

Hadronic B Decays to Open Charm at BaBar

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for the
BaBar Collaboration

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BABAR

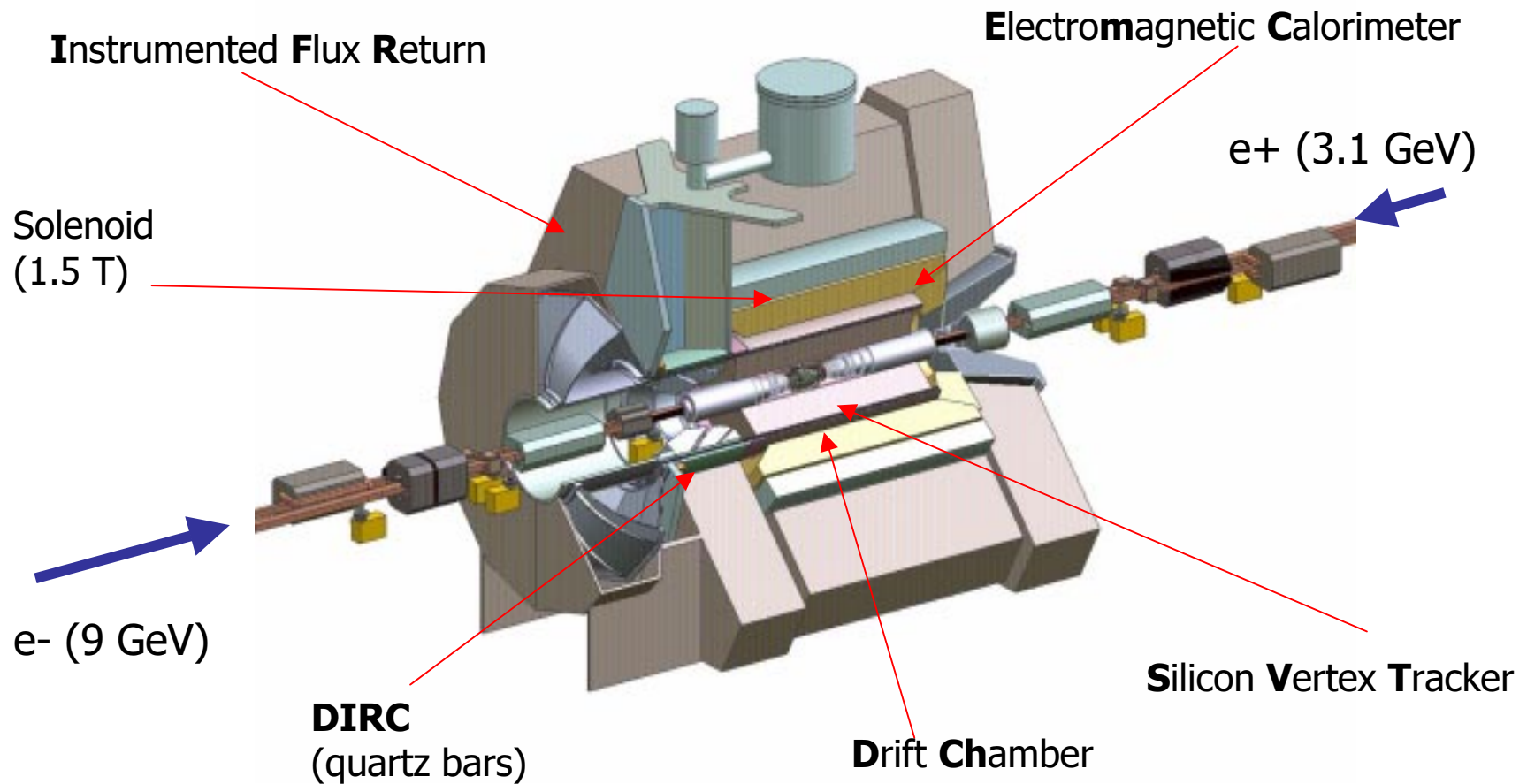


Outline of the talk

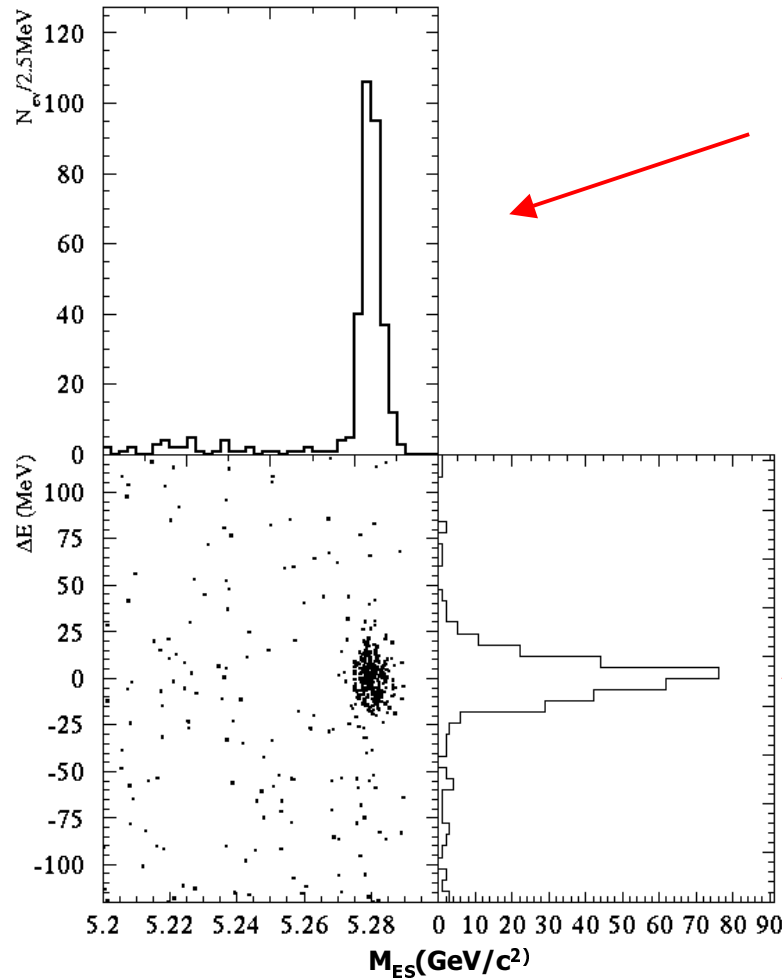
- **B to Double Charm decays**
 - Measurement of $\text{BR}(B \rightarrow D^{(*)} D^{(*)} K)$
 - Measurement of $\text{BR}(B^0 \rightarrow D^{(*)} D^{(*)})$

The Babar Experiment

- 20.7 fb⁻¹ at $\Upsilon(4S)$ resonance $\sim 22.7 \times 10^6$ $B\bar{B}$ pairs



Kinematic Variables



$$m_{ES} = \sqrt{E_{beam}^{*2} - p_B^{*2}}$$

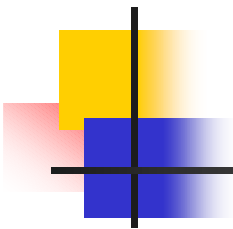
Energy substituted mass:

- Invariant mass of Beam energy and reconstructed B candidate momentum in CMS

$$\Delta E = E_{B0}^* - E_{beam}^*$$

ΔE :

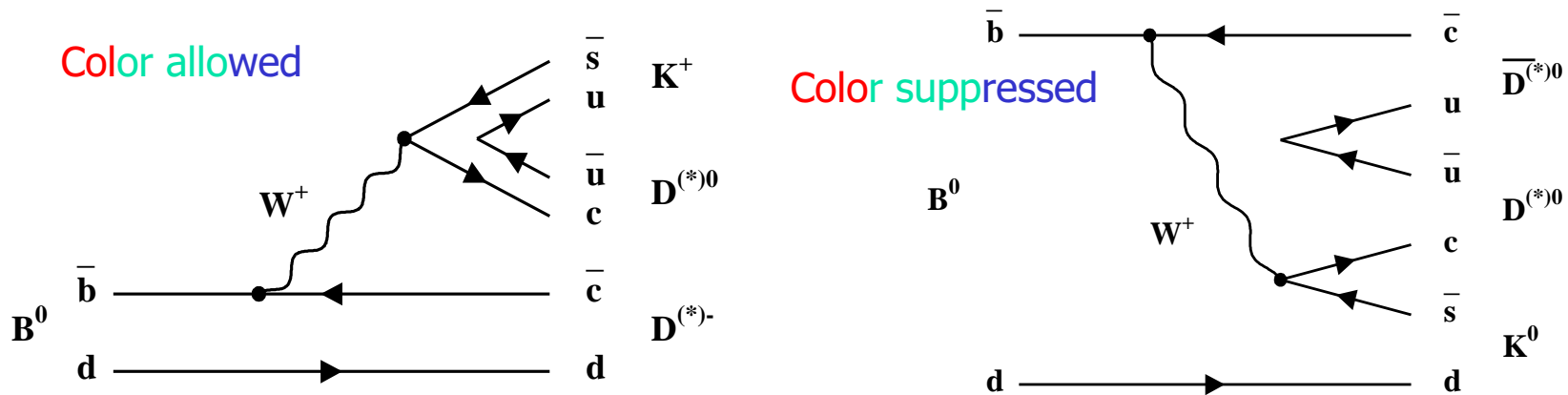
- Energy of reconstructed B candidate minus beam energy in CMS



Decay $B \rightarrow D^{(*)} D^{(*)} K$

- study of $b \rightarrow c\bar{c}s$ transition
 - $\bar{c}s$ expected to hadronize dominant in $D_s^{(*)}$
 - $b \rightarrow c\bar{c}s$ branching ratio from $BR(B \rightarrow D_s^{(*)})$ measurements alone inconsistent with theoretical predictions based on semileptonic decays
- Large $BR(B \rightarrow D^{(*)} D^{(*)} K)$ could resolve problem
 - Additional light quark pair popped out in the $b \rightarrow c\bar{c}s$ decay
 - Could contribute significantly to overall $b \rightarrow c\bar{c}s$ rate
 - External (color allowed) and internal (color suppressed) decay modes

Decay $B \rightarrow D^{(*)} D^{(*)} K$



- Previous observation by CLEO and Aleph
 - CLEO *: Total $B \rightarrow D^* D^{(*)} K^-$ of $\sim 2\%$
 - Aleph **: $Br(B \rightarrow D^{(*)} D^{(*)} K) = \left(7.1_{-1.5}^{+2.5} (stat)_{-0.8}^{+0.9} (syst) \right) \%$

*CLEO CONF 97-26

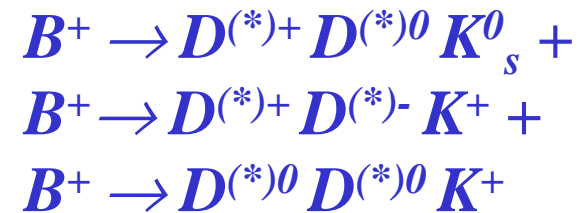
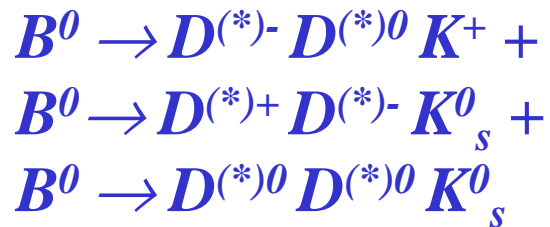
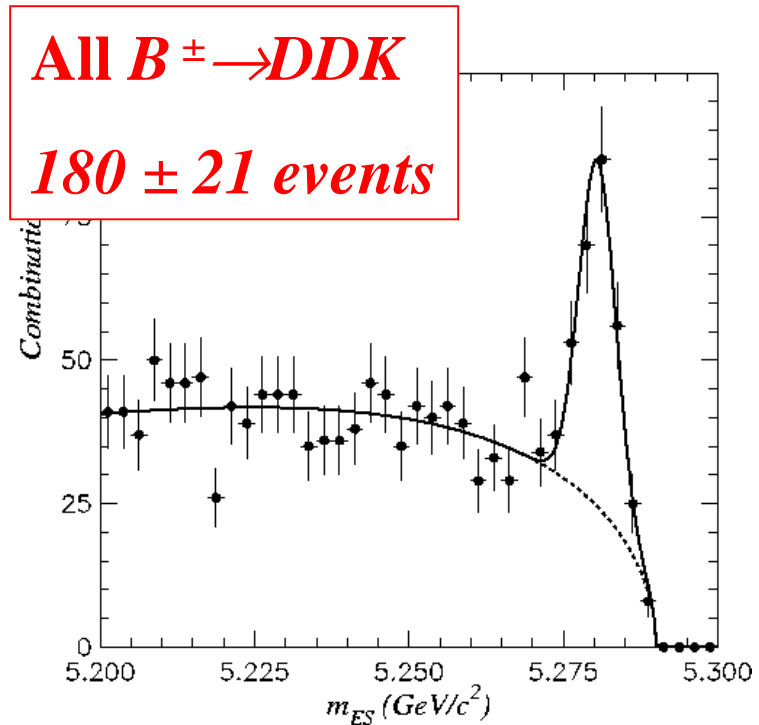
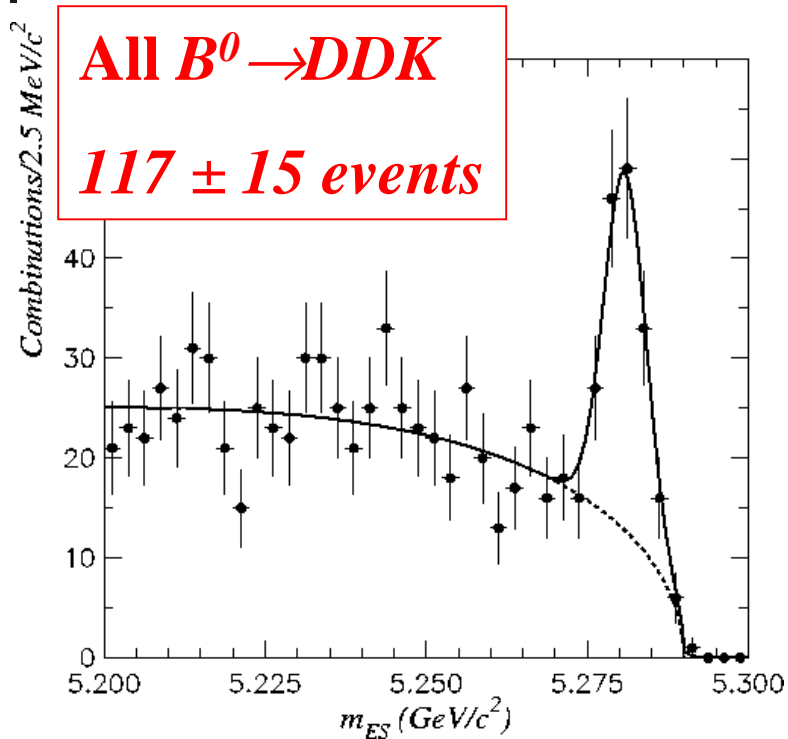
** *Eur.Phys.J.***C4**,387-407(1998)



Event Selection $B \rightarrow D^{(*)} D^{(*)} K$

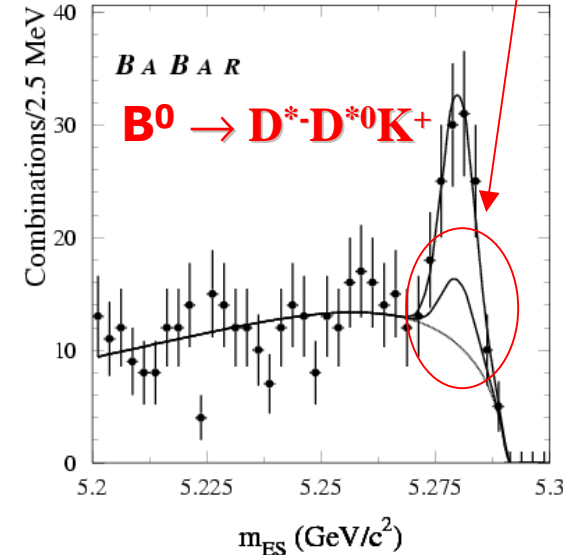
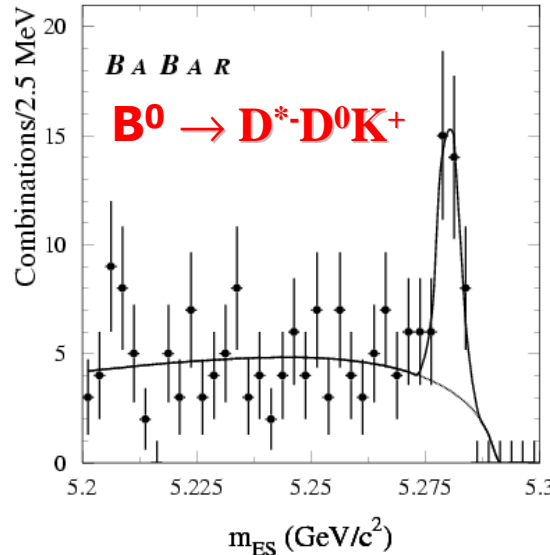
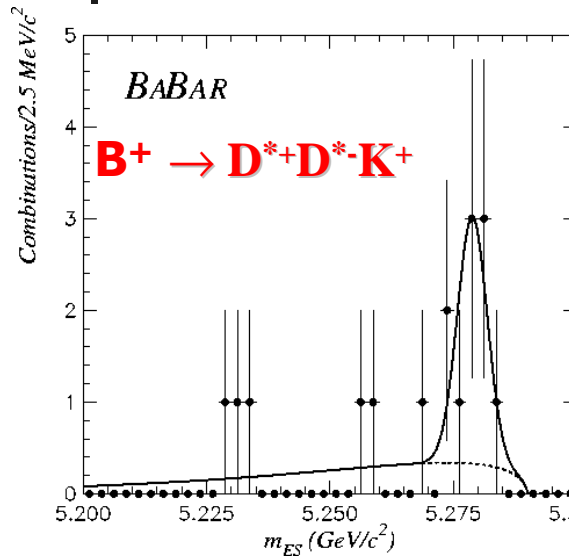
- Charmed meson reconstruction
 - $D^{*+} \rightarrow D^0 \pi^+$
 - $D^{*0} \rightarrow D^0 \pi^0, D^0 \gamma$
 - $D^0 \rightarrow K^- \pi^+, K^- \pi^+ \pi^0, K^- \pi^+ \pi^+ \pi^+$
- 'Tight' particle identification for single K
- Kinematic variables for signal/background separation
 - $\Delta E, m_{ES}$
- Selection in case of multiple candidates
 - $$\chi^2_{Mass} = \sum \left(\frac{((\Delta)m_{D^{(*)}} - m_{PDG})}{\sigma_m} \right)^2$$
- fit to m_{ES} distribution for signal and background estimation

B \rightarrow D^(*) D^(*) K



Excl. BR $B \rightarrow D^{(*)} D^{(*)} K$

Bkg from $B^+ \rightarrow D^{*+} D^{*0} K^+$ events
(due to partial reconstruction)



➤ $B^+ \rightarrow D^{*+} D^{*0} K^+$

- $N_{\text{signal}} = 8.2 \pm 3.5$
- $\text{Br} = (0.34 \pm 0.16(\text{stat}) \pm 0.09(\text{syst}))\%$

Color suppressed

➤ $B^0 \rightarrow D^{*+} D^{*0} K^+$

- $N_{\text{signal}} = 80.2 \pm 15.3$
- $\text{Br} = (0.68 \pm 0.17(\text{stat}) \pm 0.17(\text{syst}))\%$

External diagram

➤ $B^0 \rightarrow D^{*+} D^0 K^+$

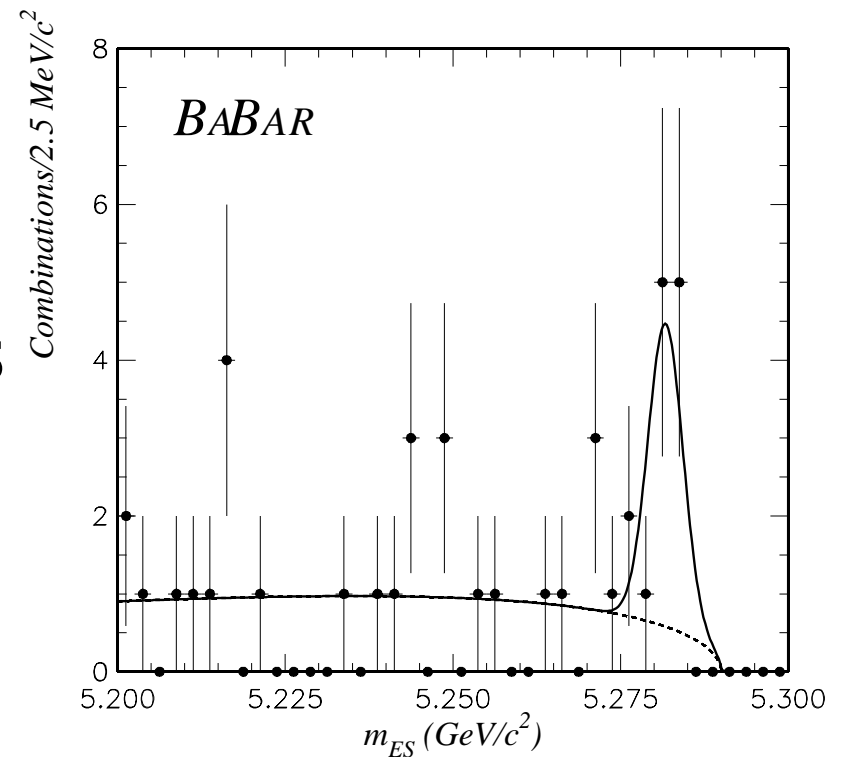
- $N_{\text{signal}} = 29.6 \pm 7.2$
- $\text{Br} = (0.28 \pm 0.07(\text{stat}) \pm 0.05(\text{syst}))\%$

Evidence for $B^0 \rightarrow D^{(*)+}D^{(*)-}K_S$

- Potentially useful mode for CP violation measurements

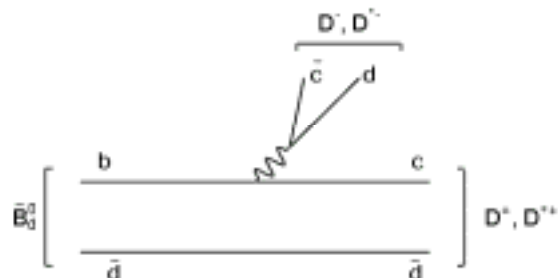
- Signal of 10.1 ± 3.7 events

- Bkg. of 3.4
- Prob. of bkg fluctuation:
 1.4×10^{-5}



Decay $B \rightarrow D^{(*)}D^{(*)}$

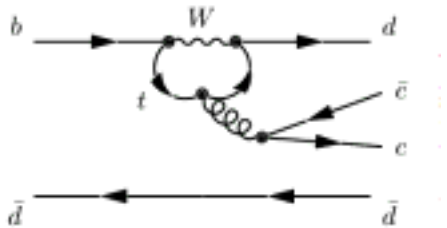
- The Standard Model predicts time-dependent **CP-violating asymmetries** in the decays $B^0 \rightarrow D^{(*)+}D^{(*)-}$ proportional to $\sin 2\beta$
 - Independent measurement of $\sin 2\beta$ in these modes, compared to the measurement from $B^0 \rightarrow J/\psi K_S$, would provide a test of the Standard Model picture of *CP* violation



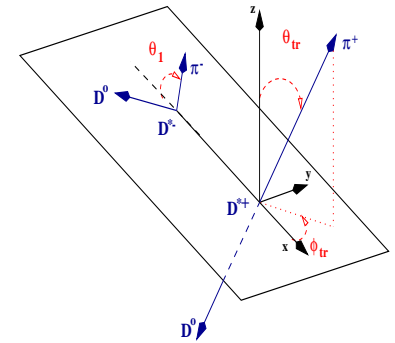
CP violation in $B^0 \rightarrow D^{*+}D^{*-}$

BUT:

- additional penguin contribution \rightarrow dilution of $\sin 2\beta$



$\sin 2\beta$ shifted by the ratio of the tree and penguin contribution \rightarrow **ratio has theoretical uncertainties**
($\Delta\beta \sim 0.01$)



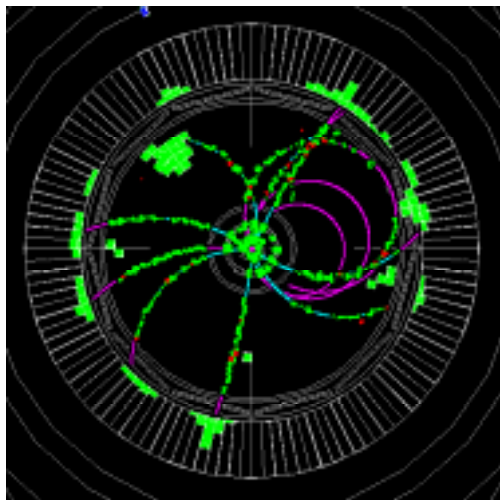
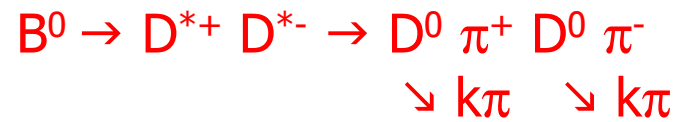
- B^0 decays to Vector-Vector final state
 - CP-odd dilution from P-wave decay component
 - Angular analysis can determine CP-even and CP-odd component of decay
- Previous branching fraction measurement (CLEO):

$$Br(B^0 \rightarrow D^{*+} D^{*-}) = (9.9_{-3.3}^{+4.2} (stat) \pm 1.2 (syst)) \times 10^{-4}$$

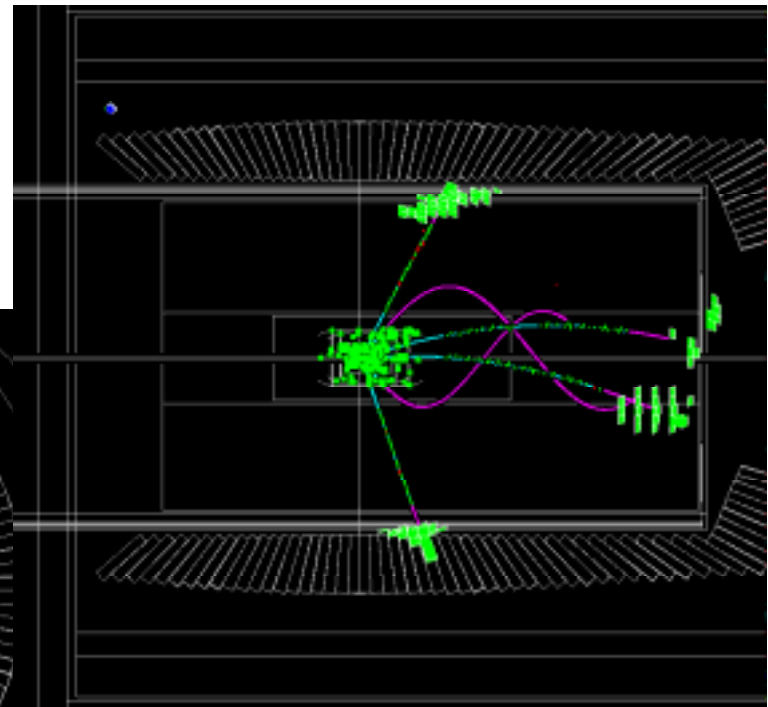
*Phys.Rev.***D62**(2000)

8 Events

Event Display for D*D*



← All Decay particles



← Only D*D* decay particles

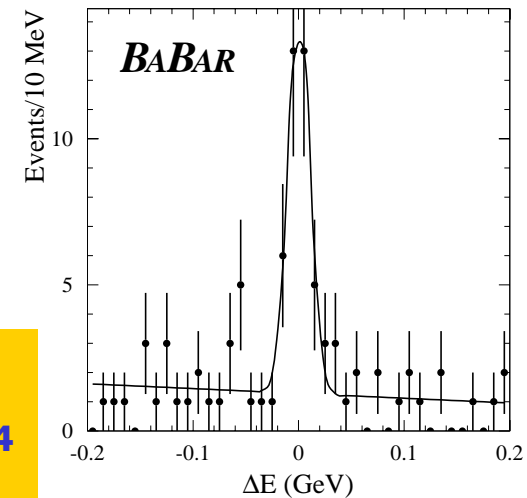
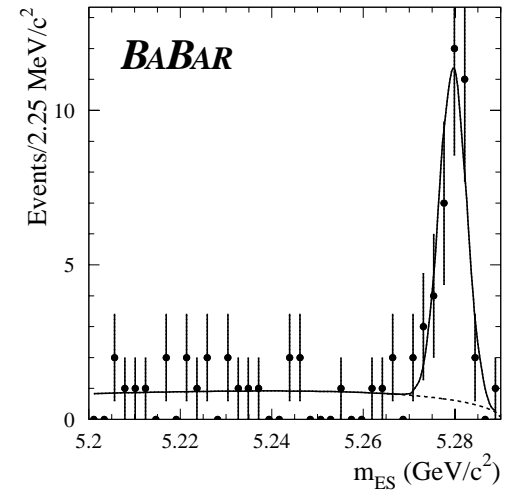
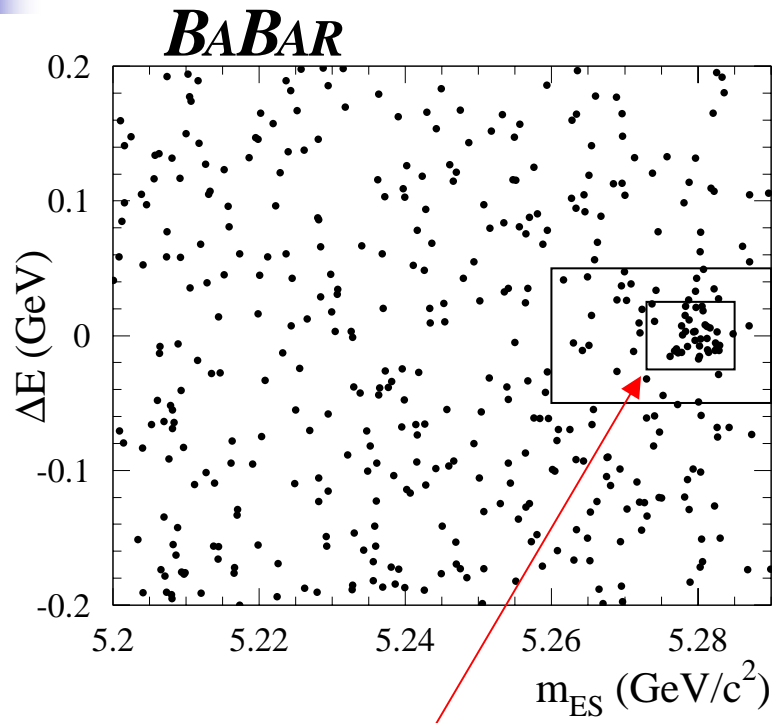
same D decay



$B \rightarrow D^{*+}D^{*-}$, Event Selection

- D^{*+} Reconstruction
- $D^{*+} \rightarrow D^0\pi^+, D^+\pi^0$
- Don't look at case where both D^* decay to $D^\pm\pi^0$
- $D^0 \rightarrow K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+, K_S\pi^+\pi^-$
- $D^+ \rightarrow K^-\pi^+\pi^+, K_S\pi^+, K^-K^+\pi^+$
- Use ΔE , M_{ES} and χ^2_{Mass} for signal/background separation

B \rightarrow D^{*+}D^{*-} Signal



- 38 events in signal region
6.2 background events estimated

$$\text{Br}(B^0 \rightarrow D^{*+}D^{*-}) = (8.0 \pm 1.6 (\text{stat}) \pm 1.2 (\text{syst})) \times 10^{-4}$$



Conclusion

- Clear observation of $B \rightarrow D^{(*)}D^{(*)}K$ decay, three exclusive branching ratios including color suppressed decay $B^+ \rightarrow D^{*+}D^{*-}K^+$
 - Measurement of all excl. Branching ratios in preparation
- 32 fully reconstructed $B^0 \rightarrow D^{*+}D^{*-}$ events
 - Most precise branching ratio measurement
 - Angular analysis in preparation
 - expected $\sigma(\sin 2\beta)$ in $B^0 \rightarrow D^{*+}D^{*-}$ 0.2–0.3 (100 fb^{-1})