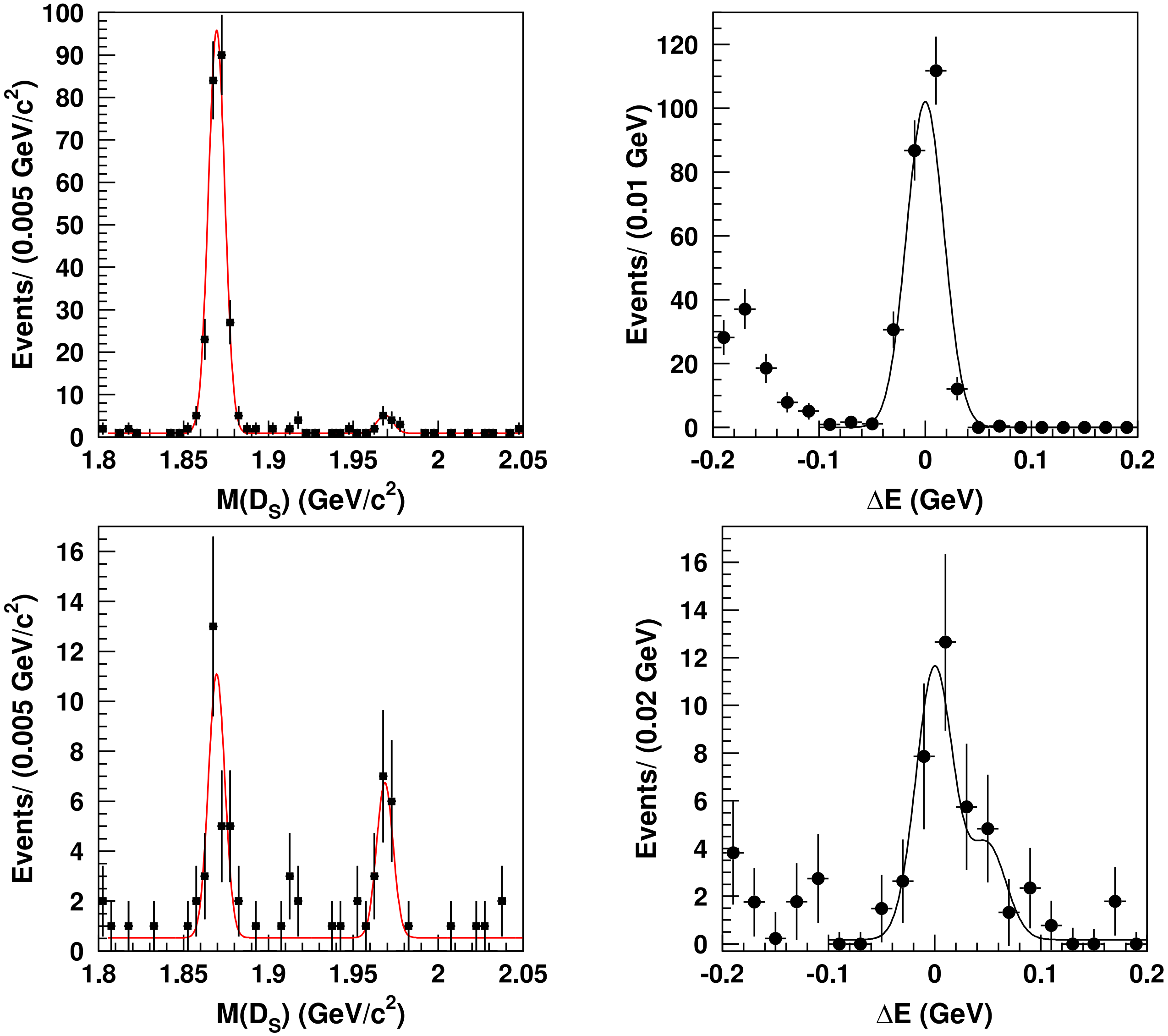
- Non zero strong phase δ_I (2.3σ) is obtained from CLEO and Belle measurements of $\mathcal{B}(B \to D\pi)$. Indications for final state interaction in $B \to D\pi$ decays.

- Belle observes $\bar{B}^0 \to D_s^+ K^-$ with $\mathcal{B} = (4.6^{+1.2}_{-1.1} \pm 1.3) \times 10^{-5}$. W-exchange or final state rescattering are important.

- First observation of all P-wave D^{**} states by Belle. The resonance parameters are measured. The $j_q = 1/2$ states are observed for the first time. Can be used to check the QCD sum rules and HQET.

- New results from B factories to come soon.

$\bar{B}^0 \to D^+ h^-$ cross check



$B^0 \to D^+\pi^-$

$\mathcal{B} = (2.85 \pm 0.20) \times 10^{-3}$

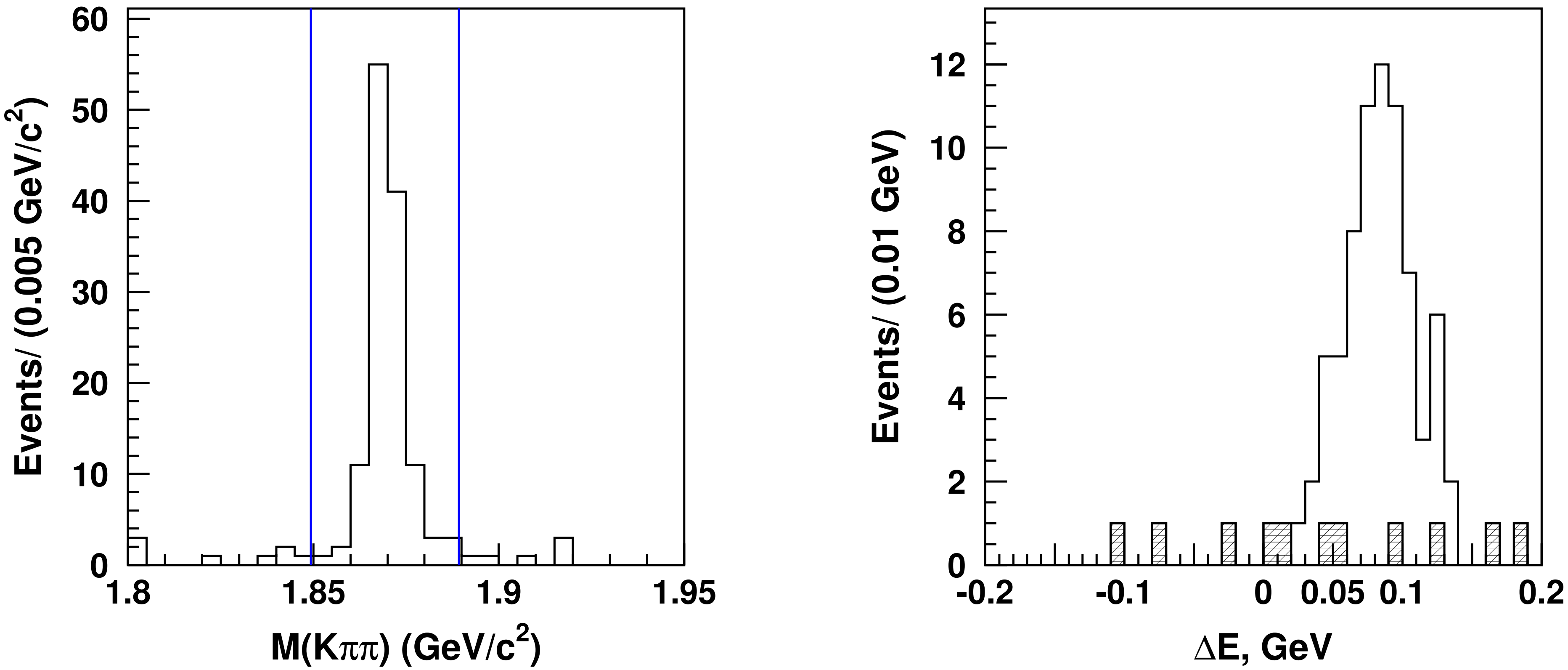
(PDG: $(3.0 \pm 0.4) \times 10^{-3}$)

$\bar{B}^0 \to D^+K^-$

$\mathcal{B} = (3.0 \pm 0.7) \times 10^{-4}$

(Belle: $(2.0\pm0.6)\times10^{-4}$)

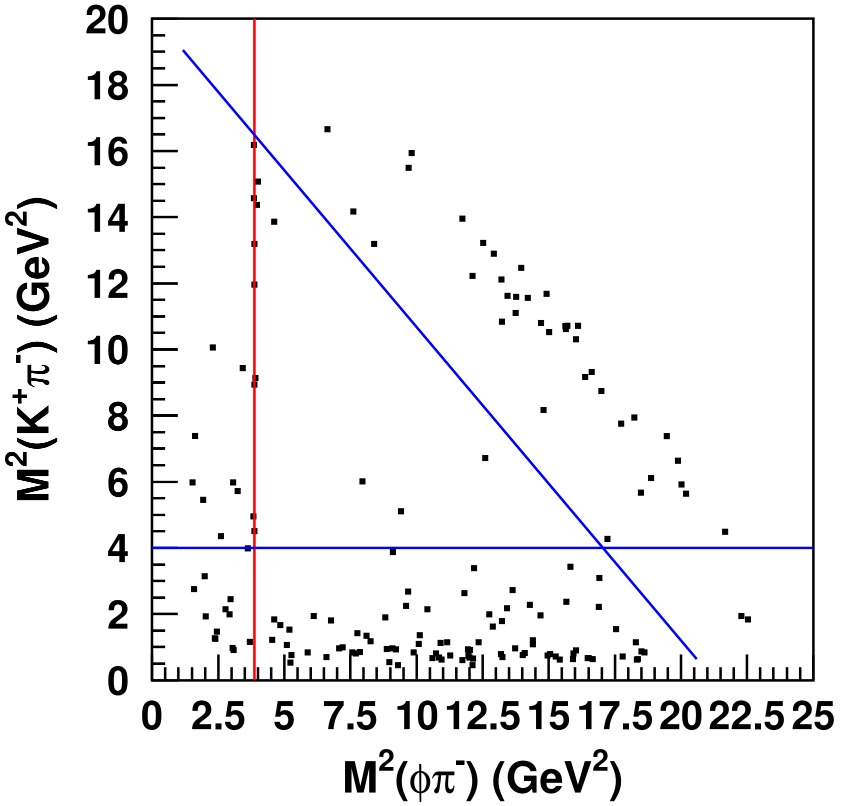
$\bar{B}^0 \to D^+ h^-$ study: D veto



We reject the D_s candidates that are consistent with $D^+ \to K^-\pi^+\pi^+$ ($D^+ \to K_s\pi^+$) mass hypothesis within 15 (20) MeV/c^2 ($\sim 3\sigma$).

Open histogram - before cut, hatched one - after cut.

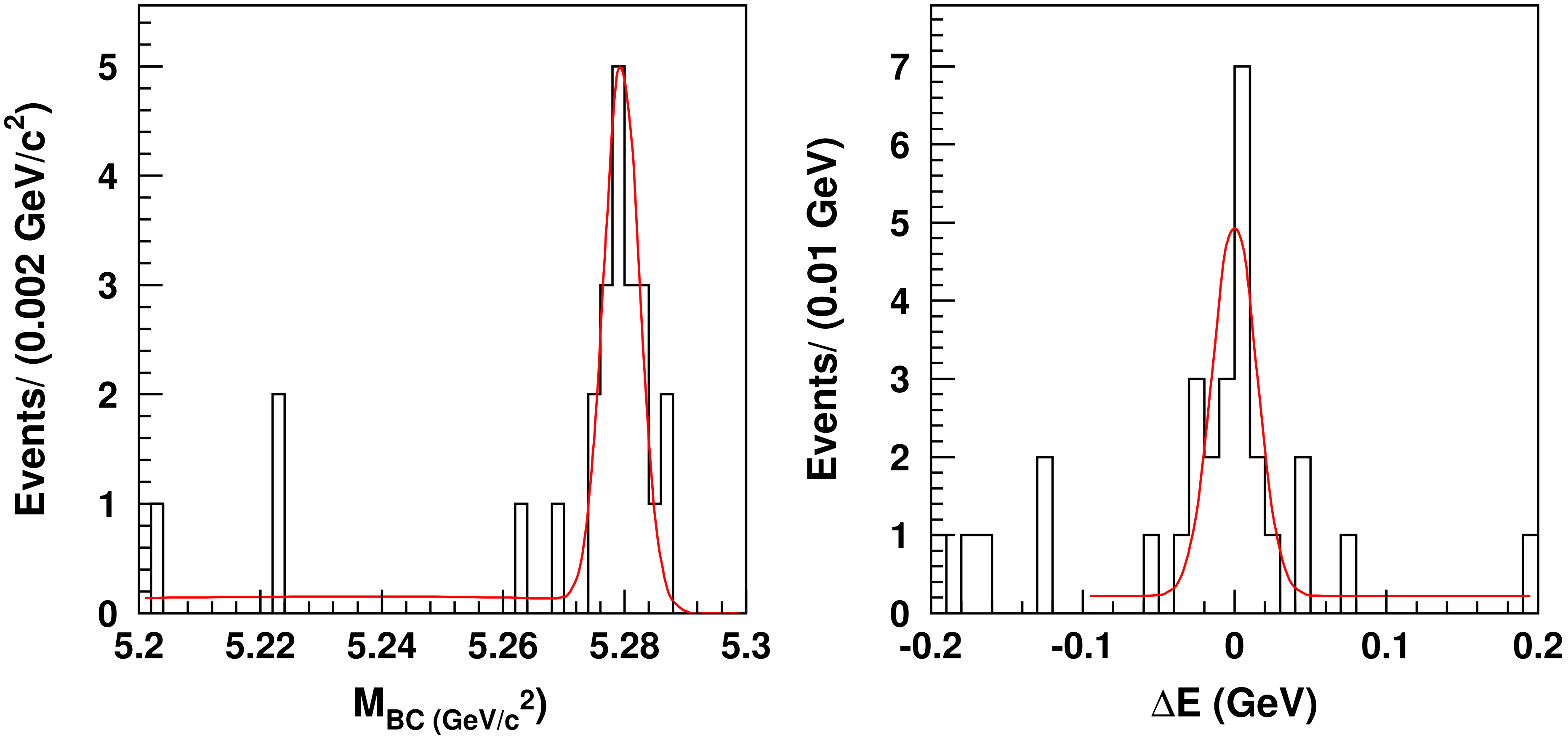
$\bar{B}^0 \to K^+K^-K^+\pi^-, K_S^0K^+K^-$ suppresion



- Charmless B decays, $\bar{B}^0 \to \bar{K}^{(*)0}K + K^-$ peak in the ΔE and M_{bc} but produce no signal in $M(D_s)$
- These decays dominated by quasi-two-body decay channels, such as $\phi\bar{K}^{(*)0}$.
- To reduce this background, we reject events with low ($<$ 2 GeV/c^2) two-body invariant masses:
  $M_{K^-\pi^+}$, $M_{\phi K^+}$ for the $D_s^+ \to \phi K^+$,
  $M_{K^+K^-}$, $M_{\bar{K}^{*0}K^-}$ for the $D_s^+ \to \bar{K}^{*0}K^+$,
  $M_{K^+K^-}$, $M_{K_S^0K^-}$ for the $D_s^+K_S^0K^+$ channels.

The remaining background is excluded by fitting the $M(D_s)$ distribution.

$\bar{B}^0 \to D_s^+ K^-$



$\bar{B}^0 \to D_s^+ K^-$

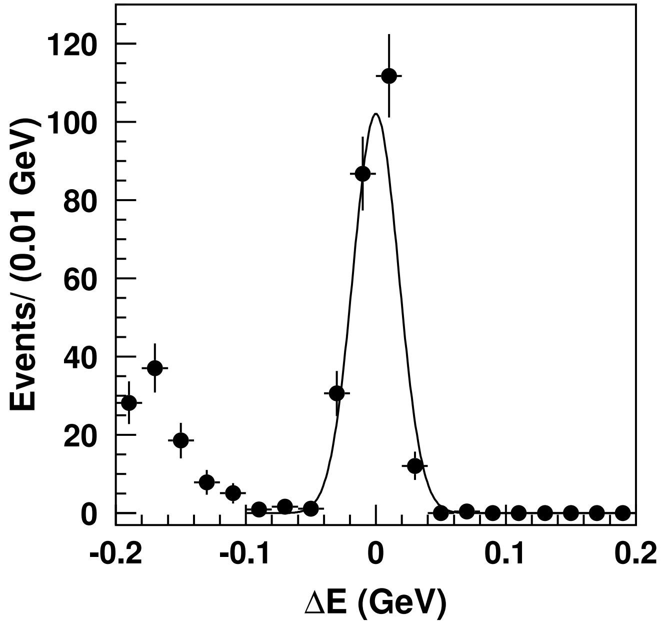
Possible background sources:

- Flat combinatorial.
- Real D_s from the $q\bar{q}$ events peaks in the $M(D_s)$, but flat in the ΔE.
- B decays peaking in the ΔE.

Method:

1. Divide ΔE range into N bins.
2. In each bin make the $M(D_s)$ distribution.
3. Determine the signal yield from the simultaneous fit for all bins.

Signal: 2D Gaussian, background: flat combinatorial, peaking in the $M(D_s)$, peaking in the ΔE.



Test with $\bar{B}^0 \to D^+ \pi^-$, $D^+ \to K^+ K^- \pi^+ (K_S^0 K^+)$
$\mathcal{B} = (2.85 \pm 0.20) \times 10^{-3}$

$D^{(*)}\pi\pi$ fit summary

$D\pi\pi$ model	Likelihood change
$D_2^\star$, $D_0^\star$, $D_v^\star$	0
$D_2^\star$, $D_0^\star$	59
$D_2^\star$, $D_0^\star$, $D_v^\star$, $B_v^\star$	-26
$D_2^\star$, $D_0^\star$, $D_v^\star$, phase space	-10
$D_2^\star$, $D_v^\star$ $B_v^\star$, +phase space	146
$D_2^\star$, $D_v^\star$ 1^-	271
$D_2^\star$, $D_v^\star$ 2^+	160

$D^*\pi\pi$ model	Likelihood change
$D_2^\star$, D_1, $D_1^\star$	0
$D_2^\star$, D_1, $D_1^\star$ phase space	-8
$D_2^\star$, D_1, +phase space	147
$D_2^\star$, D_1, 0^-	138
$D_2^\star$, D_1, 1^-	168
$D_2^\star$, D_1, 2^+	133