Measurements of B^0 and $B^{\pm}$ Lifetimes and B^0-$\overline{B}^0$ Mixing with fully-reconstructed B decays

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The BaBar Collaboration

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Parallel Session PA-07

Overview

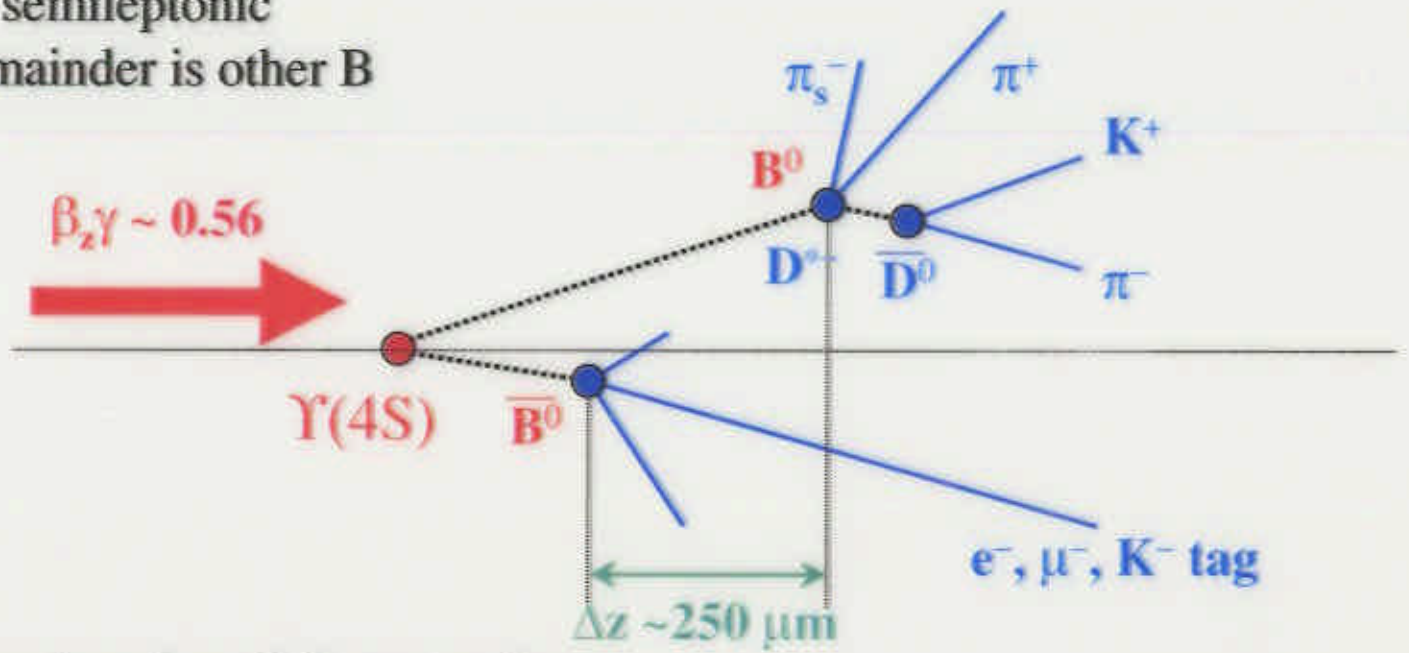
(1) B^0 or $B^{\pm}$ fully reconstructed
- ✔ hadronic
- ✔ semileptonic

Remainder is other B

(2) Reconstruction of decay vertices
- ✔ Decay time difference $\Delta t \propto \Delta z$
- ✔ Resolution function ⇒ sin2β analysis
- ✔ **Lifetime measurements**

(3) $B^0/\overline{B}^0$ flavor tagging
- ✔ Leptons, Kaons
- ✔ Neural Networks

(4) Time dependent mixing rate
- ✔ Mistag rate w ⇒ sin2β analysis
- ✔ **Δm_d measurement**



***For details*: SLAC-PUB-8529 and SLAC-PUB-8530**

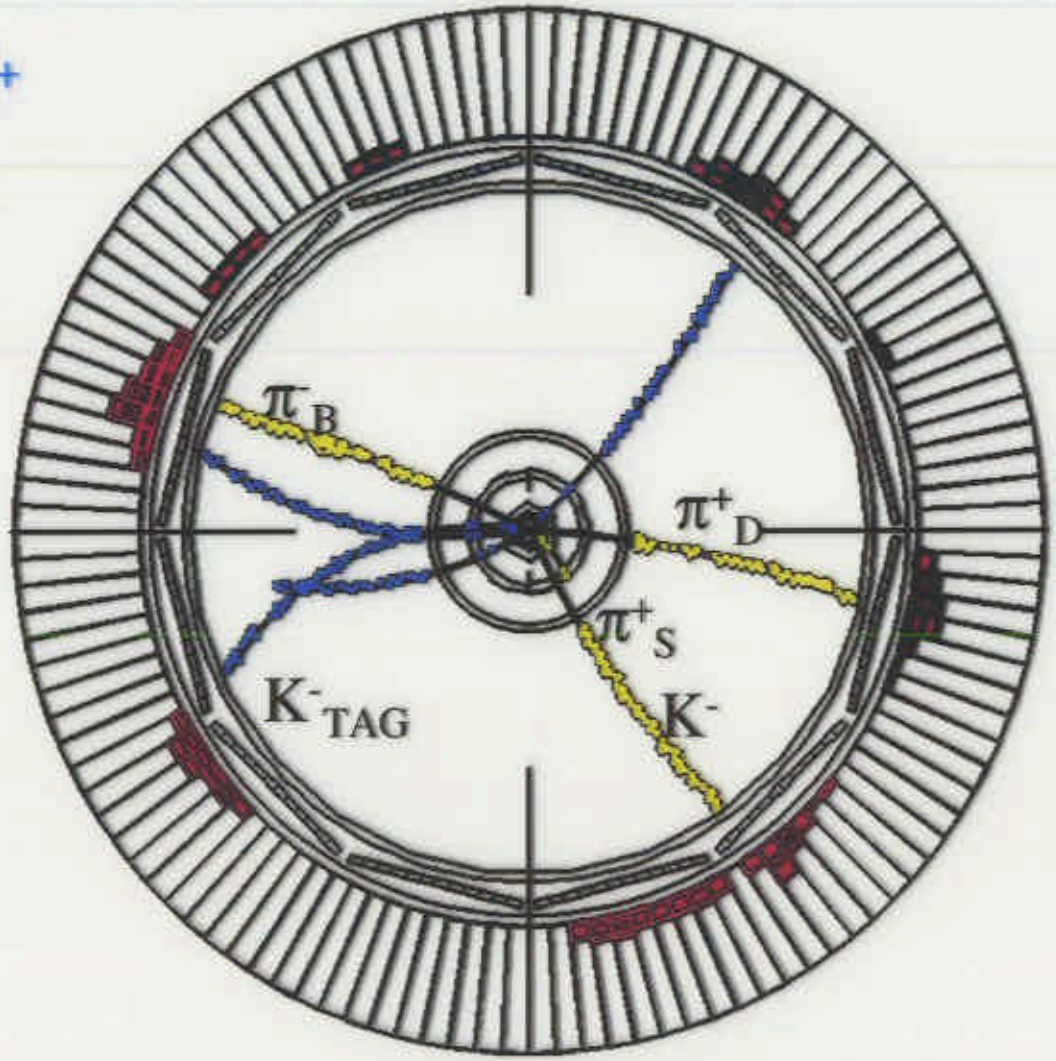
$\overline{B}^0 \to D^{*+} \pi^-$

➥ $D^0 \pi^+$

➥ $K^- \pi^+$

$B^0 \to K^- X$

Kaon Tag



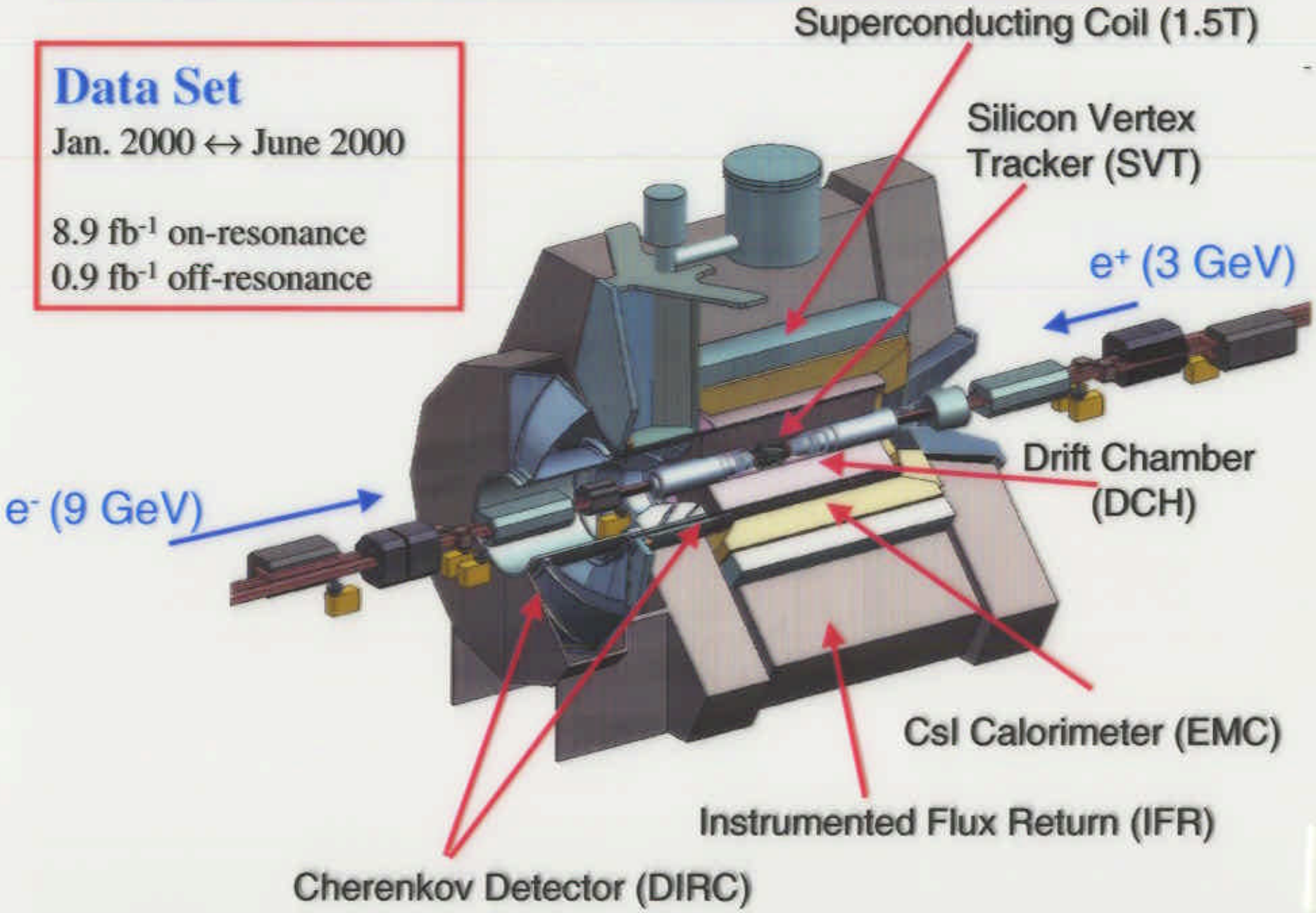
13669 (MIXED)

The BABAR Detector at PEP-II B-Factory

Data Set

Jan. 2000 ↔ June 2000

8.9 fb^{-1} on-resonance
0.9 fb^{-1} off-resonance



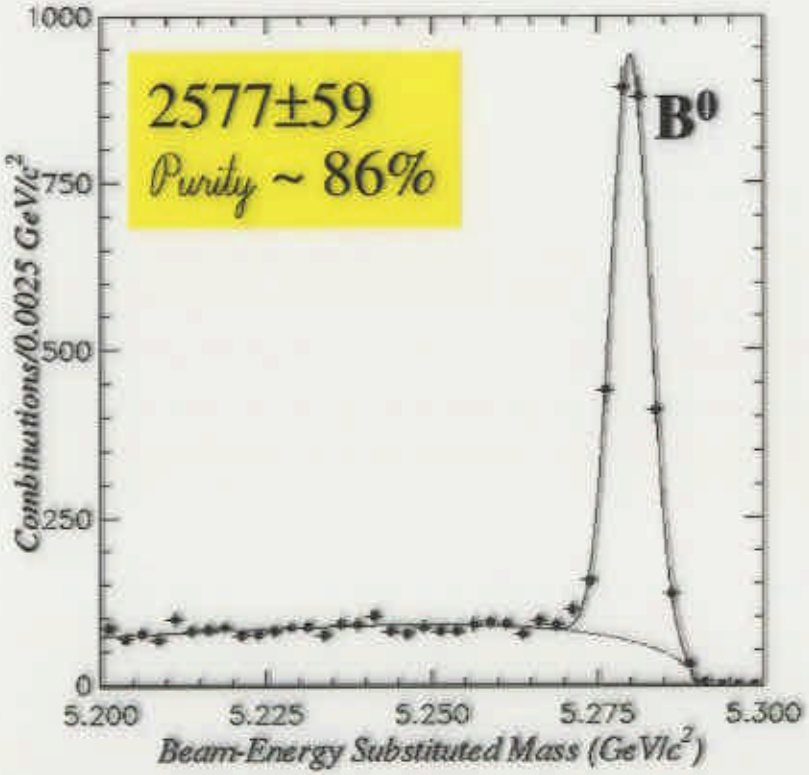
Hadronic decays

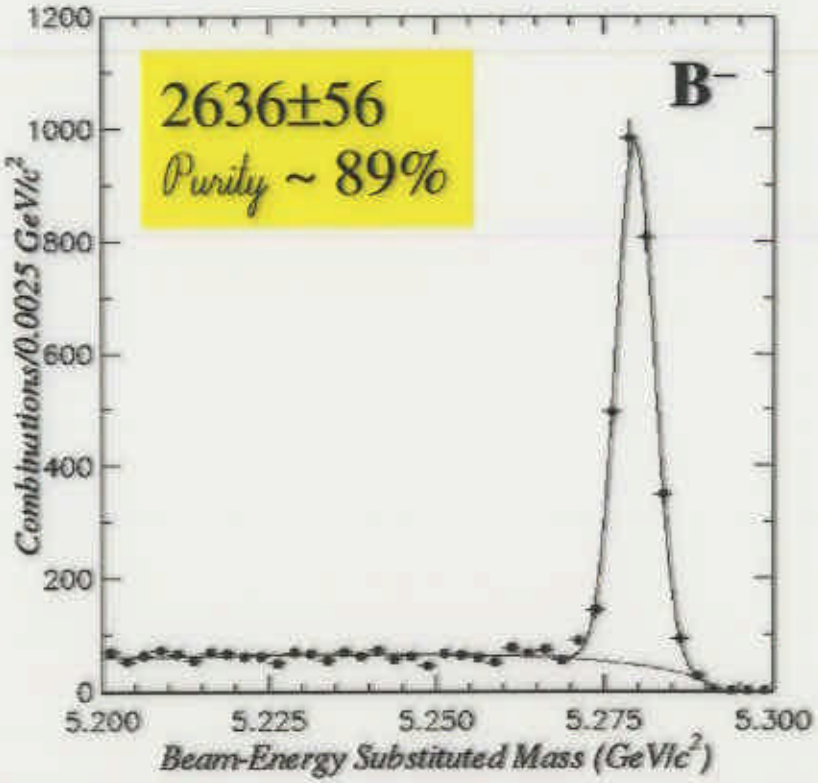
For details:
G. Vuagnin, G. Raven's talks
PA-07e, Saturday

- ✔ $B^0 \to D^{(*)} \cdot \pi^+,\ D^{(*)} \cdot \rho^+,\ D^{(*)} \cdot a_1^+,\ J/\Psi\ K^{*0}$
- ✔ $B^- \to D^{(*)0}\ \pi^-,\ J/\Psi\ K^-,\ \Psi(2S)\ K^-$
- ✔ Kinematic variables for signal and background estimates

$$\Delta E = E^*_B - \sqrt{s}/2$$

$$m_{ES} = \sqrt{(s/4 - p^{*2}_B)}$$





Background from m_{ES} sideband

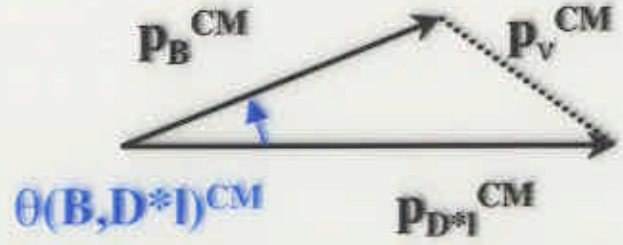
- ✔ ARGUS shape
- ✔ Combinatorial
  - ~4% fake B same charge, ~3% fake B opp charge
  - ~5% ccbar, ~1% uds

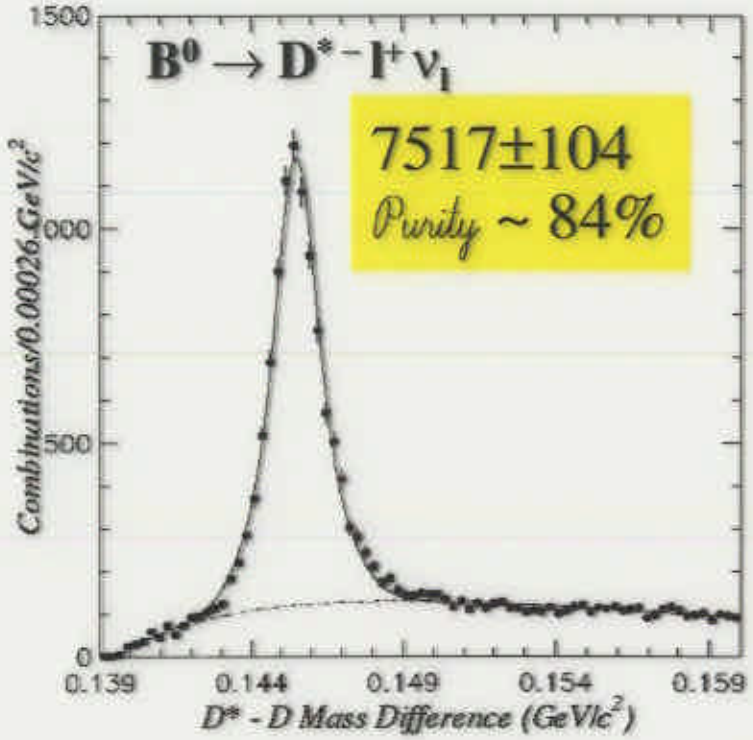
Semileptonic decays

- ✔ $B^0 \to D^{*-} l^+ \nu_l$
- ✔ Identify electrons and muons using calorimeter and Instrumented Flux Return
- ✔ D* and lepton tend to be back-to-back, p*(lepton)>1.2 GeV
- ✔ Require kinematic consistency with missing neutrino

$$|\cos\theta(B,D^*l)^{CM}| < 1$$

(equivalent to missing-mass cut)



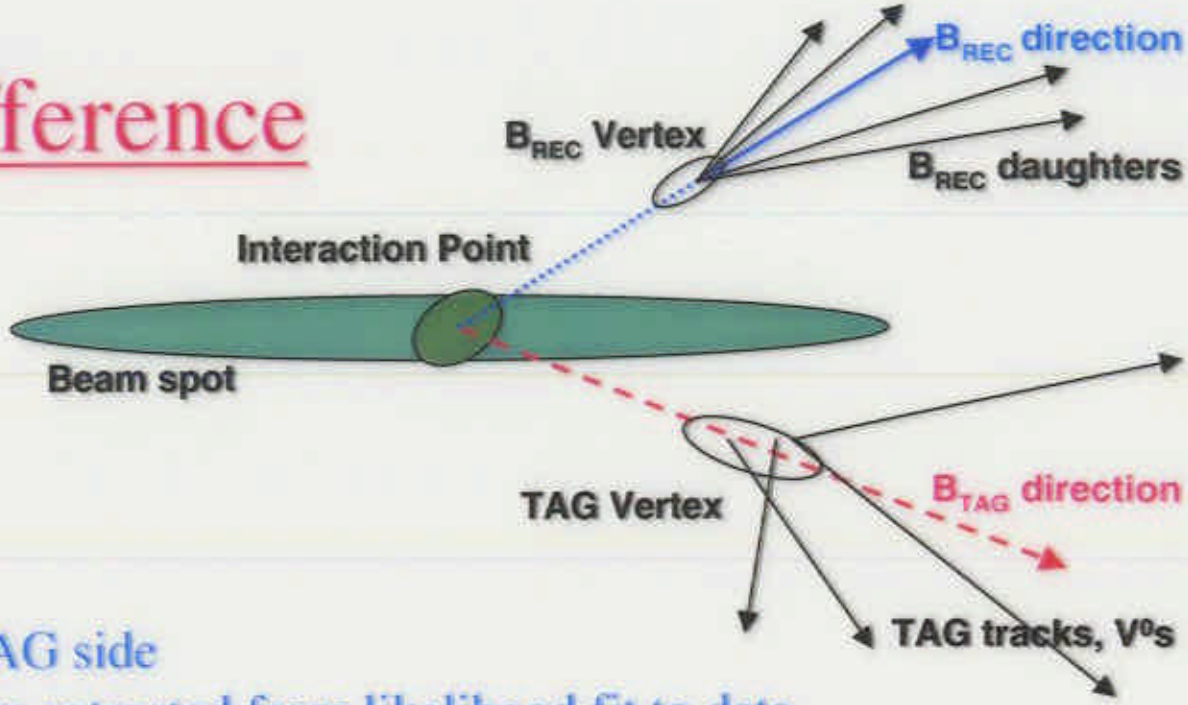


Background from control samples

- ✔ Combinatorial ⇒ D* - D sideband
- ✔ Wrong-lepton:
  - fake leptons ⇒ tracks + lepton mis-id
  - uncorrelated leptons ⇒ "lepton-flipping"
  - cascade leptons ⇒ <1% (Simulation)
  - $c\bar{c}$ ⇒ off-resonance data
- ✔ $B^\pm$ background ($B^- \to D^{*-} X\, l^+ \nu_l$) ($D^{**}$)
  - Δt distributions from hadronic B^+
  - fraction from LEP data and MC simulation:

$$f(B^+)=(7.1\pm5.0)\%$$

Decay time difference



✔ **Boost approximation**

$$\Delta t = (z_{REC} - z_{TAG}) / c\langle\beta\gamma\rangle$$

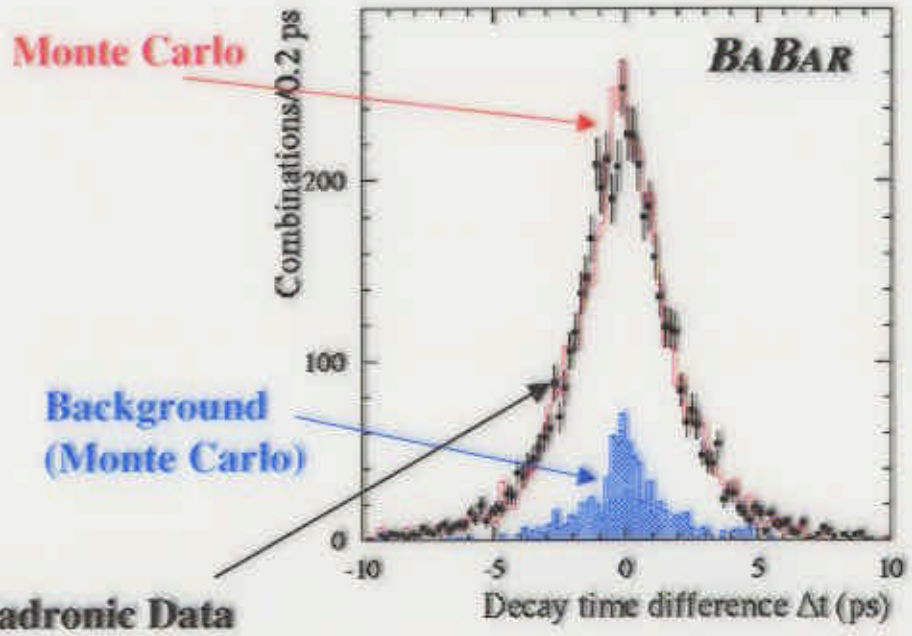
✔ **Resolution function**

- largely dominated by TAG side
- most relevant parameters extracted from likelihood fit to data
- uses event-by-event error
- described by 3 Gaussians:

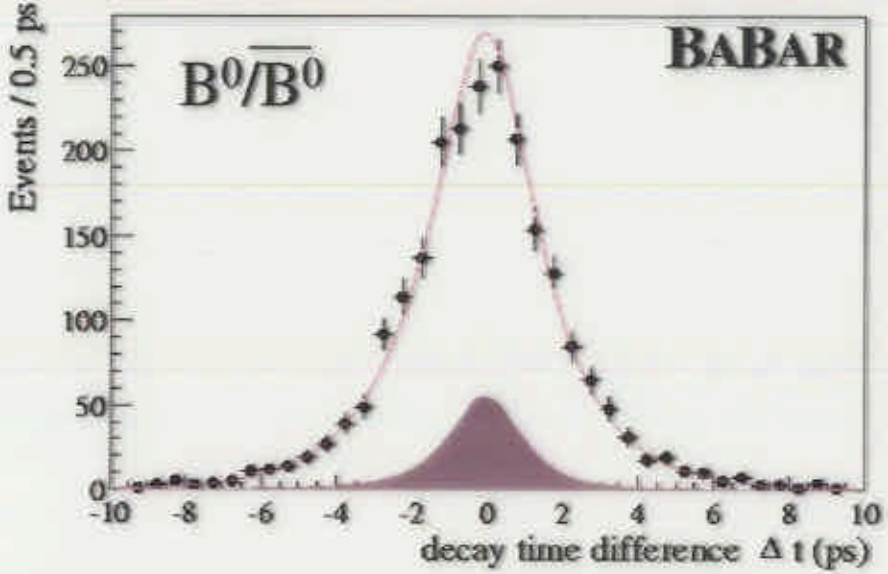
  f_{core} ~ 75%, σ_{core} ~ 0.6 ps

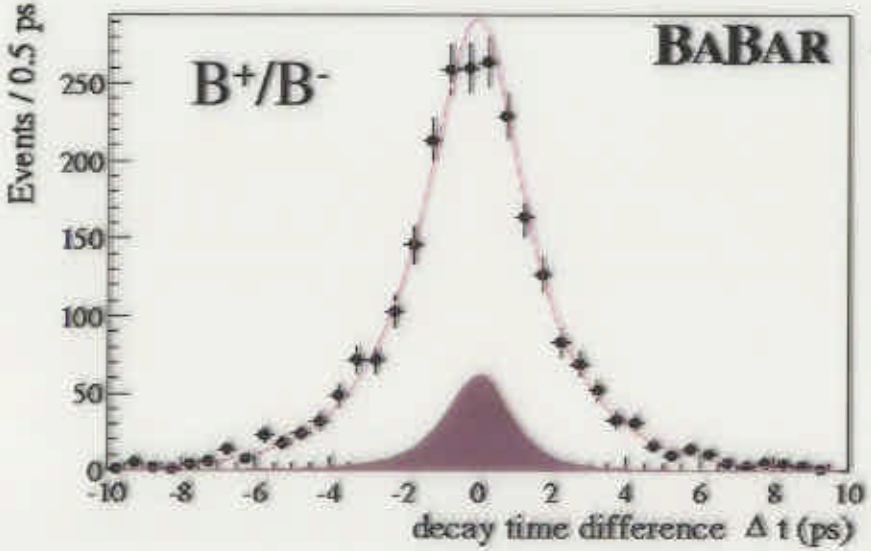
  f_{tail} ~ 24%, σ_{tail} ~ 2 ps

  $f_{outliers}$ ~ 1%, $\sigma_{outliers}$ ~ 8 ps
- slightly biased (~0.2 ps) due to secondary decays



Lifetime measurements





- ✔ Simultaneous unbinned maximum likelihood fit to Δt distributions of **hadronic B^0 and $B^\pm$ data** with common resolution function
- ✔ Empirical Δt background description from m_{ES} sidebands, different parameters for B^0 and B^-
- ✔ Use full m_{ES} distribution to define signal probability
- ✔ Results based on 7.4 fb^{-1}

$\tau_{B^0} = 1.51 \pm 0.05$ (stat) ± 0.03 (syst) ps
$\tau_{B^+} = 1.60 \pm 0.05$ (stat) ± 0.04 (syst) ps
$\tau_{B^+}/\tau_{B^0} = 1.065 \pm 0.044$ (stat) ± 0.021 (syst)

PRELIMINARY

- ✔ Systematics dominated by
  - Monte Carlo statistics
  - Understanding of *outliers*
  - z scale

B flavor tagging

- ✔ Determine the flavor of the B by the charge of decay products
- ✔ **Effective tagging efficiency**

$$1/\sigma^2_{stat} \sim N_{Brec}\, Q$$

$$Q = \varepsilon D^2,\ D = 1-2w$$

Fraction of tagged events — ε

Dilution — D

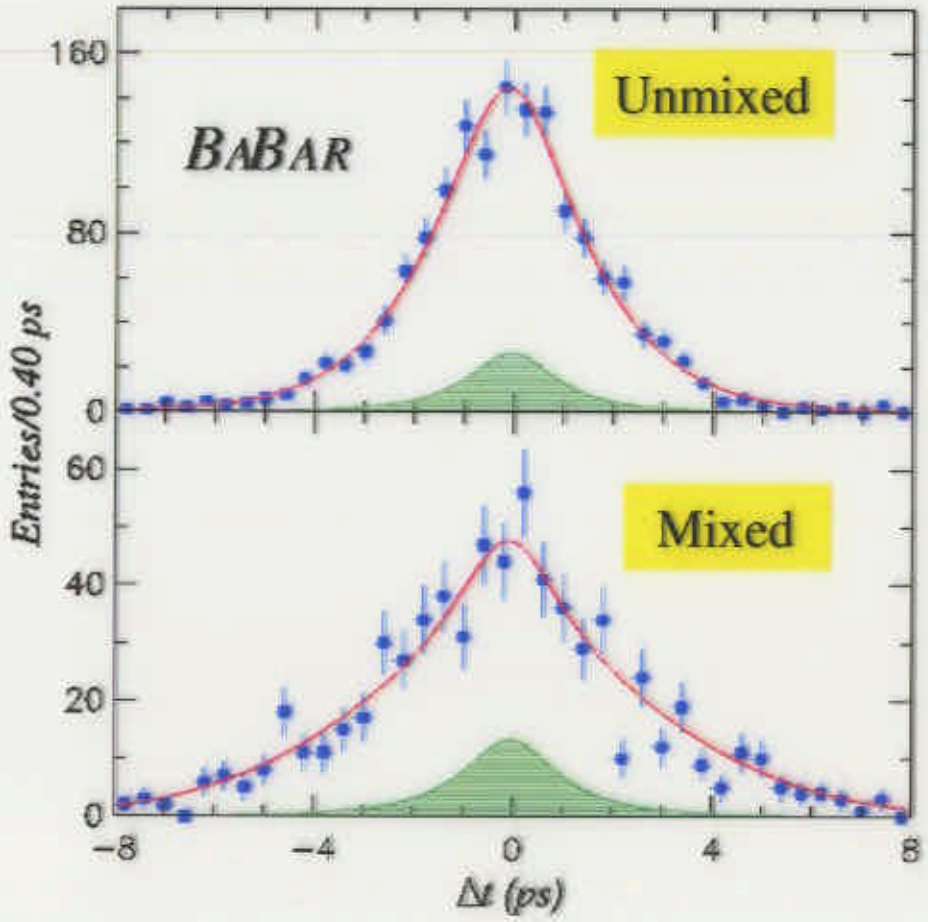
Wrong tag fraction — w

- ✔ 4 mutually exclusive tagging categories

Category	Priority	Definition	ε
Lepton	+	Charge of fastest lepton with p*>1.1 GeV/c. Higher priority to electrons over muons	12.1 ± 0.5%
Kaon		Total charge of identified kaons	36.2 ± 0.9%
NT1	−	Neural Network, $\|x_{NT}\|>0.5$, sign x_{NT}	11.5 ± 0.3%
NT2		Neural Network, $0.2<\|x_{NT}\|<0.5$, sign x_{NT}	17.2 ± 0.3%
		Total	74.6 ± 0.5%

- ✔ **Neural network** exploits information carried by non-identified leptons and kaons, soft leptons (from charm semileptonic decays), soft pions from D* decays, and more generally, by the momentum spectrum of charged particles (Jet Charge) from B decays

Mixing results: hadronic decays



18% C.L.

- ✔ Simultaneous likelihood fit to each tagging category, mixed and unmixed events with common resolution function

$$1/4\ \Gamma\, e^{-\Gamma|\Delta t|}\ [1 \pm (1-2w)\cos\Delta m_d\, \Delta t] \otimes R(\Delta t;a)$$

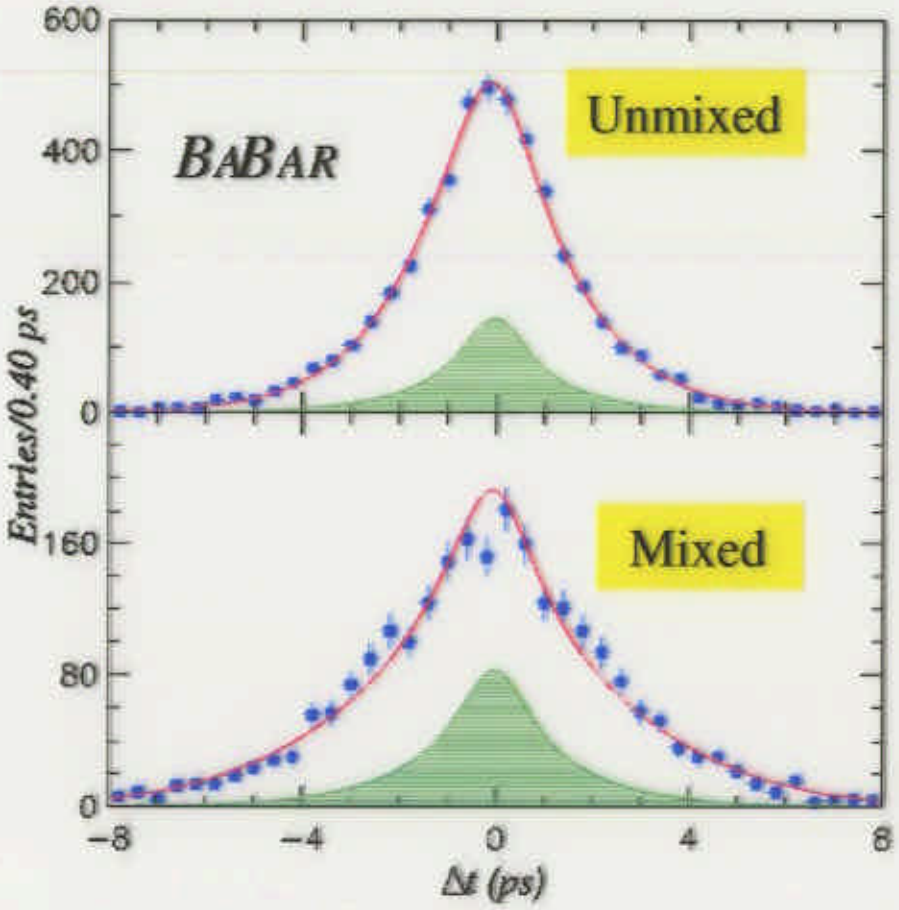
- ✔ Empirical Δt background description from m_{ES} distribution (same shape, different resolution function). Two components:
  - zero lifetime
  - non-zero lifetime, no mixing
- ✔ Use full m_{ES} distribution to define signal probability
- ✔ Result:

$$\Delta m_d = 0.516 \pm 0.031\ (\text{stat}) \pm 0.018\ (\text{syst})\ \text{ps}^{-1}$$

PRELIMINARY

- ✔ Systematics dominated by
  - Monte Carlo statistics
  - Resolution function

Mixing results: semileptonic decays



28% C.L.

- ✔ Similar procedure as for hadronic decays with two main differences
- ✔ Fit separately background control samples. Three components:
  - zero lifetime
  - non-zero lifetime, no mixing
  - non-zero lifetime, mixing
- ✔ Fit data in signal region with background fractions, Δt resolutions and dilutions from background control samples
- ✔ Result:

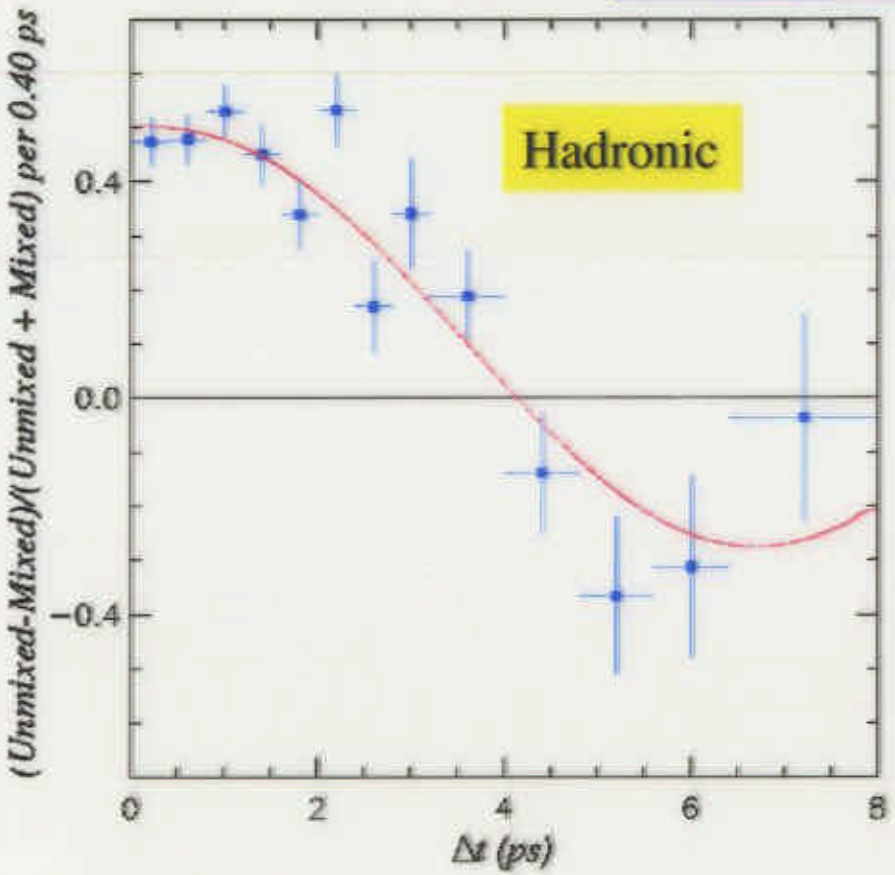
$\Delta m_d = 0.508 \pm 0.020\ (stat) \pm 0.022\ (syst)\ ps^{-1}$

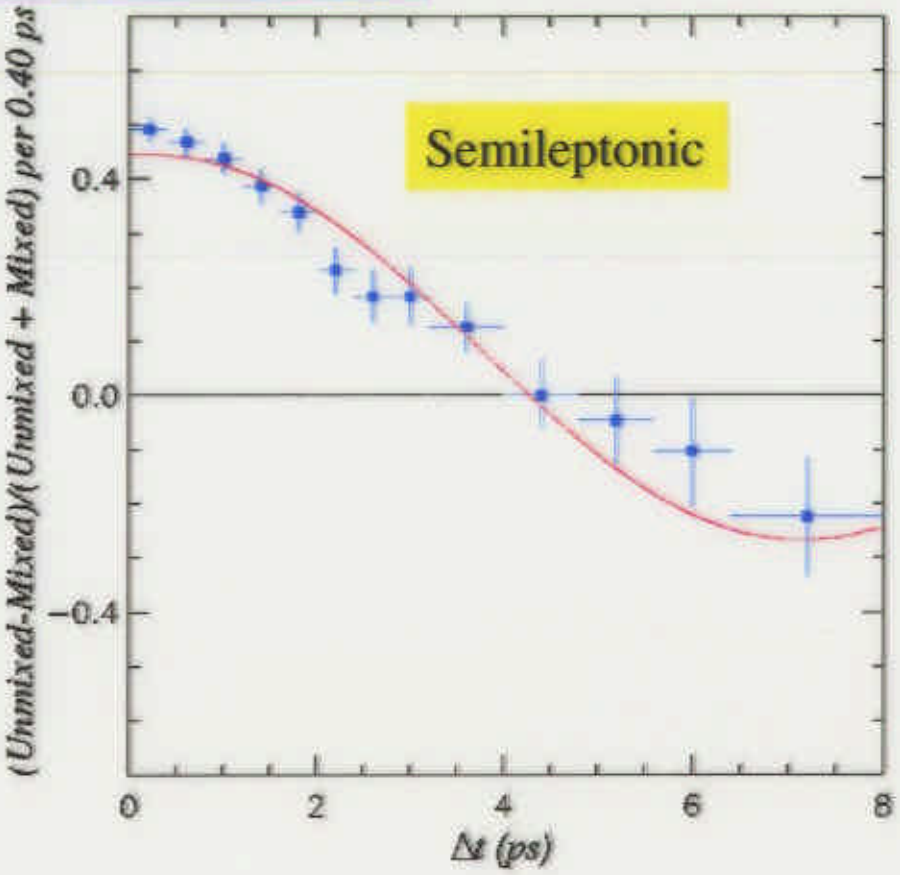
PRELIMINARY

- ✔ Systematics dominated by
  - Monte Carlo statistics
  - Resolution function
  - $B^{\pm}$ background uncertainty

Mixing results

$$a(\Delta t) = (N_{unmix} - N_{mix})/(N_{unmix}+N_{mix})$$





$\Delta m_d = 0.512 \pm 0.017\ (stat) \pm 0.022\ (syst)\ ps^{-1}$

PRELIMINARY

Outlook and Prospects

- ✔ **PRELIMINARY** measurements of B^0, B^- lifetimes (~4%) and $B^0\overline{B}^0$ Mixing (~3%) with first 8.9 fb^{-1} of BaBar data

$\tau_{B^0} = 1.51 \pm 0.05\ (stat) \pm 0.03\ (syst)\ ps$
$\tau_{B^+} = 1.60 \pm 0.05\ (stat) \pm 0.04\ (syst)\ ps$
$\tau_{B^+}/\tau_{B^0} = 1.065 \pm 0.044\ (stat) \pm 0.021\ (syst)$

$\Delta m_d = 0.512 \pm 0.017\ (stat) \pm 0.022\ (syst)\ ps^{-1}$

Compatible with BaBar dilepton analysis and of similar precision

$\Delta m_d = 0.507 \pm 0.015\ (stat) \pm 0.022\ (syst)\ ps^{-1}$

- ✔ Mixing provides resolution function and mistag rates for sin2β analysis (D. Hitlin's talk at plenary session)

Lepton	$0.096 \pm 0.017\ (stat) \pm 0.013\ (syst)$
Kaon	$0.197 \pm 0.013\ (stat) \pm 0.011\ (syst)$
NT1	$0.167 \pm 0.022\ (stat) \pm 0.020\ (syst)$
NT2	$0.331 \pm 0.021\ (stat) \pm 0.021\ (syst)$

Q ~ 28%

- ✔ Further systematic studies underway; more Monte Carlo statistics
- ✔ More data being delivered by PEP-II (>20 fb^{-1} for end october)

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