Recent Results from BaBar

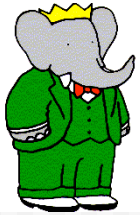
BEACH 2008 Conference

Columbia, South Carolina

David Norvil Brown

University of Louisville

Recent Results From BaBar



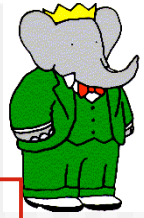
Physics Reach

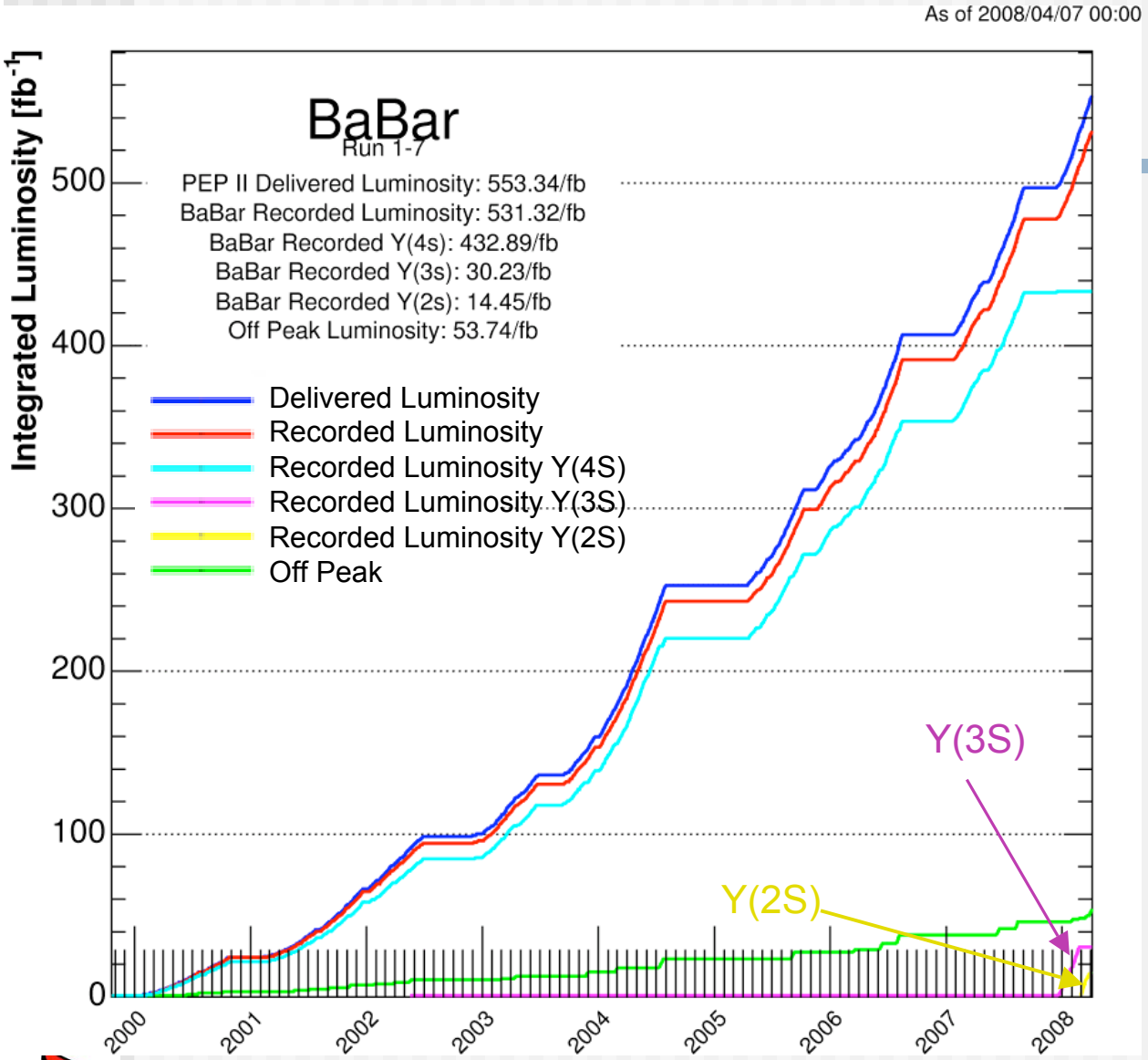
- *B*-physics
  - *CP Violation &* Mixing, CKM matrix elements, leptonic & semi-leptonic decays, penguin decays, etc
- Charm and charmonium
- Tau physics
- Initial state radiation (ISR)
- Upsilon spectroscopy
- Beyond the Standard Model
- More

This Talk

- The BaBar running era
- Recent Results on *B*-physics
  - B^0-B^+ mass difference
  - Exclusive leptonic and semi-leptonic decays
- Recent Results on Initial State Radiation
  - $e^+e^- \to p\bar{p}p\bar{p}$
  - *ISR production of charmonium*
- 'Future Recent Results:' Looking ahead to Upsilon Spectroscopy

The BaBar Running Period





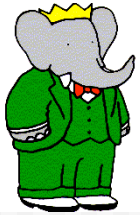
7 Runs over the course of 9 years

- First collisions with BaBar May 26, 1999
- Final data taken 12:43 p.m., April 7, 2008
- Final Run cut short by ~6 months due to federal budget impasse.

Recent Results in *B*-physics

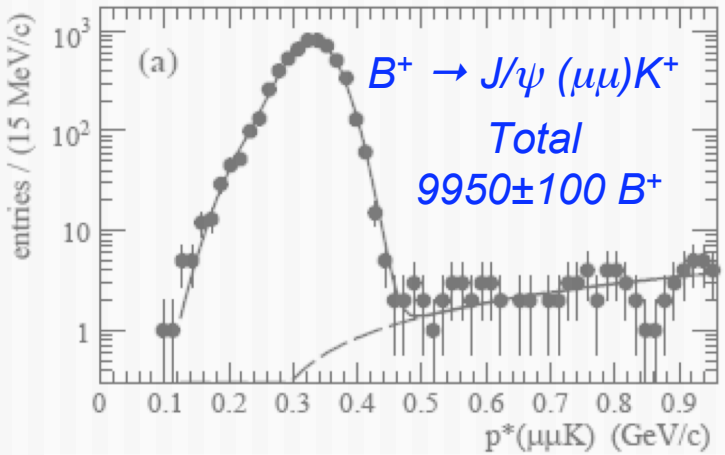
- B^0-B^+ mass difference
- $K(*)l^+l^-$ Branching Fractions, Asymmetry, and CP-Violation
- Exclusive $B \rightarrow X_u l \nu$ decays with semi-leptonic tags

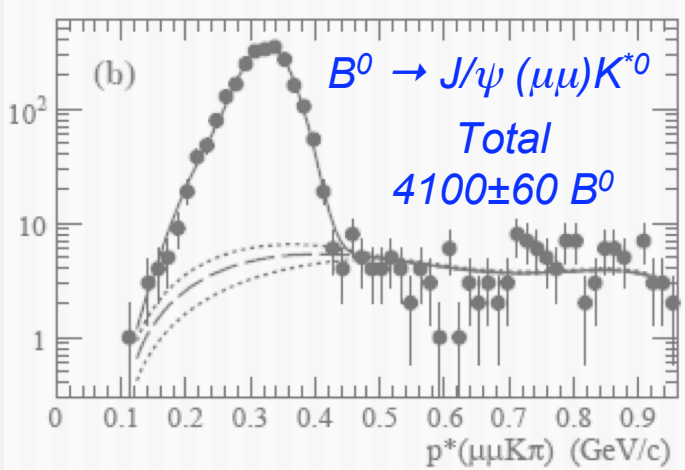
B^0 - B^+ mass difference



Affects the production ratio for neutral and charged *B* mesons

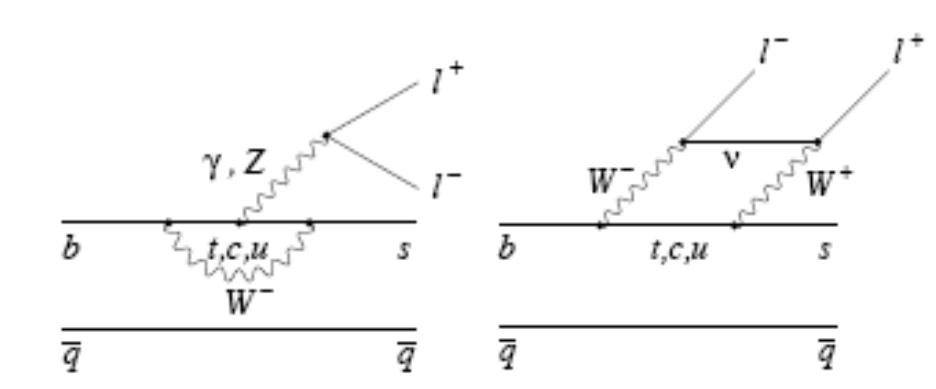
- Use decay modes $B^0 \to J/\psi K^+\pi^-$ and $B^+ \to J/\psi K^+$ ($J/\psi \to \mu^+\mu^-$ and $J/\psi \to e^+e^-$) for large signals and low backgrounds.
- Excellent resolution in p^*
- Analysis uses 232 million B pairs.
- Find $m(B^0)-m(B^+) = 0.33\pm0.05\pm0.03$ MeV/c^2
  - First time Δm_B can be excluded from null at the 5σ level!





$B \rightarrow K^* l^+ l^-$ (ll=ee,$\mu\mu$)

Flavor Changing Neutral Current (FCNC) decay.



- Decay is not allowed at the tree-level. Potential for new physics to enter at the loop.
- Reconstruct $K^* \rightarrow K\pi$
- Measure angle between K and B in K^* frame to determine K^* longitudinal polarization.
- Measure angle between $l^+(l^-)$ and $B(\overline{B})$ in l^+l^- frame to determine A_{FB}.

Analysis performed in 6 modes:
$K^+\pi^0\mu^+\mu^-$, $K^0_S\pi^+\mu^+\mu^-$,
$K^+\pi^-\mu^+\mu^-$, $K^+\pi^0e^+e^-$,
$K^0_S\pi^+e^+e^-$, and $K^+\pi^-e^+e^-$
Results from all 6 modes agree.

Standard Model predicts interference between radiative penguin and box modes, leading to angular dependencies of decay rate.

$B \to K^* l^+ l^-$ ($ll = ee, \mu\mu$)

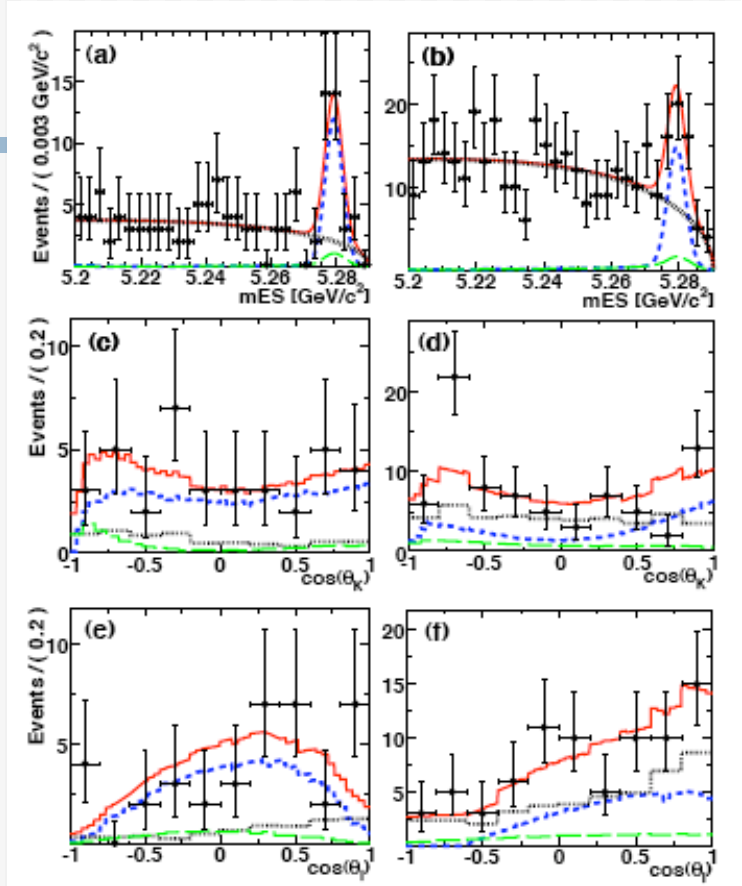
Analysis uses 384 million *B* pairs

- The analysis is performed in two q^2 regions:
  - low q^2, with $q^2 < 6.25\ MeV^2/c^2$, and
  - high q^2, with $q^2 > 10.24\ MeV^2/c^2$. Vetoes lepton pairs from J/ψ. Also veto $\psi(2S)$ mass range.

$$\text{low } q^2: \quad F_L = 0.35 \pm 0.16 \pm 0.04, \quad A_{FB} = 0.24^{+0.18}_{-0.23} \pm 0.05$$

$$\text{high } q^2: \quad F_L = 0.71^{+0.20}_{-0.22} \pm 0.04, \quad A_{FB} = 0.76^{+0.52}_{-0.32} \pm 0.07$$

Angular distributions are governed by Wilson coefficients C7,9,10, calculable in the Standard Model.
Our work rules out wrong sign C_9C_{10} (purely right-hand weak current) at 3σ level.

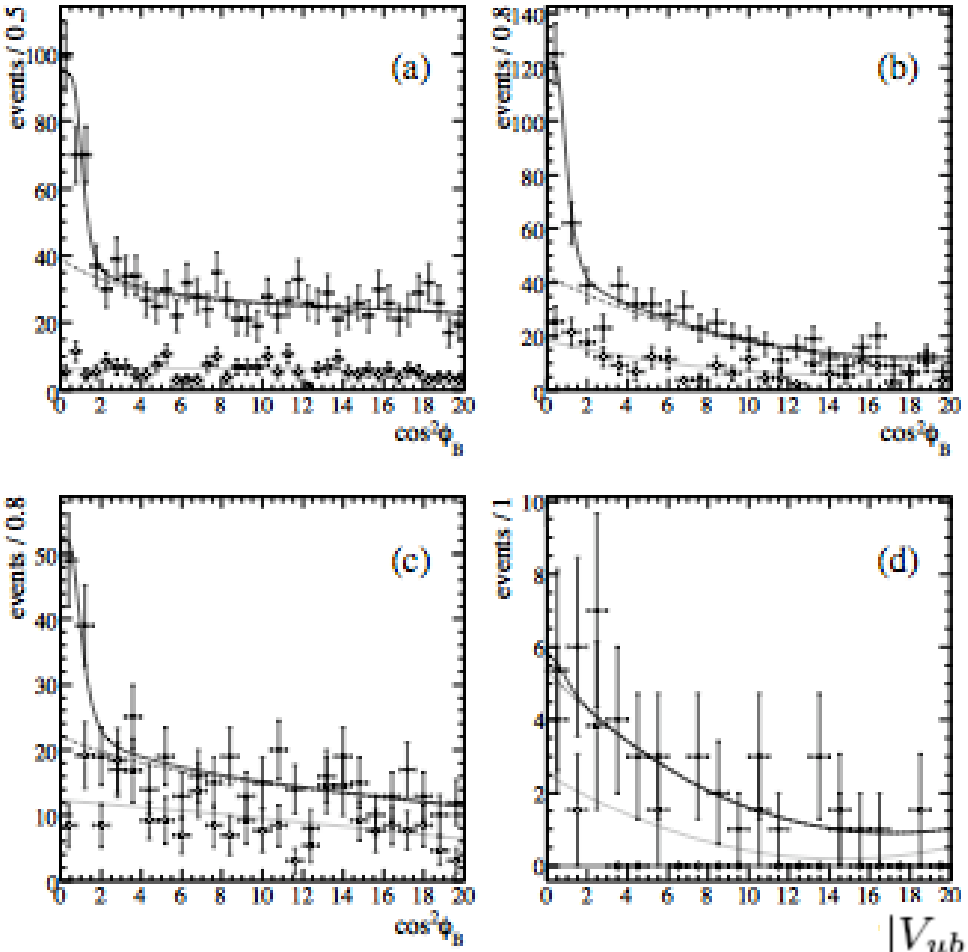


A_{FB} consistent with 0, in agreement with both SM and new physics predictions

$B \to \{\pi,\eta,\eta'\}l\nu_l$ with semi-leptonic tags

Useful for measuring CKM element V_{ub}

BABAR Preliminary



- Tag events with $B \to D(^*)l\nu$ decay and search for the other B decaying semi-leptonically to charmless pseudoscalar mesons.

$$\mathcal{B}(B^0 \to \pi^-\ell^+\nu_\ell) = (1.38 \pm 0.21 \pm 0.07) \times 10^{-4},$$
$$\mathcal{B}(B^+ \to \pi^0\ell^+\nu_\ell) = (0.96 \pm 0.15 \pm 0.07) \times 10^{-4},$$
$$\mathcal{B}(B^+ \to \eta\ell^+\nu_\ell) = (0.64 \pm 0.20 \pm 0.30) \times 10^{-4},$$

$$\mathcal{B}(B^+ \to \eta'\ell^+\nu_\ell) < 0.47 \times 10^{-4}$$

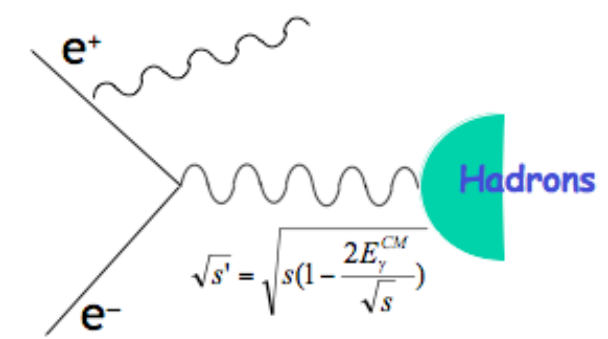
$$|V_{ub}| = (4.0 \pm 0.5_{(\mathrm{stat})} \pm 0.2_{(\mathrm{syst})} {}^{+0.7}_{-0.5}{}_{(\mathrm{theory})}) \times 10^{-3}$$

Recent Results With Initial State Radiation

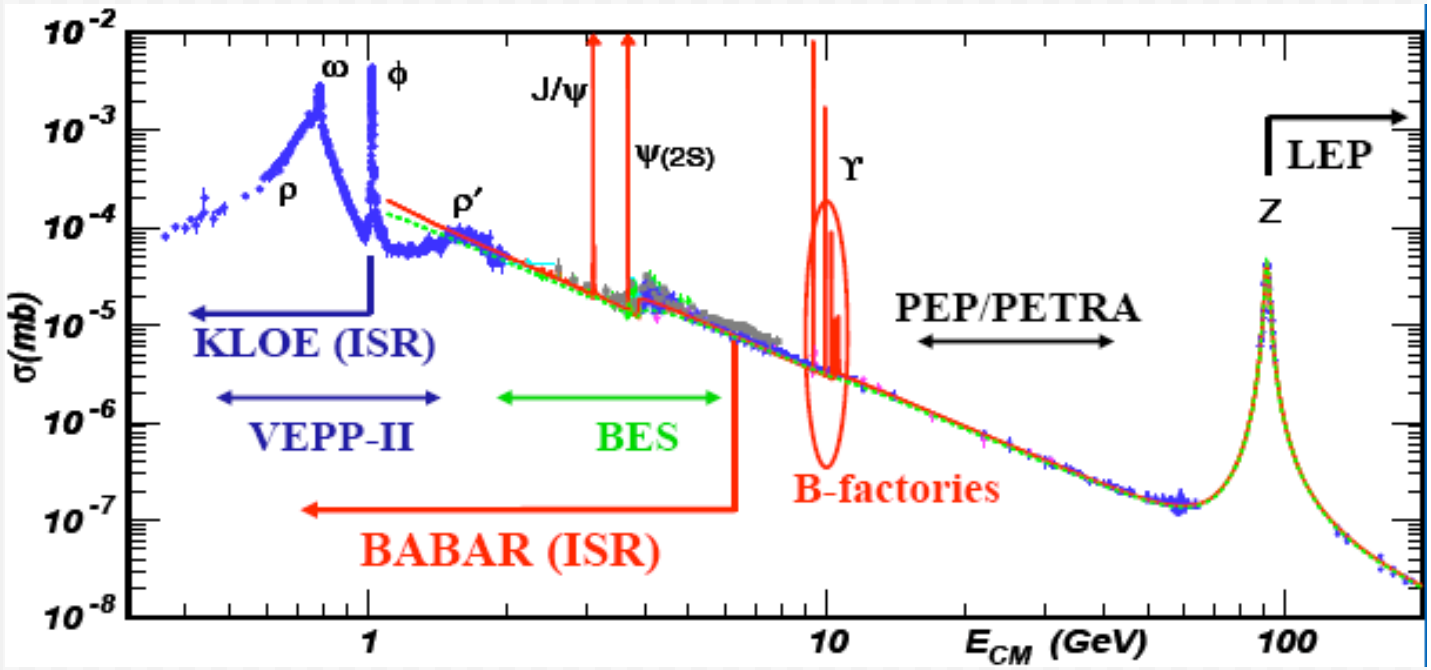
- First Observation of $e^+e^- \rightarrow p\bar{p}p\bar{p}$
- Production of charmonium states with initial state radiation

Initial State Radiation Generalities

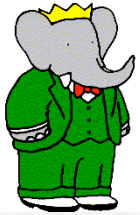
Broad energy range available through ISR at BaBar



- No energy scan necessary: continuous range of energies produced sitting at one beam energy point. Reduces systematic uncertainties.
- High luminosity and detector performance at BaBar make it competitive with targeted, lower-energy experiments.

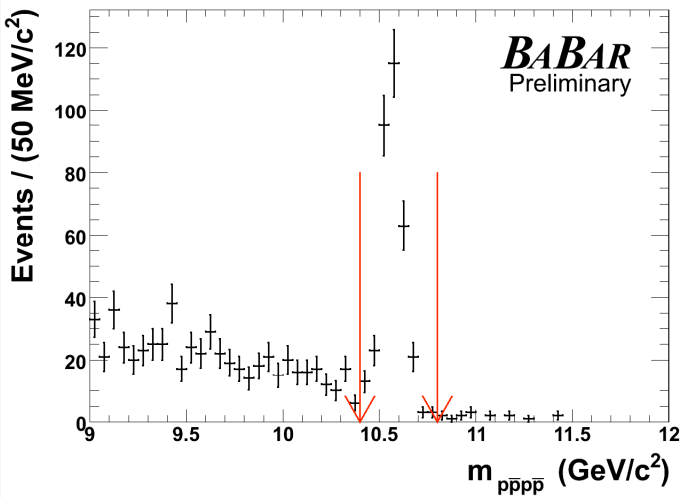


First Observation of $e^+e^- \rightarrow p\bar{p}p\bar{p}$



Previously unobserved at any energy
Interesting questions about production mechanism

- Requires 4 charged tracks with a common vertex
- All tracks identified as protons or anti-protons.
- Invariant mass of tracks in the range 9-12 GeV/c^2.
- Observe a peak of 365 events at 10.58 GeV/c^2 in 427 fb^{-1}

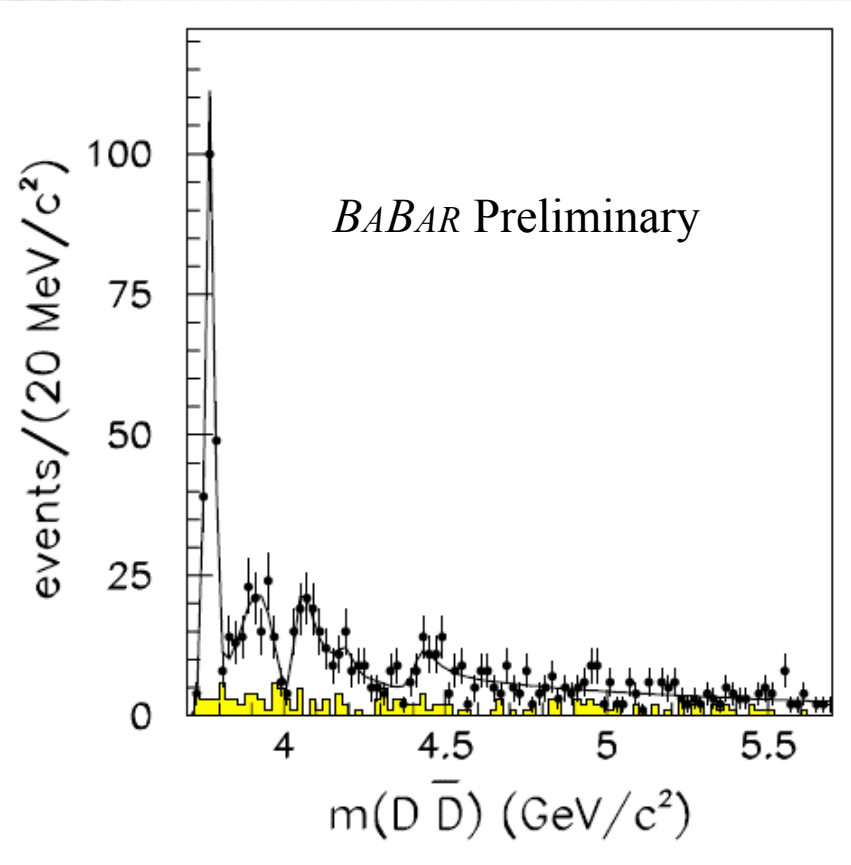


We measure the cross-section as 2.8 ±0.2±0.3 fb

Angular distributions favor jet hadronization, exclude two virtual photon annihilation, and disfavor but do not exclude sub-threshold resonance production

ISR Production of Charmonium

Probe charm-containing states



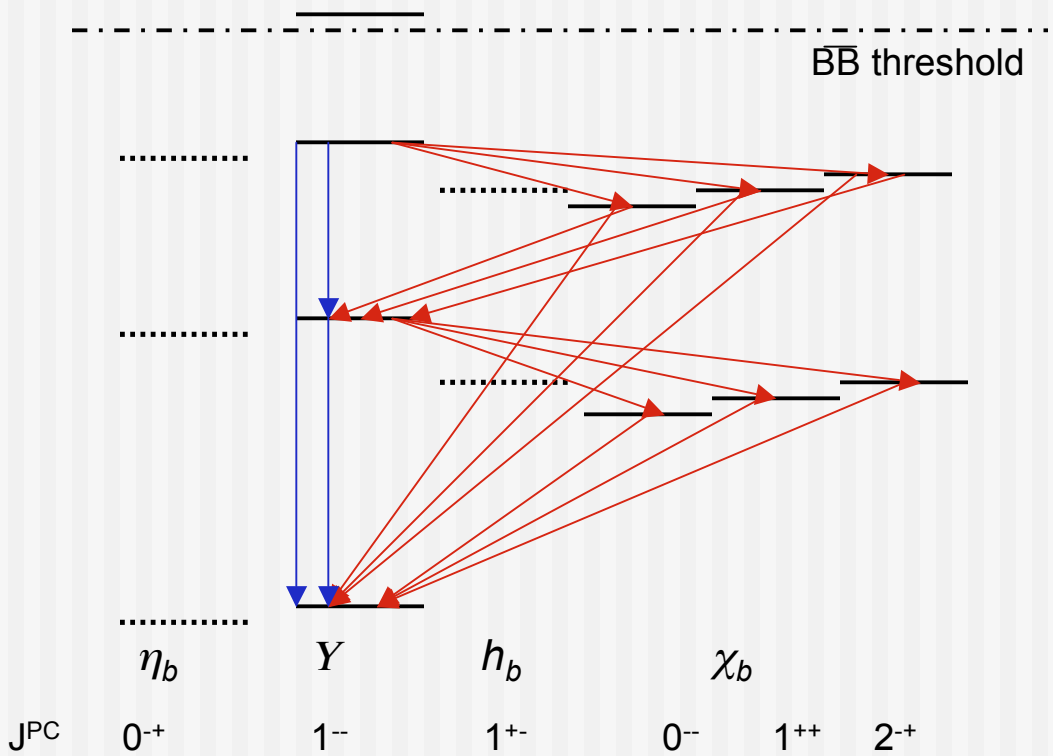
- Search for $e^+e^- \rightarrow D\bar{D}$
- *D reconstructed in 7 modes*
- *All charged tracks must be accounted for in D daughters.*
- *Resonant structure observed in $D\bar{D}$ invariant mass.*
- *No evidence of $Y(4260)$*

Puzzle: $Y(4260)$ decays prodigiously to $J/\Psi\pi^+\pi^-$. Why not to $D\bar{D}$?

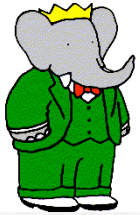
Upsilon Spectroscopy

BaBar's Υ(3S) and Υ(2S) samples are world's largest

- The *bb* bound state system contains many states and transitions and is well-modeled in QCD, yet puzzles remain.
  - Why have we not seen η_b and h_b states?
  - Why does dipion invariant mass spectrum in $\pi\pi$ transitions not match QCD predictions?
  - BaBar observes $\Upsilon(4S) \rightarrow \eta \Upsilon(1S)$ two orders of magnitude larger than corresponding rates for transitions from $\Upsilon(3S)$ or $\Upsilon(2S)$. Unexpected.



Summary



- BaBar has contributed significantly to precision measurements and discoveries in the *b* sector for years. Recent results have, among other things:
  - demonstrated a statistically significant difference between charged and neutral *B masses*
  - measured rare decay branching ratios and associated parameters
  - demonstrated the utility of initial state radiation in probing a range of energies and phenomena
  - provided a platform for tests of QCD in the Upsilon system
- Though data taking has ceased, BaBar has a tremendous data set and looks forward to a future with many exciting new results ahead!