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Experimental Study of $B \to D_{sJ}^{(*)} \bar{D}^{(*)}$ Decays

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on behalf of the BaBar Collaboration

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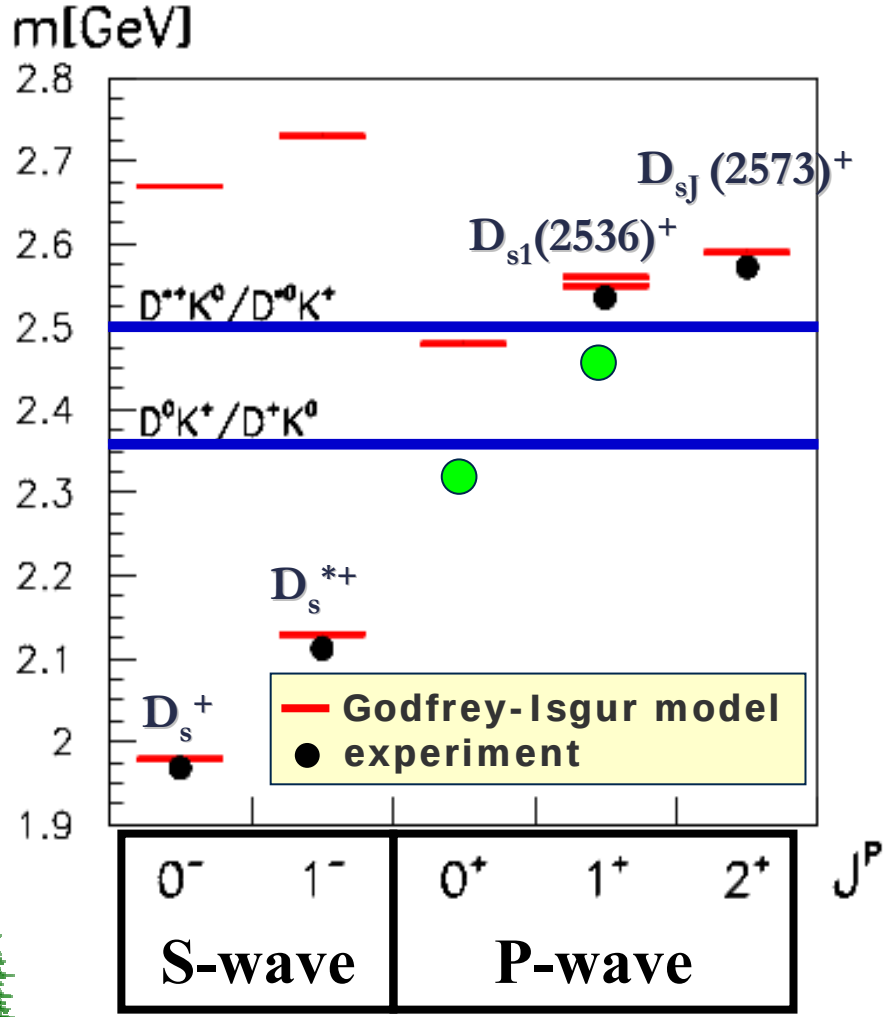
$c\bar{s}$ Meson Spectroscopy



- **$D^*_{sJ}(2317)^+$, $D_{sJ}(2460)^+$**
  - **observed** by BaBar, CLEO and BELLE (first in $e^+e^- \to c\bar{c}$)
  - unexpectedly found **below $D^{(*)}K$ decay threshold**
  - if $c\bar{s}$: **decays to $D_s^{(*)}\pi^0$ isospin violating**

→ narrow states

NB: non-$c\bar{s}$ interpretations of the new $D^{(*)}_{sJ}$ states not ruled out

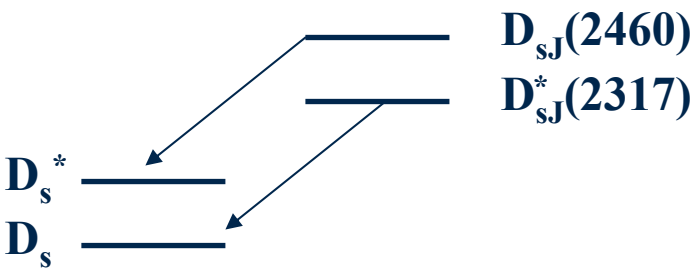
$D_{sJ}^{(*)}$ Production in B Decays

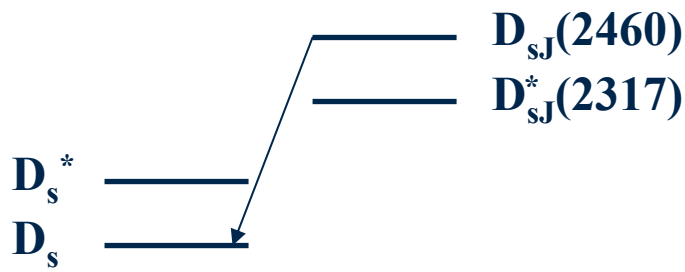
$B^+ \to \bar{D}^{(*)0} D_{sJ}^{(*)+}$ $\quad$ $B^0 \to D^{(*)-} D_{sJ}^{(*)+}$

$D_{sJ}(2317)^+ \to D_s^+ \pi^0$

$D_{sJ}(2460)^+ \to D_s^{*+} \pi^0$

$D_{sJ}(2460)^+ \to D_s^+ \gamma$





- observe all these channels and measure branching fractions
- D_{sJ} produced from well-defined initial state
  → determine $D_{sJ}(2460)$ spin through angular analysis

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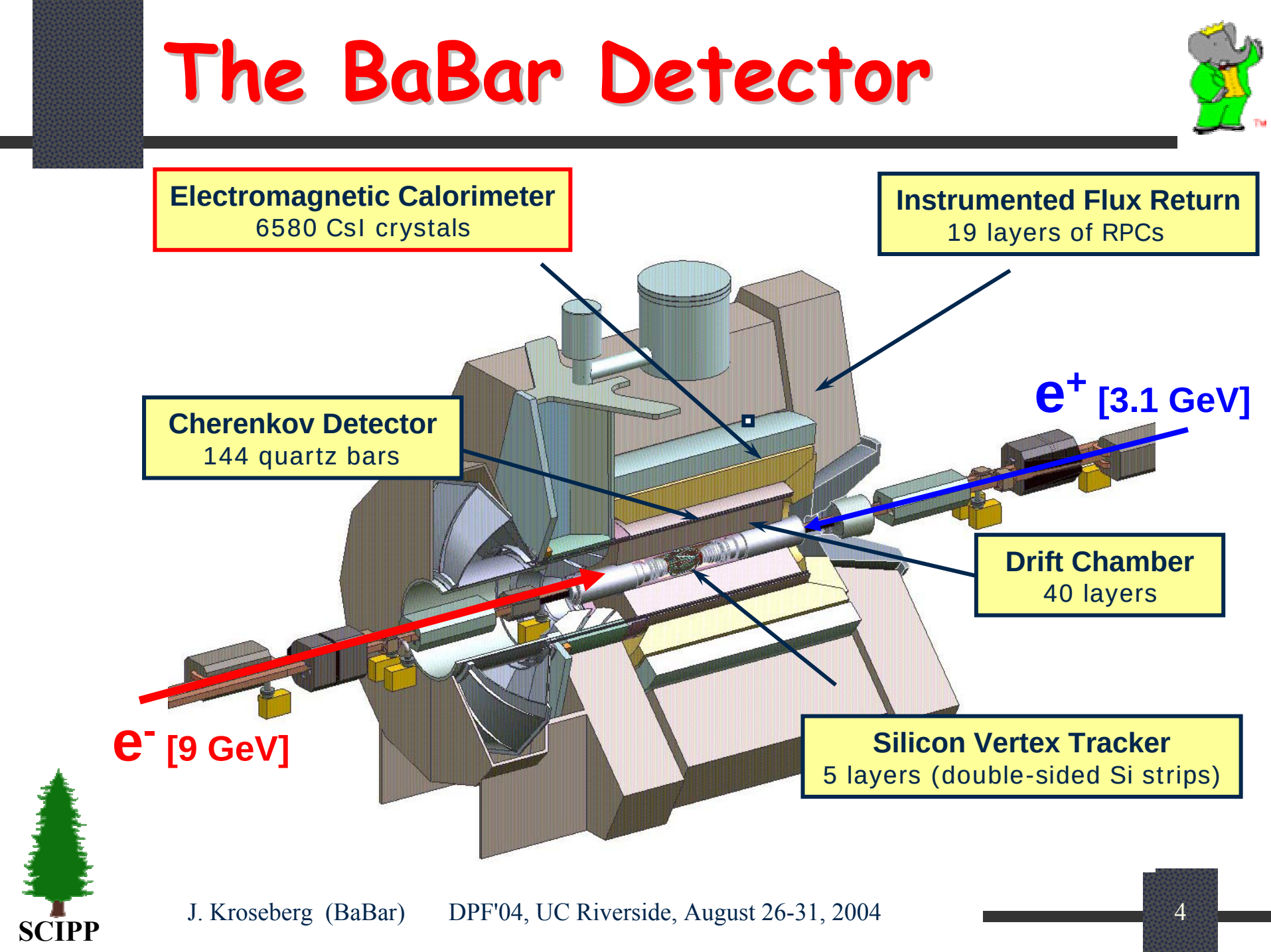
The BaBar Detector



Analysis Overview

- **reconstruct D mesons:**

  $D^{*0} \to D^0\pi^0, D^0\gamma$ $\qquad$ $D^0 \to K\pi, K\pi\pi^0, K\pi\pi\pi$

  $D_s^{*+} \to D_s\gamma$ $\qquad$ $D_s^+ \to \varphi\pi, K^{*0}K$

  $D^{*+} \to D^0\pi^+, D^+\pi^0$ $\qquad$ $D^+ \to K\pi\pi$

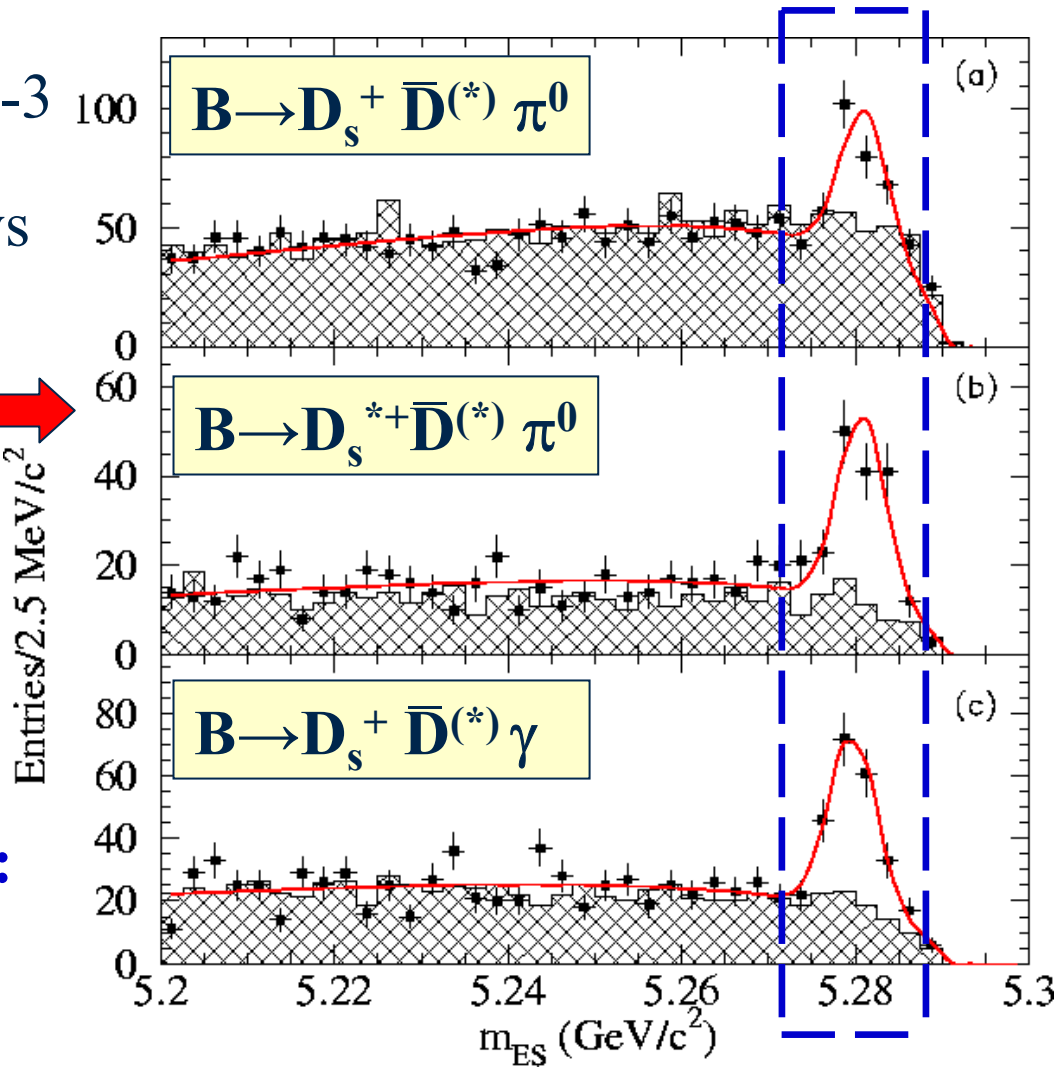
- **construct 3-body final states**

  $B \to D_s^{(*)+}\,\bar{D}^{(*)}\pi^0$; $B \to D_s^+\,\bar{D}^{(*)}\gamma$

- **select one B candidate** per event
- **determine signal yields** from $m(D_s\gamma)$ and $m(D_s^{(*)}\pi^0)$ **fits**
- **calculate branching fractions**
- **perform angular analysis** for $\bar{D}D_{sJ}(2460)^+$, $D_{sJ}(2460)^+ \to D_s^+\gamma$

Event Selection

- **data sample:** BaBar run 1-3
  $\mathcal{L} \approx 113$ fb^{-1} ; 122.1×10^6 B$\bar{\text{B}}$
- **D selection:** mass windows
- **B selection:**
  energy-substituted mass
  $$m_{\rm ES} \equiv \sqrt{s/4 - p_B^{*\,2}}$$
  and missing energy
  $$\Delta E \equiv E_B^* - \sqrt{s}/2$$
- **best B candidate:**
  minimum $|\Delta E|$
- **background suppression:**
  minimum $m(\mathrm{D}\pi^0)$, $m(\mathrm{D}\gamma)$



$D_{sJ}^{(*)}$ Mass Resolution

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

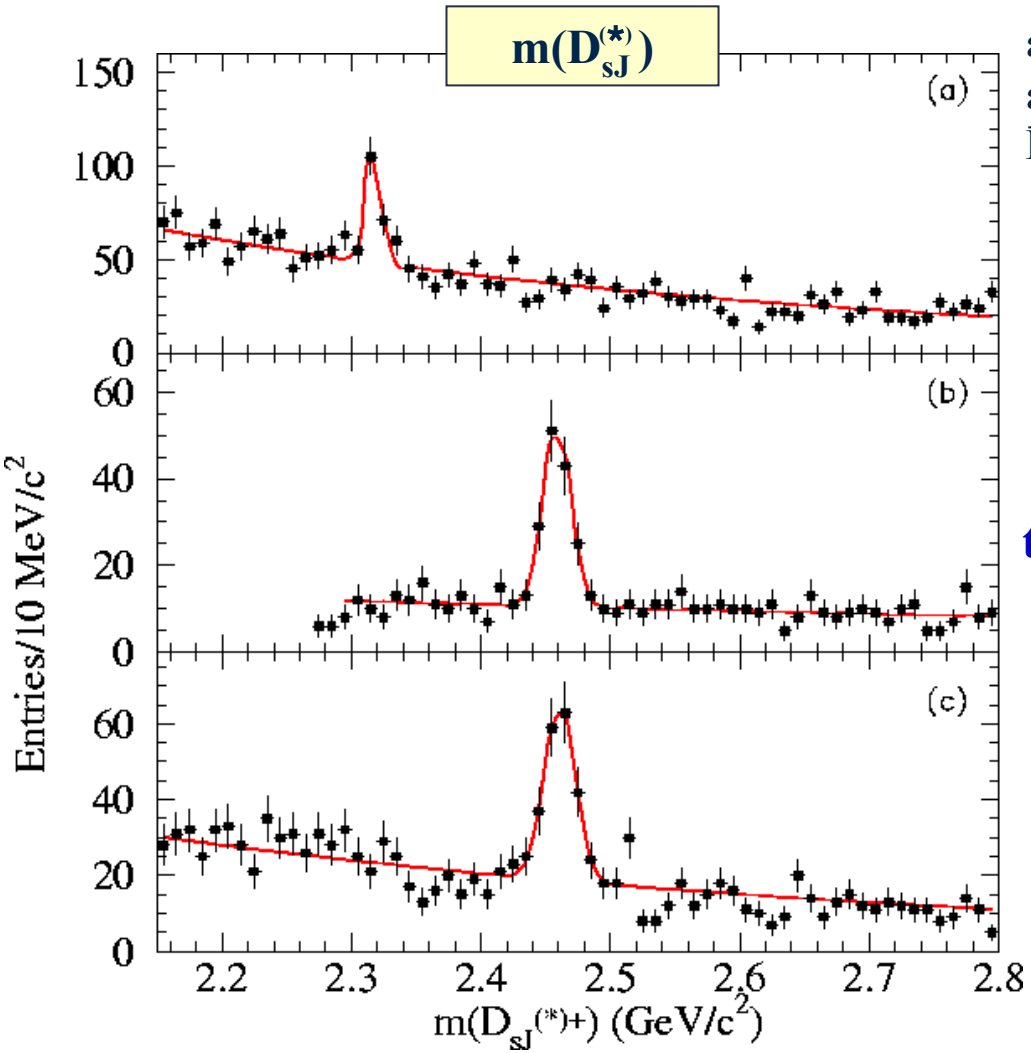
(88±17) signal events

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

(112±14) signal events

$B \to D_s^+ \bar{D}^{(*)} \gamma$

(139±17) signal events



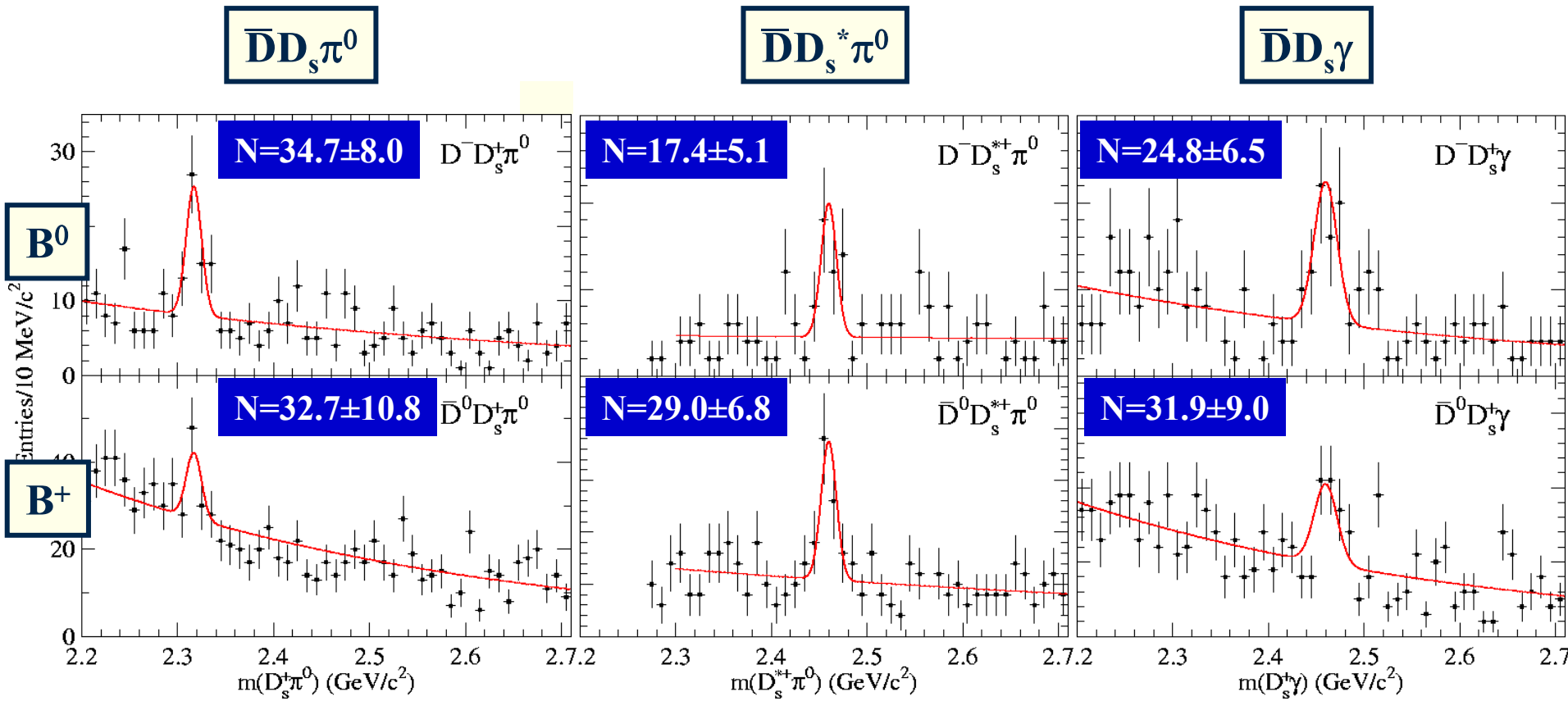
after combining B^+/B^0 and summing over $\bar{D}^{(*)}$ modes

$\sigma \sim 8$ MeV/c^2

to be used in $m(D_{sJ}^{(*)})$ fits for the 12 individual channels

$\sigma \sim 12$ MeV/c^2

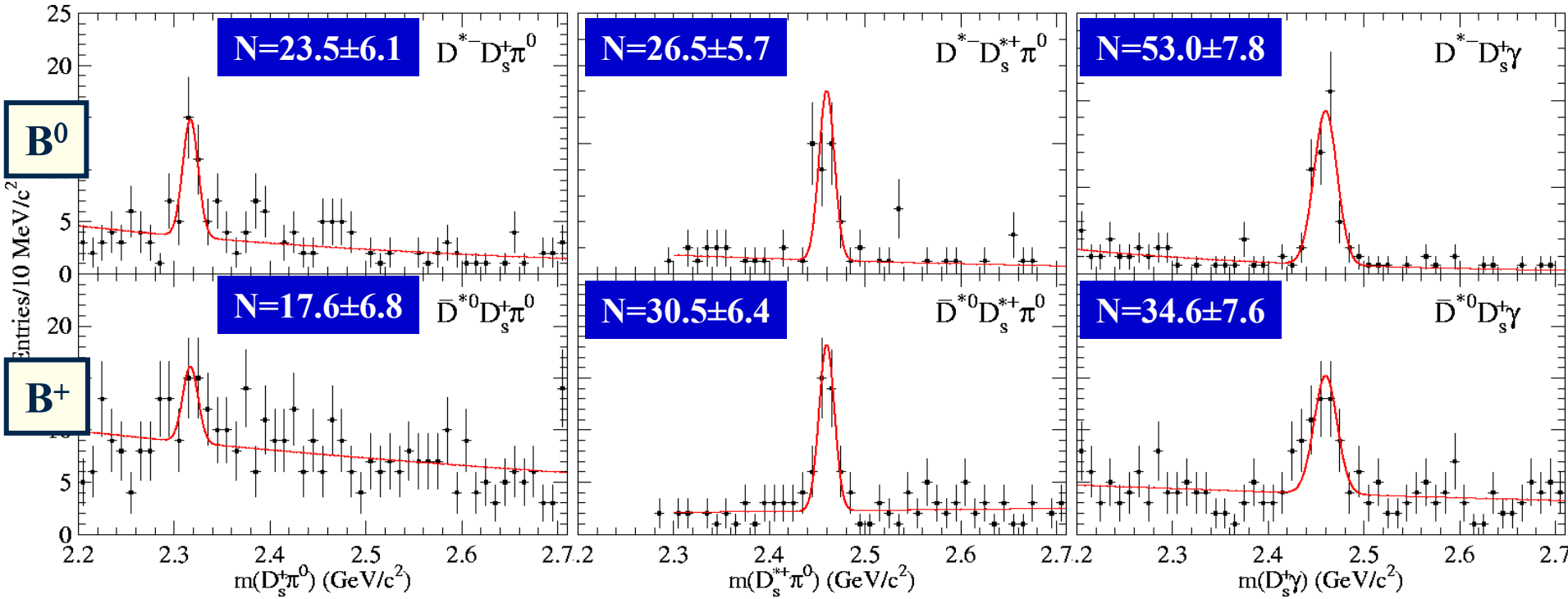
Event Yields: $B \to \bar{D} D_s^{(*)} \pi^0/\gamma$



previously observed by BELLE

Event Yields: $B \to \bar{D}^* D_s^{(*)} \pi^0/\gamma$

$\bar{D}^* D_s \pi^0$ | $\bar{D}^* D_s^* \pi^0$ | $\bar{D}^* D_s \gamma$



observed for the first time

Backgrounds

no significant peaking **background except** for

cross-feed between signal modes

D^{*+}	reconstructed as	D^{*0}
$D^{*}_{sJ}(2317)\bar{D}^{*0/+}$	reconstructed as	$D_{sJ}(2460)\bar{D}^{0}$
$D_{sJ}(2460)\bar{D}^{0}$	reconstructed as	$D^{*}_{sJ}(2317)\bar{D}^{*0}$

relative contributions **typically small** (well below 10%) **or negligible** except for $\bar{D}^{*0}\,D_s^{+}\gamma$ (~20%) and $\bar{D}^{*0}\,D_s^{+}\pi^0$ (~40%)

obtained from simulation and taken into account in BF measurement

Systematic Uncertainties

main branching fraction systematics

- **tracking efficiency** : **1.3%** per track
- **γ/π^0 efficiency** : **2.5%** per photon
- **Δm resolution** : **5%** per D^*
- **ΔE resolution** : **6%**
- **D_{sJ} width** used in fits : **5-10%**
- **fit model** : **5%**

[…]

- **total** : **10-24%**
- **intermediate D branching fractions**

(dominated by **$\sigma(BF[Ds\rightarrow \phi\pi]) \sim 25\%$**) **given separately**

Branching Fraction Results

	Decay Mode		Branching fraction × 10^3	
			this analysis	BELLE
I	$B^0 \to D^*_{sJ}(2317)^+ D^-$	$[D^*_{sJ}(2317)^+ \to D_s^+ \pi^0]$	$1.8 \pm 0.4 \pm 0.3^{+0.6}_{-0.4}$	$0.9 \pm 0.3^{+0.3}_{-0.3}$
II	$B^0 \to D^*_{sJ}(2317)^+ D^{*-}$	$[D^*_{sJ}(2317)^+ \to D_s^+ \pi^0]$	$1.5 \pm 0.4 \pm 0.2^{+0.5}_{-0.3}$	new
III	$B^+ \to D^*_{sJ}(2317)^+ \overline{D}^0$	$[D^*_{sJ}(2317)^+ \to D_s^+ \pi^0]$	$1.0 \pm 0.3 \pm 0.1^{+0.4}_{-0.2}$	$0.8 \pm 0.2^{+0.3}_{-0.3}$
IV	$B^+ \to D^*_{sJ}(2317)^+ \overline{D}^{*0}$	$[D^*_{sJ}(2317)^+ \to D_s^+ \pi^0]$	$0.9 \pm 0.6 \pm 0.2^{+0.3}_{-0.2}$	new
V	$B^0 \to D_{sJ}(2460)^+ D^-$	$[D_{sJ}(2460)^+ \to D_s^{*+} \pi^0]$	$2.8 \pm 0.8 \pm 0.5^{+1.0}_{-0.6}$	$2.3 \pm 0.7^{+0.7}_{-0.6}$
VI	$B^0 \to D_{sJ}(2460)^+ D^{*-}$	$[D_{sJ}(2460)^+ \to D_s^{*+} \pi^0]$	$5.5 \pm 1.2 \pm 1.0^{+1.9}_{-1.2}$	new
VII	$B^+ \to D_{sJ}(2460)^+ \overline{D}^0$	$[D_{sJ}(2460)^+ \to D_s^{*+} \pi^0]$	$2.7 \pm 0.7 \pm 0.5^{+0.9}_{-0.6}$	$1.2 \pm 0.4^{+0.6}_{-0.5}$
VIII	$B^+ \to D_{sJ}(2460)^+ \overline{D}^{*0}$	$[D_{sJ}(2460)^+ \to D_s^{*+} \pi^0]$	$7.6 \pm 1.7 \pm 1.8^{+2.6}_{-1.6}$	new
IX	$B^0 \to D_{sJ}(2460)^+ D^-$	$[D_{sJ}(2460)^+ \to D_s^+ \gamma]$	$0.8 \pm 0.2 \pm 0.1^{+0.3}_{-0.2}$	$0.8 \pm 0.3^{+0.2}_{-0.2}$
X	$B^0 \to D_{sJ}(2460)^+ D^{*-}$	$[D_{sJ}(2460)^+ \to D_s^+ \gamma]$	$2.3 \pm 0.3 \pm 0.3^{+0.8}_{-0.5}$	new
XI	$B^+ \to D_{sJ}(2460)^+ \overline{D}^0$	$[D_{sJ}(2460)^+ \to D_s^+ \gamma]$	$0.6 \pm 0.2 \pm 0.1^{+0.2}_{-0.1}$	$0.6 \pm 0.2^{+0.2}_{-0.2}$
XII	$B^+ \to D_{sJ}(2460)^+ \overline{D}^{*0}$	$[D_{sJ}(2460)^+ \to D_s^+ \gamma]$	$1.4 \pm 0.4 \pm 0.3^{+0.5}_{-0.3}$	new

stat. syst. stat. syst.

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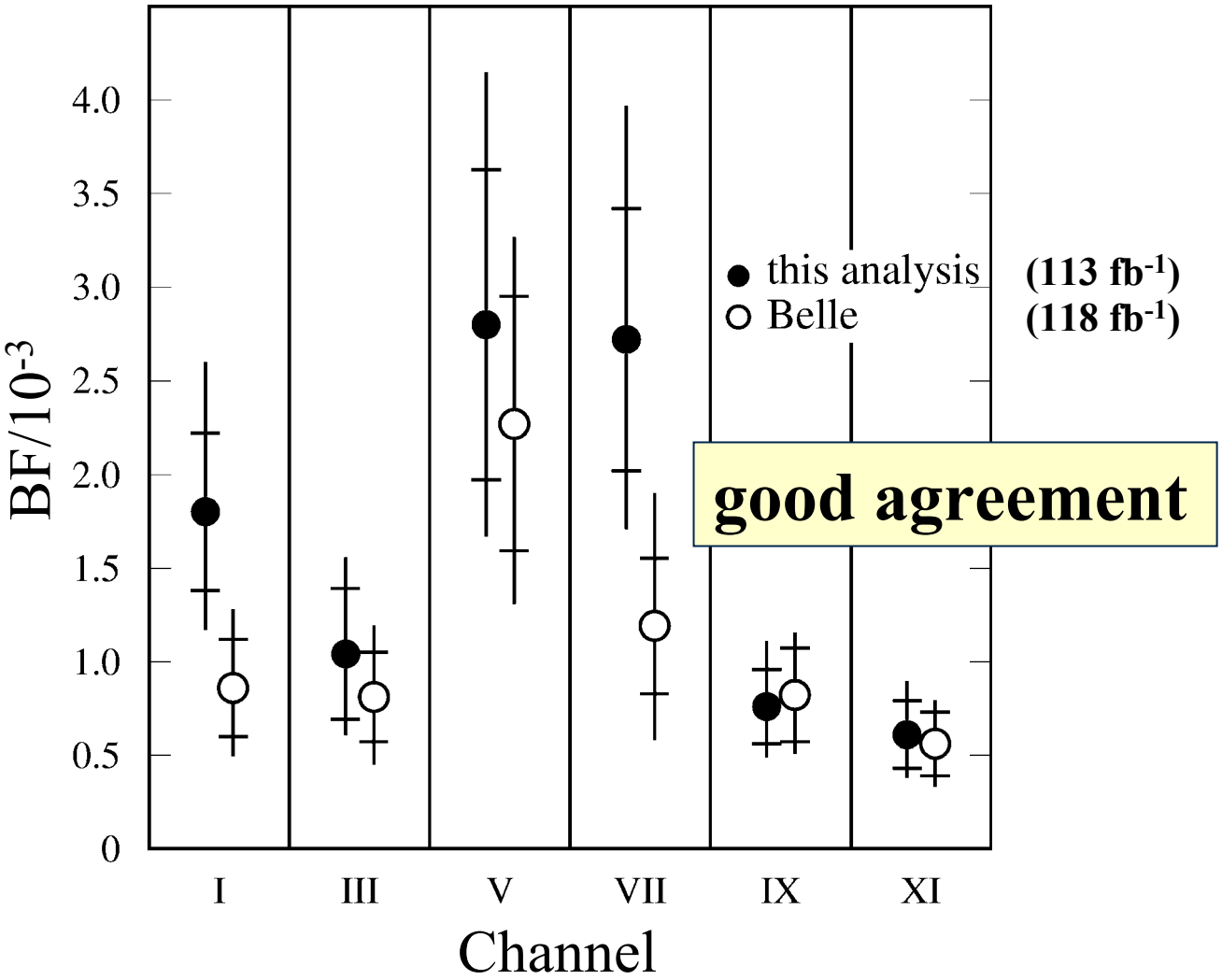
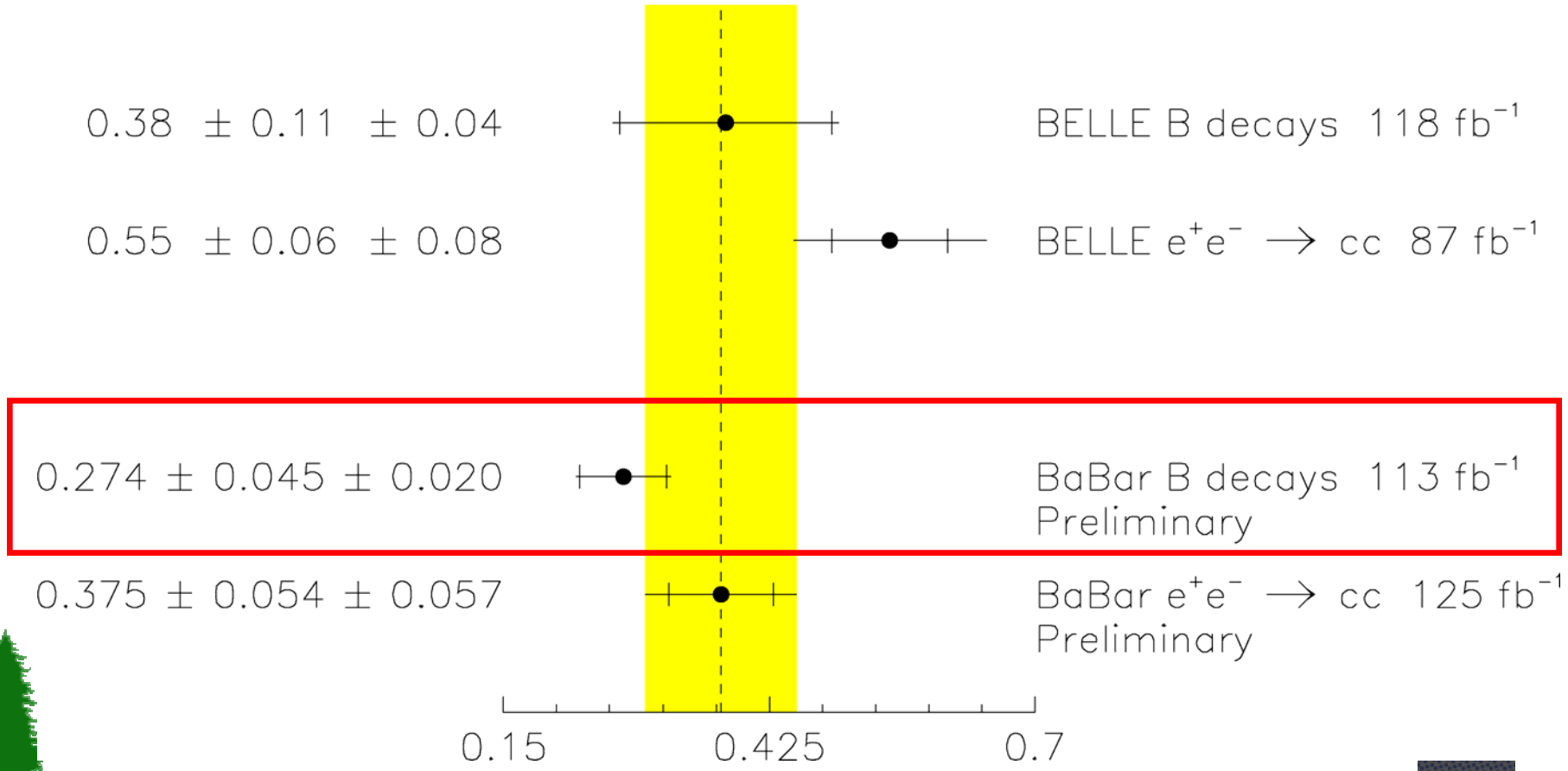
Comparison with BELLE



$D_{sJ}(2460)$ BF Ratio

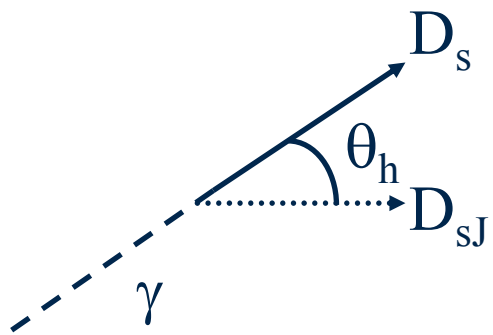
$$\frac{BF(D_{sJ}(2460) \to D_s\gamma)}{BF(D_{sJ}(2460) \to D_s^*\pi^0)} = 0.274 \pm 0.045 \pm 0.020$$



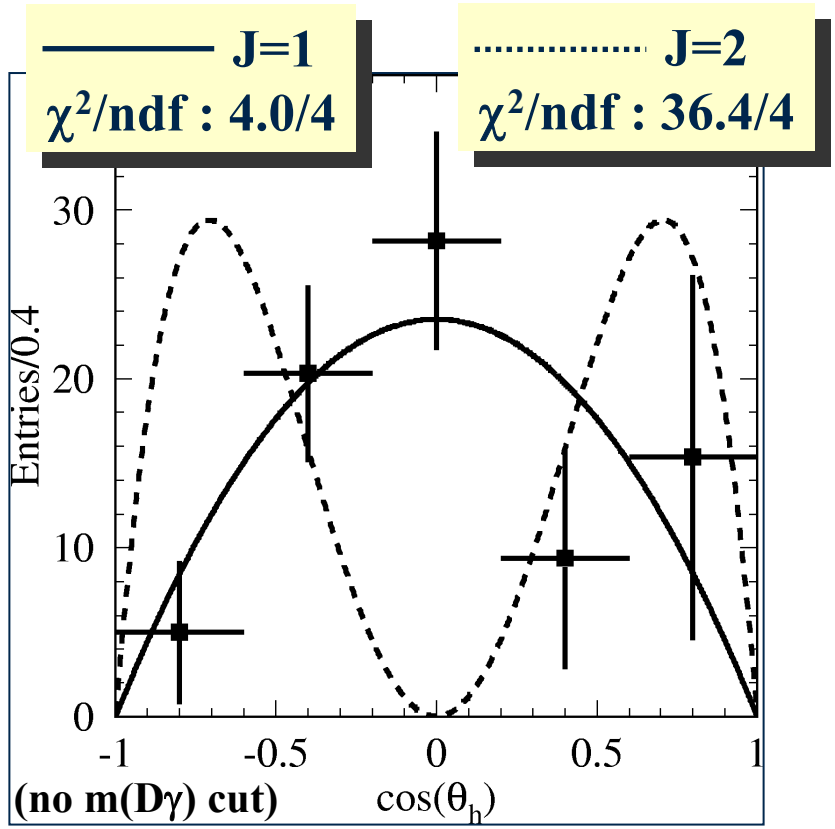
$D_{sJ}(2460)$ Helicity Analysis

$B^0 \to D_{sJ}(2460)^+ D^-$ and $B^+ \to D_{sJ}(2460)^+ \bar{D}^0$ (with $D_{sJ}(2460) \to D_s\gamma$)

- D_{sJ} is **polarized**
- compute **helicity angle** θ_h



- fit **D_{sJ} yields in $\cos(\theta_h)$ bins**
- **compare with prediction**
  for D_{sJ} Spin J=1 and J=2



data strongly **favors J=1** (confirms earlier BELLE result)

Summary

- **$D_{sJ}^{(*)}$ observed in B decays** based on 113 fb^{-1} (122.1×10^6 B$\bar{B}$)
  - $B \to D_{sJ}^{*}(2317)\,\bar{D}^{(*)}$ $[D_{sJ}^{*}(2317) \to D_s\pi^0]$ BF ~ (1-2) × 10^{-3}
  - $B \to D_{sJ}(2460)\,\bar{D}^{(*)}$ $[D_{sJ}(2460) \to D_s^{*}\pi^0]$ BF ~ (3-8) × 10^{-3}
  - $B \to D_{sJ}(2460)\,\bar{D}^{(*)}$ $[D_{sJ}(2460) \to D_s\gamma]$ BF ~ (1-2) × 10^{-3}

- **$B \to D_{sJ}^{(*)}\bar{D}^{*}$ decays observed for the first time**
  $B \to D_{sJ}^{(*)}\bar{D}$ BF agree with earlier BELLE results

- **helicity analysis of $B \to D_{sJ}(2460)\,\bar{D}$ $[D_{sJ}(2460) \to D_s\gamma]$**
  → J=1 hypothesis is favored for $D_{sJ}(2460)$
  (in agreement with earlier BELLE result)

all results preliminary; submitted to PRL (hep-ex/0408041)

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