Charm Physics at BaBar

DIS 2005

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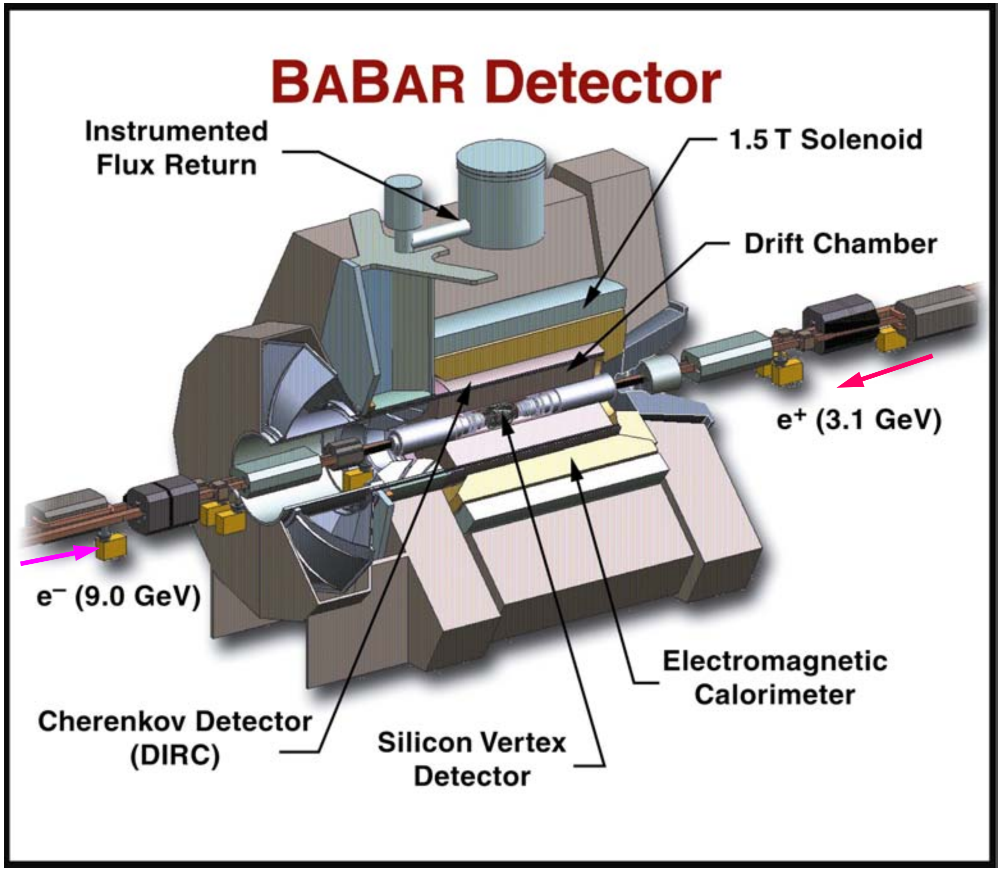
The BaBar Experiment



- Detector optimized for B physics
- Excellent tracking
- Excellent particle identification
- Excellent γ, π^0 detection
- Data:

  ~90% @ $\sqrt{s}$=10.58 GeV $\Upsilon(4S)$

  ~10% @ $\sqrt{s}$=10.54 GeV $q\bar{q}$

- 244 fb^{-1} recorded so far

  256M $B\bar{B}$ pairs

  317M $c\bar{c}$ events

BaBar is also a charm factory

Ongoing Charm Physics at BaBar

- BaBar has extensive charm physics program:
  - Charm mixing and direct CP violation.

    e.g.: Hadronic D^0 mixing, Semileptonic D^0 mixing, $D^+ \to K^+K^-\pi^+$, ……
  - Rare and forbidden decays. e.g. : $D^0 \to l^+l^-$, ……
  - Spectroscopy. e.g. : $D_{sJ}(2317)$, $D_{sJ}(2632)$,……
  - Dalitz plot analyses. e.g. : $D^0 \to K^0_s\pi^+\pi^-$, $D^0 \to K^0_sK^+K^-$,……
  - Production and decay branching fraction measurements.

    e.g. : Cabibbo suppressed Λ_c decays, $\Xi^0_c \to \Omega^- K^+$, $\Xi^0_c \to \Xi^-\pi^+$, ……
  - Measurement of charm hadron mass values. e.g. : Λ_c mass, ……
  - And more ……
- Present a few of the most recent measurements (highlighted in red)
- Use of charge conjugate states is implicit throughout, unless stated otherwise.

Semileptonic Charm Mixing

- Neutral D^0 mixing is expected to be small ($\sim 10^{-3}$) in SM
- New physics effects may enhance the mixing rate
- Search for mixing using semileptonic charm decays
  No contamination from Doubly-Cabibbo-Suppressed decay

Right-sign unmixed decays

$D^{*+} \to D^0 \pi^+_{tag}$, $D^0 \to K^- e^+ \nu$
$D^{*-} \to \bar{D}^0 \pi^-_{tag}$, $\bar{D}^0 \to K^+ e^- \bar{\nu}$

Wrong-sign mixed decays

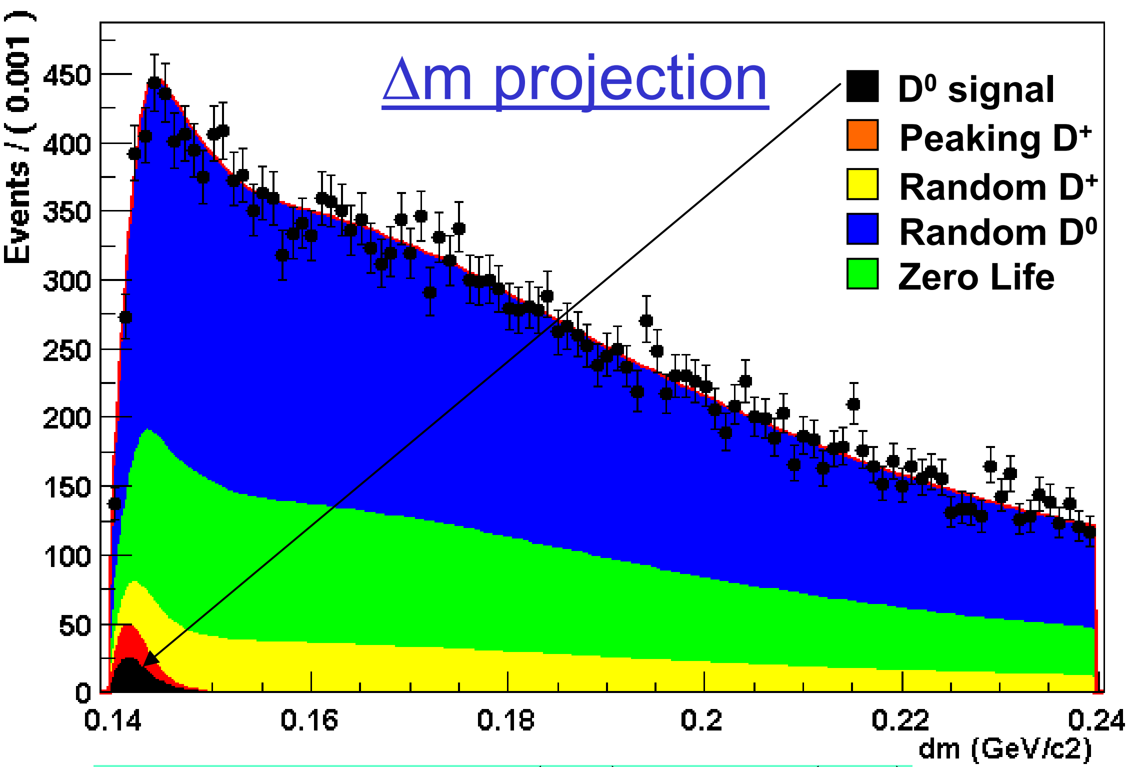
$D^{*+} \to D^0 \pi^+_{tag}$, $D^0 \to \bar{D}^0 \to K^+ e^- \bar{\nu}$
$D^{*-} \to \bar{D}^0 \pi^-_{tag}$, $\bar{D}^0 \to D^0 \to K^- e^+ \nu$

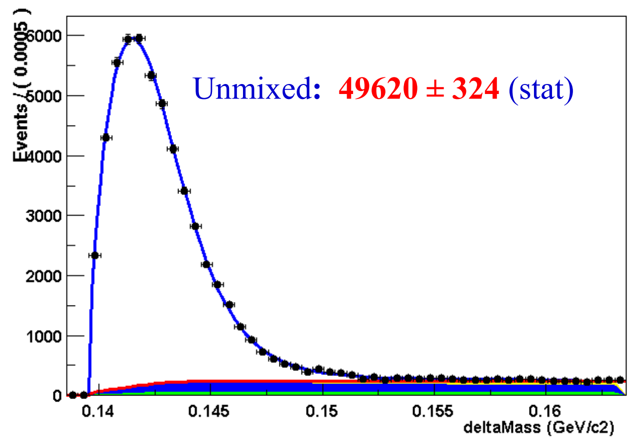
$$R_{mix} = \Gamma(D^0 \to \bar{D}^0 \to K^+ e^- \bar{\nu}) / \Gamma(D^0 \to K^- e^+ \nu)$$

Using $\Delta m = m(D^0\pi^+) - m(D^0)$ and D^0 proper time to separate signal and background

Semileptonic Charm Mixing (87fb^{-1})

$\Delta m = m(D^0\pi^+) - m(D^0)$





Fix the signal and bg PDF using high statistics RS events

N(mix): 114 ± 61

(~5% probability of getting a N(mix) value larger than 114 for $R_{mix}=0$)

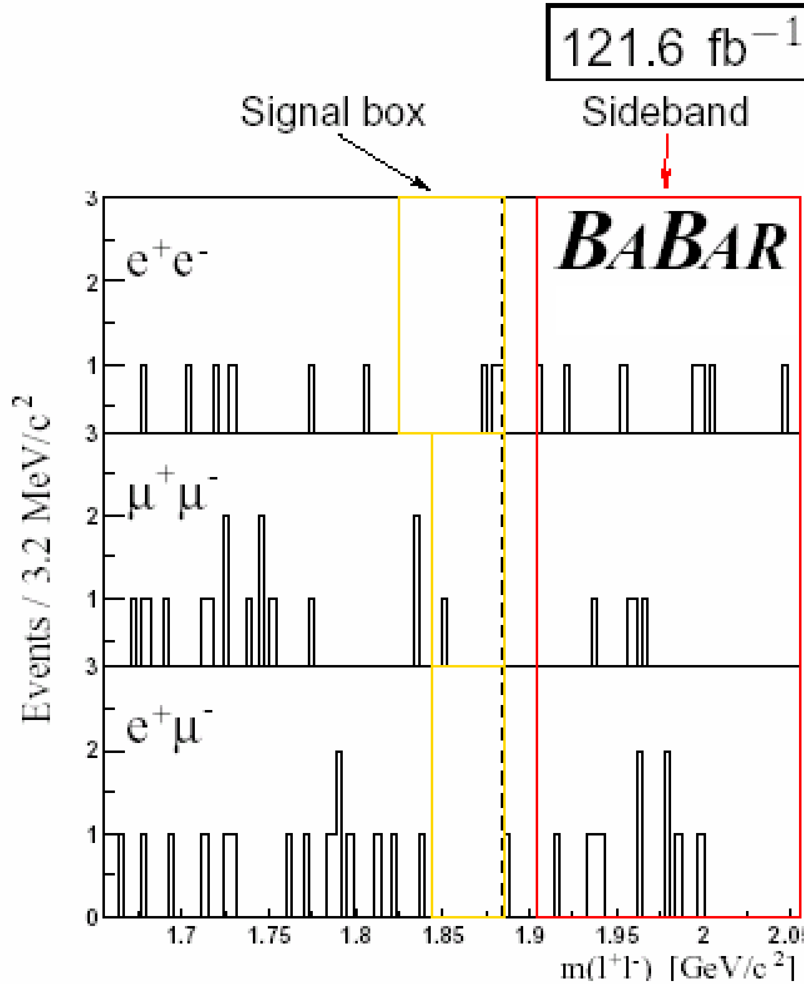
$$R_{mix} = 0.0023 \pm 0.0012(\text{stat}) \pm 0.0004(\text{syst})$$

$$R_{mix} < 0.0042 \quad (90\%\,\text{C.L.})$$

Phys. Rev. D70 (2004) 091102

Search for $D^0 \to l^+ l^-$

- Small or zero branching fraction in SM
- New Physics may enhance these
  - e.g.: R-parity violating SUSY
- Search for $D^0 \to e^+e^-$, $\mu^+\mu^-$, $e^+\mu^-$
  - Blind analysis
  - Normalized to $D^0 \to \pi^+\pi^-$
  - $D^{*+} \to D^0\pi^+$ tag to reduce background
  - UL set by Feldman-Cousins method



$$\mathcal{B}(D^0 \to e^+e^-) < 1.2 \times 10^{-6} \quad 90\,\%\,\text{C.L}$$

$$\mathcal{B}(D^0 \to \mu^+\mu^-) < 1.3 \times 10^{-6} \quad 90\,\%\,\text{C.L}$$

$$\mathcal{B}(D^0 \to e^\pm\mu^\mp) < 8.1 \times 10^{-7} \quad 90\,\%\,\text{C.L}$$

A factor of 2-10 improvement over previous measurements

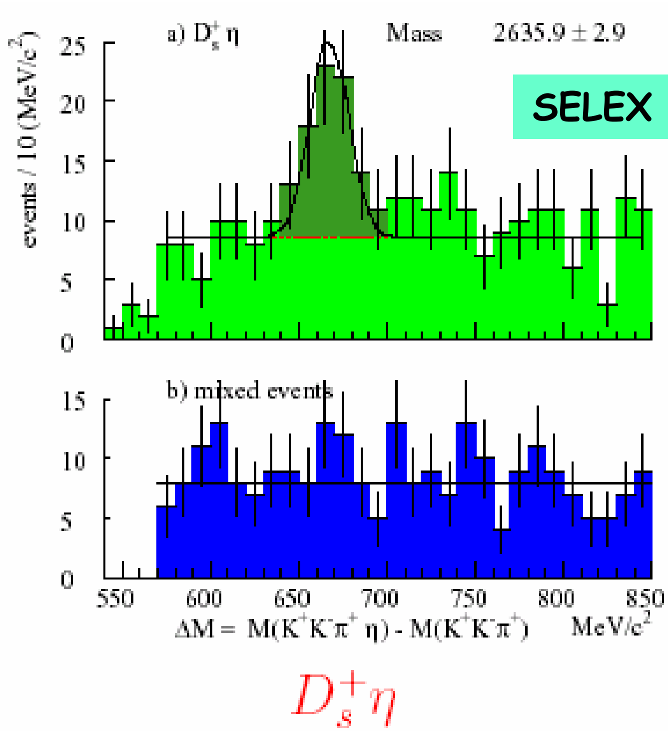
Phys.Rev.Lett. 93 (2004) 191801

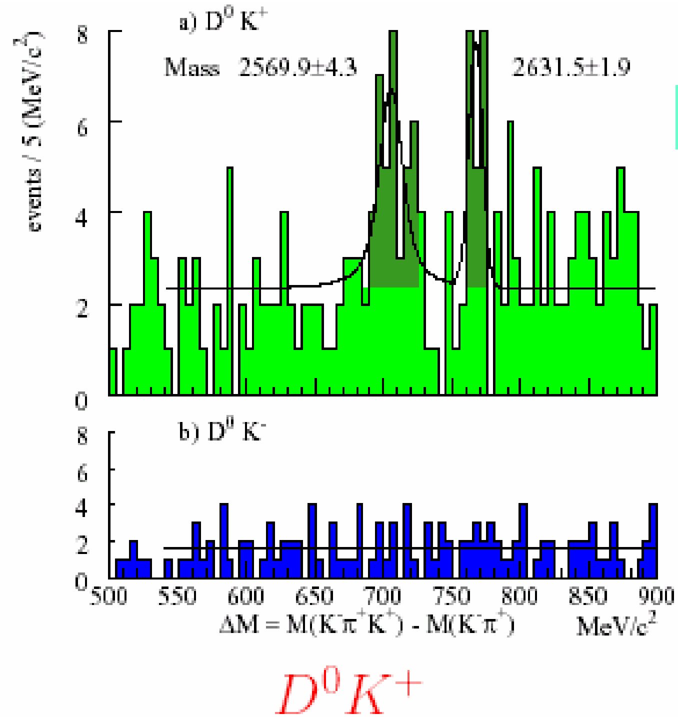
Search for $D_{sJ}(2632)$

SELEX reported the observation of a new heavy state decaying to

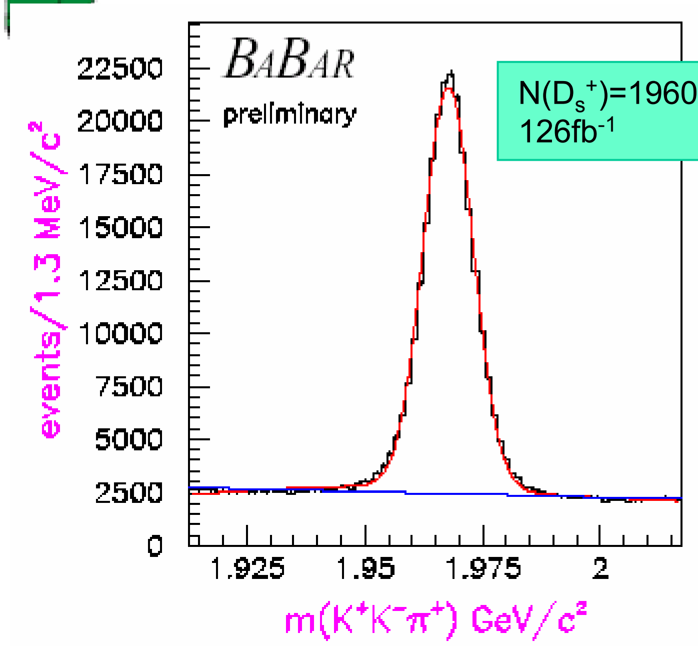
$$D_{sJ}^{+}(2632) \to D_s^+\eta\ ,\quad D_{sJ}^{+}(2632) \to D^0K^+$$

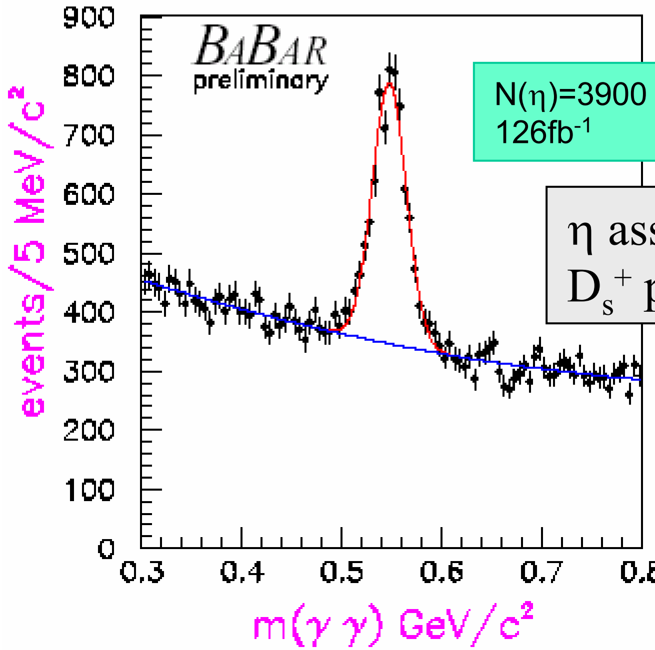
Phys.Rev.Lett.93:242001 (2004)



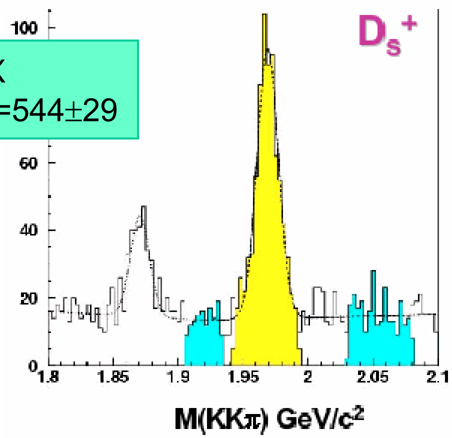


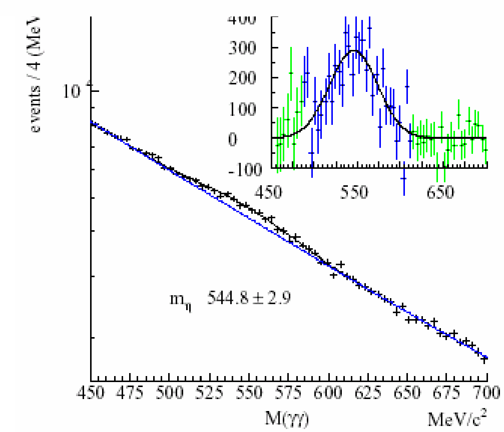
Search for $D_{sJ}(2632) \to D_s^+ \eta$





η associated with D_s^+ production

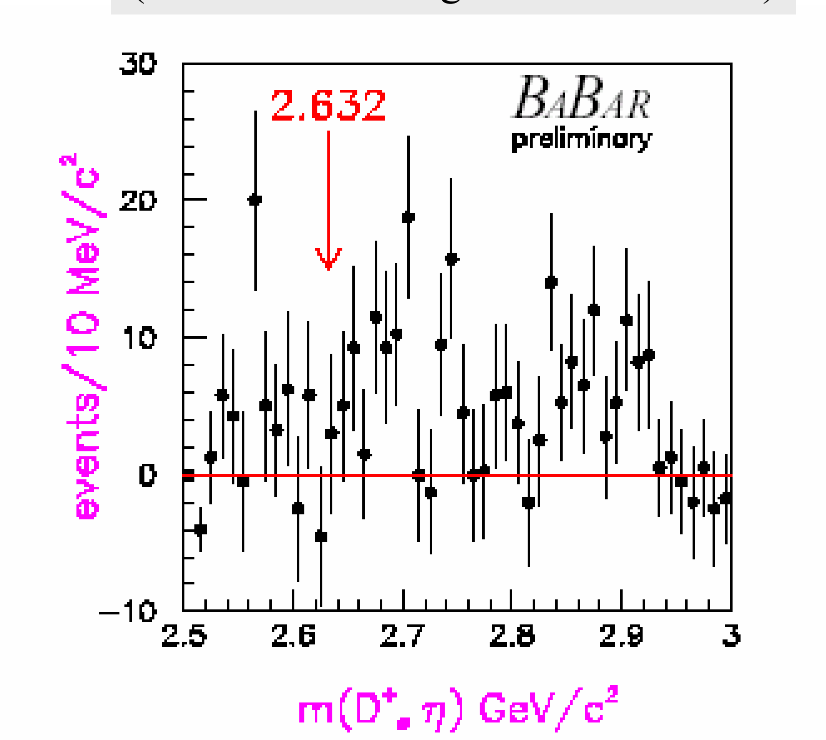




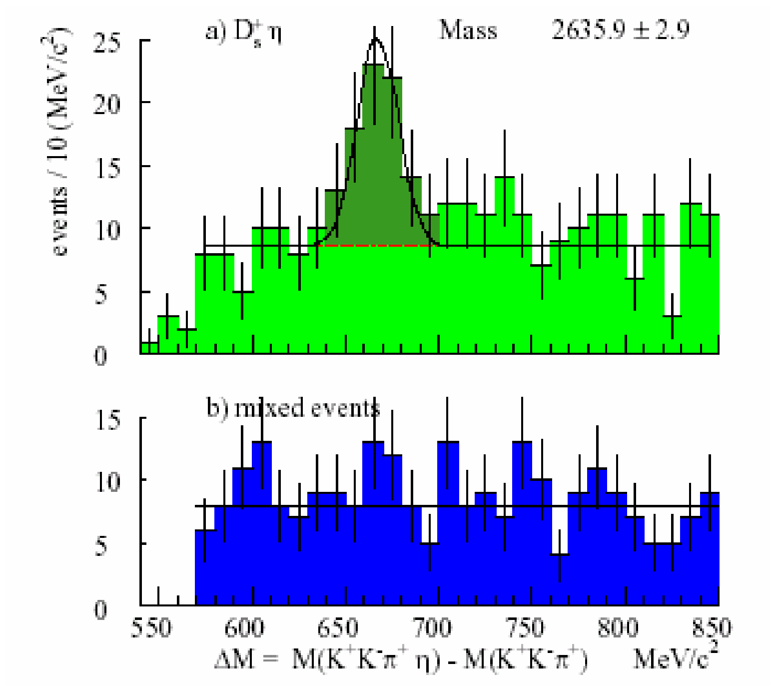
Inclusive η without requirement of D_s^+ association

Search for $D_{sJ}(2632) \to D_s^+ \eta$

Correlated $D_s^+\eta$ spectrum
(i.e. after 2D background subtraction)



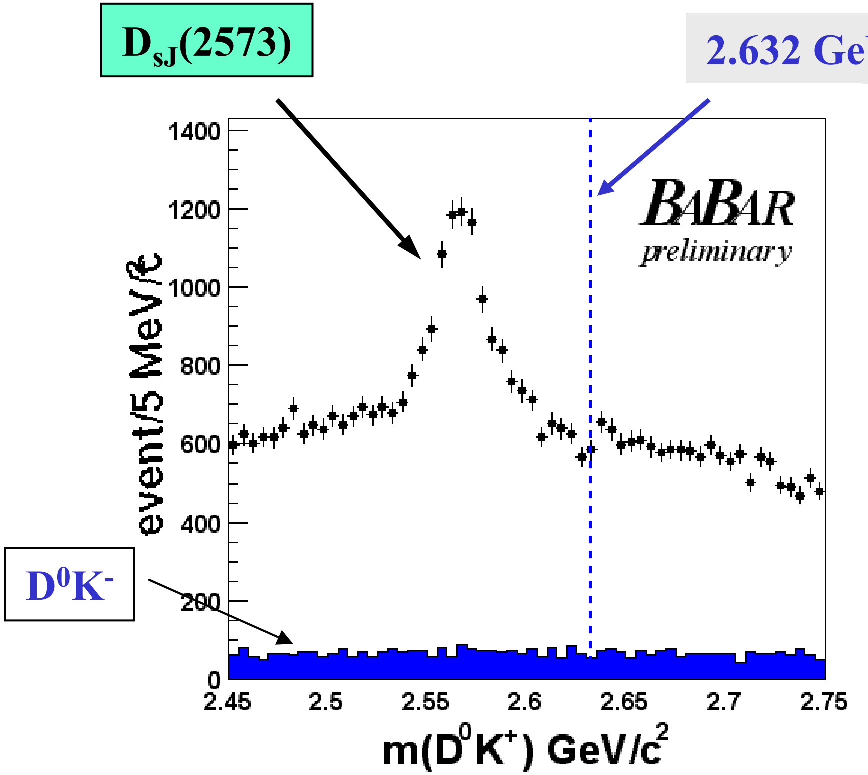
SELEX

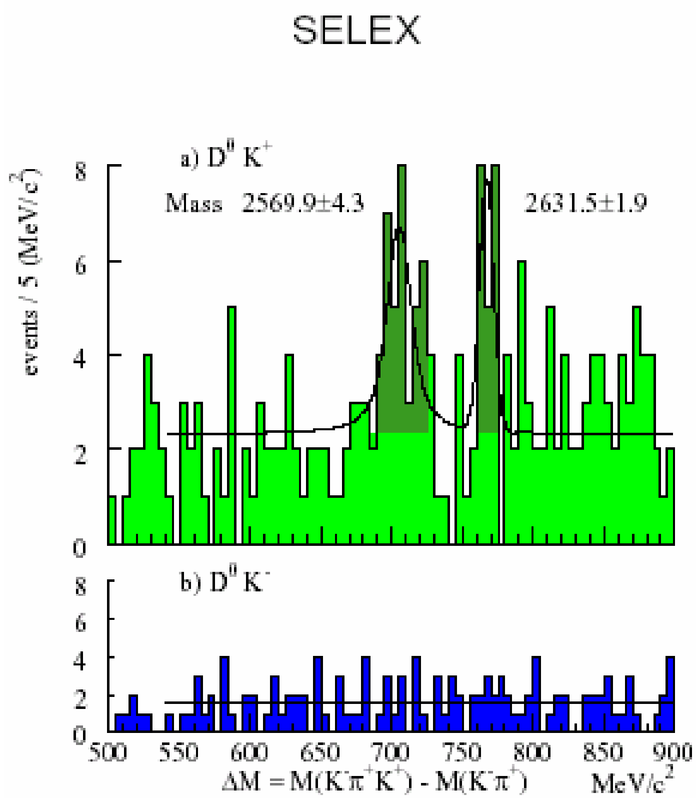


BaBar sees no evidence for $D_{sJ}^+(2632) \to D_s^+\eta$ in 125 fb^{-1} data

hep-ex/0408087

Search for $D_{sJ}(2632) \to D^0K^+$

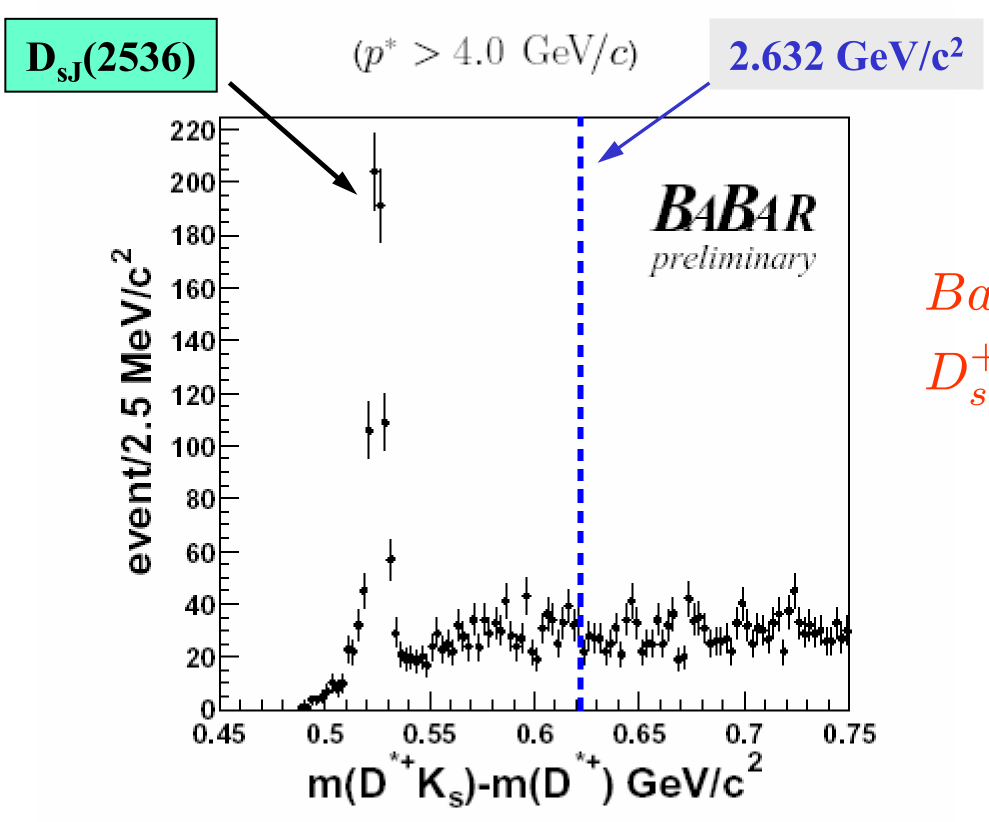




BaBar sees no evidence for $D^+_{sJ}(2632) \to D^0 K^+$ in 125 fb^{-1} data

hep-ex/0408087

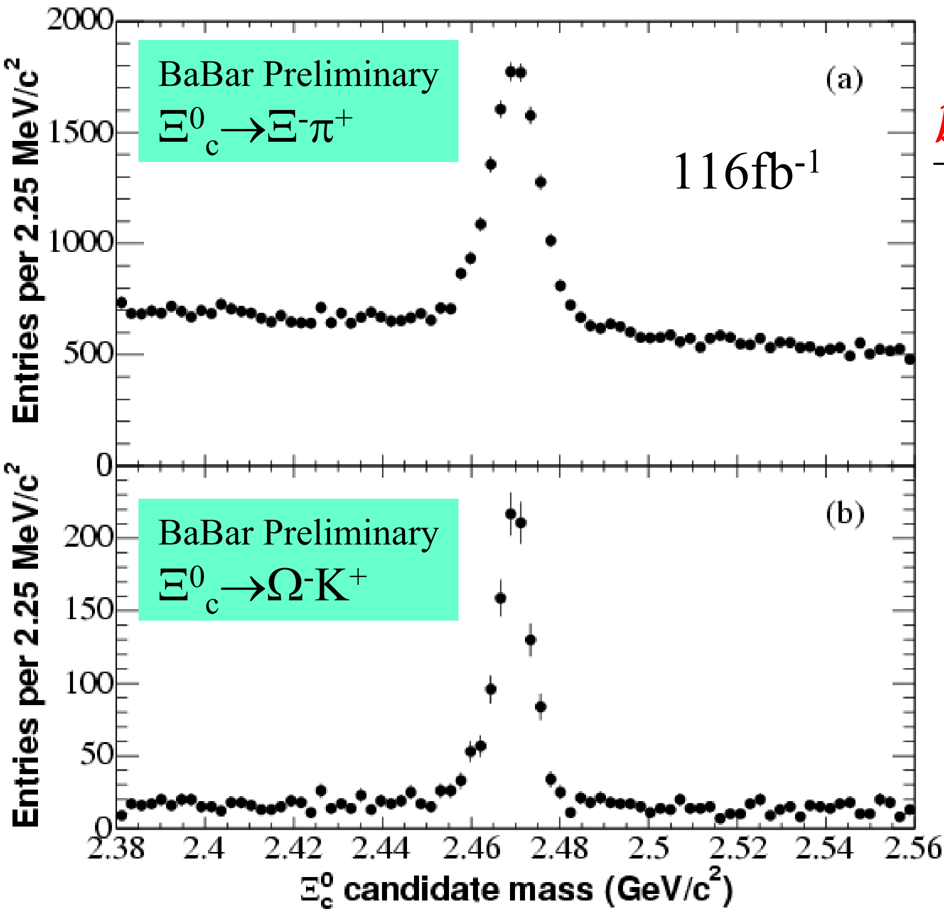
Search for $D_{sJ}(2632) \to D^{*+}K_s$



BaBar sees no evidence for $D^+_{sJ}(2632) \to D^{*+}K_s$ in 125 fb^{-1} data

hep-ex/0408087

Study of Ξ^0_c Production and Decays



BaBar result: **hep-ex/0504014**

$$\frac{\mathcal{B}(\Xi^0_c \to \Omega^- K^+)}{\mathcal{B}(\Xi^0_c \to \Xi^- \pi^+)} = 0.294 \pm 0.018 \pm 0.016$$

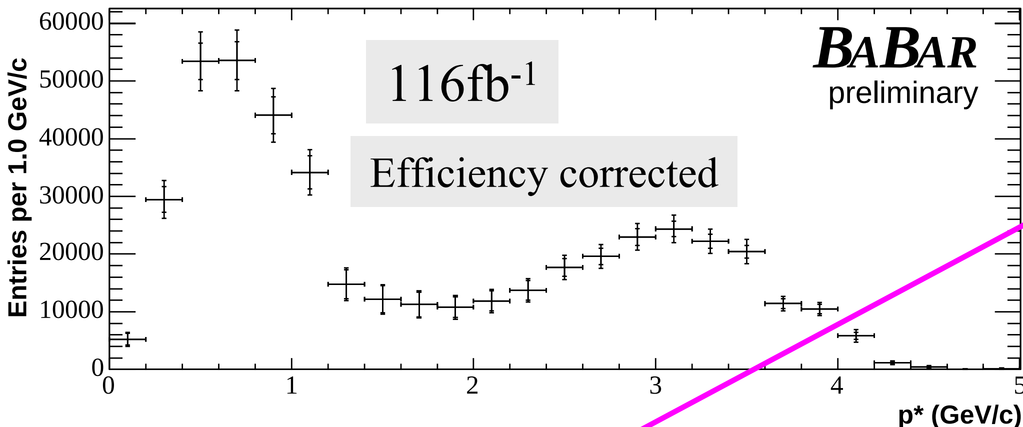
Consistent with spectator quark model prediction: 0.32
Z. Phys. C 55, 659 (1992)

Previous result: CLEO
Phys. Rev. Lett. 79, 3599 (1997)

$$\frac{\mathcal{B}(\Xi^0_c \to \Omega^- K^+)}{\mathcal{B}(\Xi^0_c \to \Xi^- \pi^+)} = 0.50 \pm 0.21 \pm 0.05$$

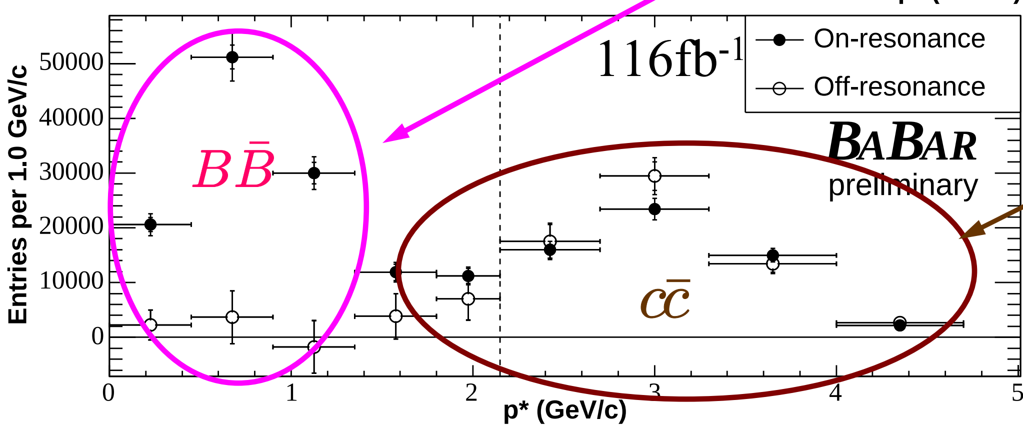
Study of Ξ^0_c Production and Decay

Ξ^0_c produced in both $e^+e^- \to b\bar{b}$ (B mesons) and $e^+e^- \to c\bar{c}$.
Study the production using p*(Ξ^0_c) in e^+e^- c.m. frame



Production from B decays

$$\mathcal{B}(B \to \Xi^0_c X) \times \mathcal{B}(\Xi^0_c \to \Xi^- \pi^+) = (2.11 \pm 0.19 \pm 0.25) \times 10^{-4}$$



Continuum Production

$$\sigma(e^+e^- \to \Xi^0_c X) \times \mathcal{B}(\Xi^0_c \to \Xi^- \pi^+) = (388 \pm 39 \pm 41) \text{ fb},$$

hep-ex/0504014

Measurement of Charm Hadron Mass

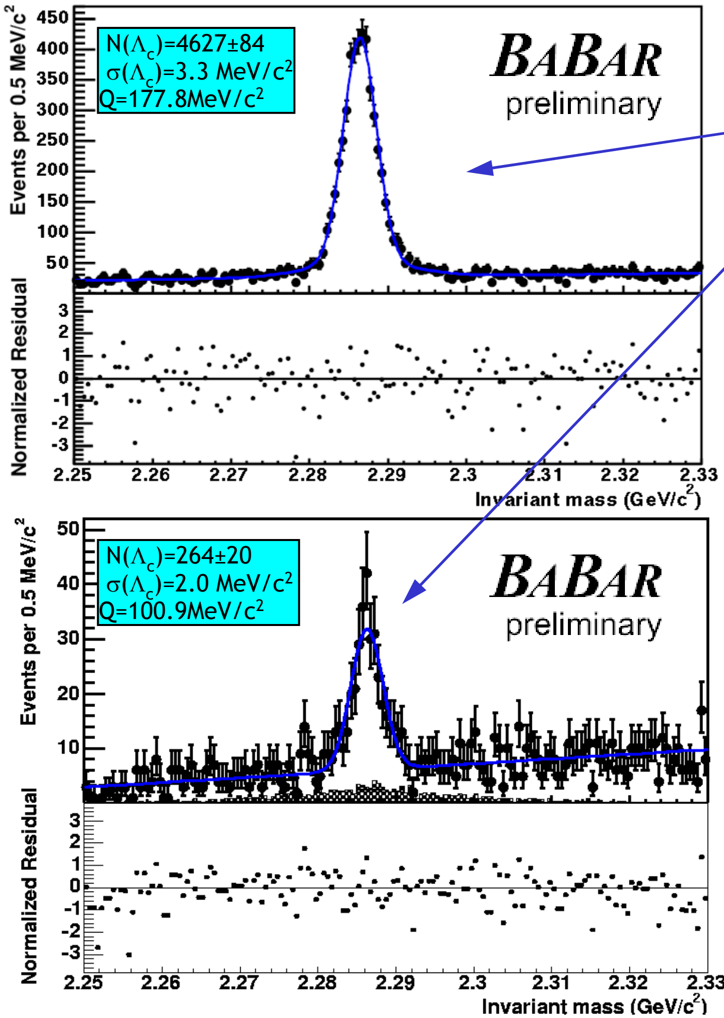
- Charm hadron masses are known to a precision ~ 0.5-1.5 Mev, e.g.:
  - $m(D^0) = 1864.6 \pm 0.5$ MeV/c^2
  - $m(D^+) = 1869.4 \pm 0.5$ MeV/c^2
  - $m(D_s) = 1869.4 \pm 0.5$ MeV/c^2
  - $m(\Lambda_c) = 2284.9 \pm 0.6$ MeV/c^2
  - $m(\Xi_c^+) = 2466.3 \pm 1.4$ MeV/c^2
  - $m(\Xi_c^0) = 2471.8 \pm 1.4$ MeV/c^2

PDG 2004

- Most measurements done 15-20 yrs ago with $O(10^2\text{-}10^3)$ events
- BaBar has large sample of fully-reconstructed charm hadrons
- Well understood detector performance

Accurate measurements of charm hadron mass

Precision Measurement of Λ_c Mass



Decay mode:

$$\Lambda_c \rightarrow \Lambda \bar{K}^0 K^+, \Lambda \rightarrow p\pi^-, \bar{K}^0 \rightarrow \pi^+\pi^-$$

$$\Lambda_c \rightarrow \Sigma^0 \bar{K}^0 K^+, \Sigma^0 \rightarrow \Lambda\gamma$$

Small Q value (minimize sys error)

Dominant systematic error sources:

- Detector Material Model
- Magnetic field
- Detector alignment

Cross check the systematics with larger control sample:

$K_s \rightarrow \pi^+\pi^-$: ~$2.5\times10^6$ signal events

$\Lambda \rightarrow p\pi^-$: ~$3.2\times10^6$ signal events

$\Lambda_c^+ \rightarrow pK^-\pi^+$: ~$1.5\times10^6$ signal events

$\Lambda_c^+ \rightarrow pK_s$: ~$2.4\times10^5$ signal events

Measurement of Λ_c Mass

- The preliminary results:

  $\Lambda_c \rightarrow \Lambda K^0_S K^+$ $\quad m(\Lambda_c)=2286.501\pm0.042$ (stat.) $\pm$ 0.144 (syst.) MeV/c^2

  $\Lambda_c \rightarrow \Sigma^0 K^0_S K^+$ $\quad m(\Lambda_c)=2286.303\pm0.181$ (stat.) $\pm$ 0.126 (syst.) MeV/c^2

- Control sample

  $\Lambda_c \rightarrow pK^-\pi^+$ $\quad m(\Lambda_c)=2286.393\pm0.018$ (stat.) $\pm$ 0.447 (syst.) MeV/c^2

  $\Lambda_c \rightarrow pK_S$ $\quad m(\Lambda_c)=2286.361\pm0.034$ (stat.) $\pm$ 0.428 (syst.) MeV/c^2

  due to large Q value

- Combined result:

  $m(\Lambda_c)=2286.46 \pm 0.14$ MeV/c^2

- The result is four times more precise than the PDG value (2284.9±0.6 MeV/c2) and about 2.5σ higher
- Λ_c study can be used as a basis for improving other charm hadron mass measurements

Conclusion

- BaBar has a rich charm physics program
- Have presented a few results of the most recent analyses
  - Semileptonic D^0 mixing
  - Search $D^0 \to l^+ l^-$
  - Search for $D_{sJ}(2632)$
  - $\Xi^0_c \to \Omega^- K^+$, $\Xi^0_c \to \Xi^- \pi^+$
  - Λ_c mass measurement
- Much more to come