B-decays Properties at BABAR

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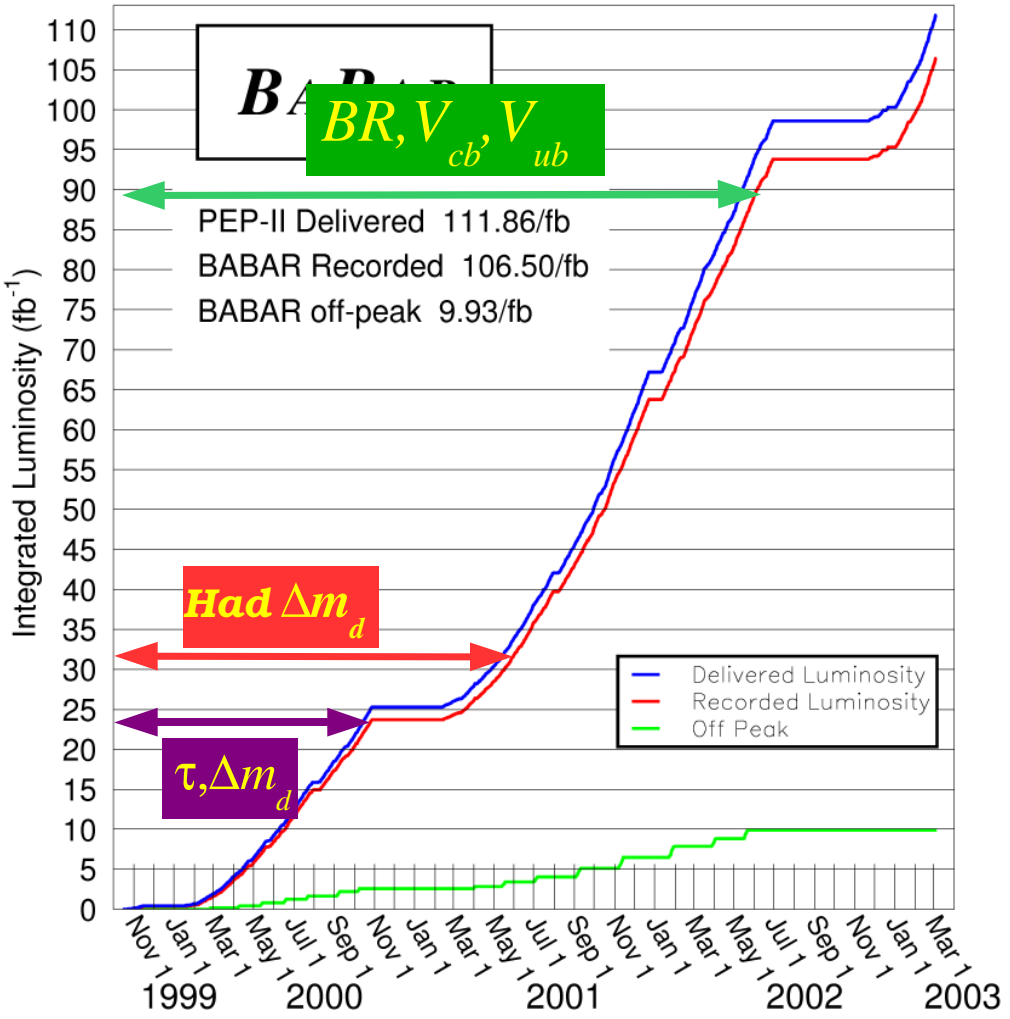
on behalf of BABAR

- The Environment:
  - PEP II & BABAR
- The Measurements:
  - Lifetime, Mixing & Δm_d
  - Charmed Semileptonic Decays & V_{cb}
  - Chamless Semileptonic Decays & V_{ub}
- Conclusions

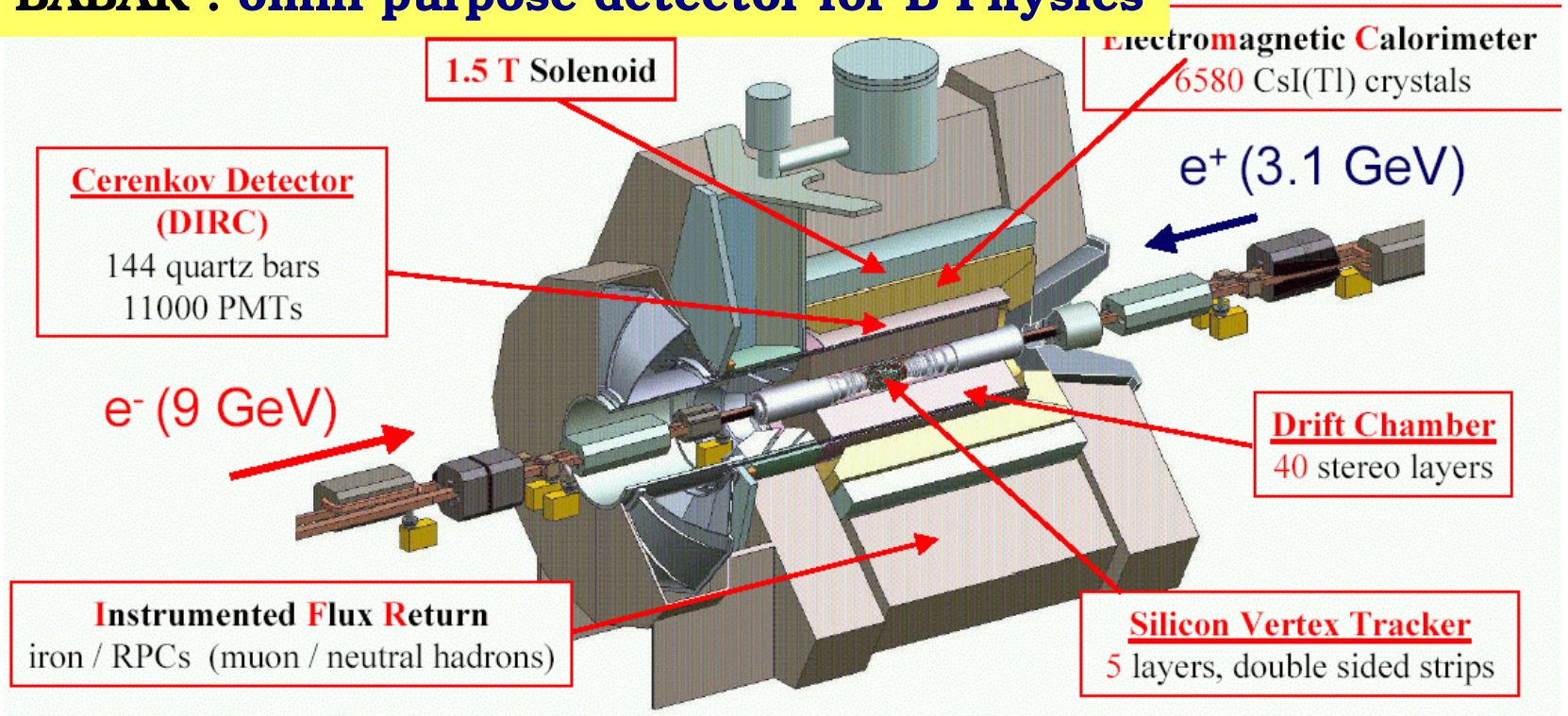
Performances

- **PEP II & BABAR operated successfully**
- **> 100 fb^{-1} collected**
- **approved results:**
  - **~20-30 fb^{-1} (τ,Δm_d)**
  - **~90 fb^{-1} (BR,V_{cb},V_{ub})**



The Detector

BABAR : omni purpose detector for B Physics

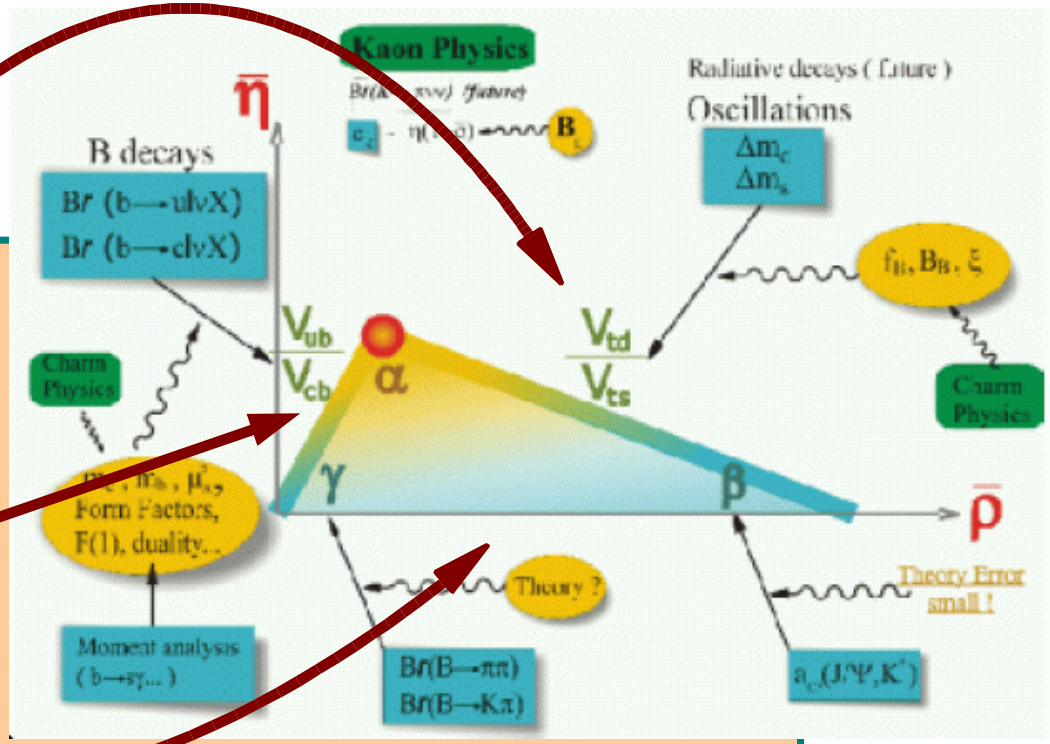


SVT:	97% efficiency, 15 μm z hit resolution (inner layers, perp. tracks)	***Vertex***
SVT+DCH:	$\sigma(p_T)/p_T = 0.13\ \% \times p_T\ +\ 0.45\ \%$	***Tracking & PID (dE/dX)***
DIRC:	K-π separation 4.2σ @ 3.0 GeV/c → >3.0σ @ 4.0 GeV/c	***PID e/π/K/p***
EMC:	$\sigma_E/E = 2.3\ \% \cdot E^{-1/4} \oplus 1.9\ \%$	***γ/π⁰ / e-PID***

Physics Motivation

Measurements of

- Δm_d (V_{td})
- $B \to X_u l\nu$ (V_{ub})
- $B \to X_c l\nu$ (V_{cb})



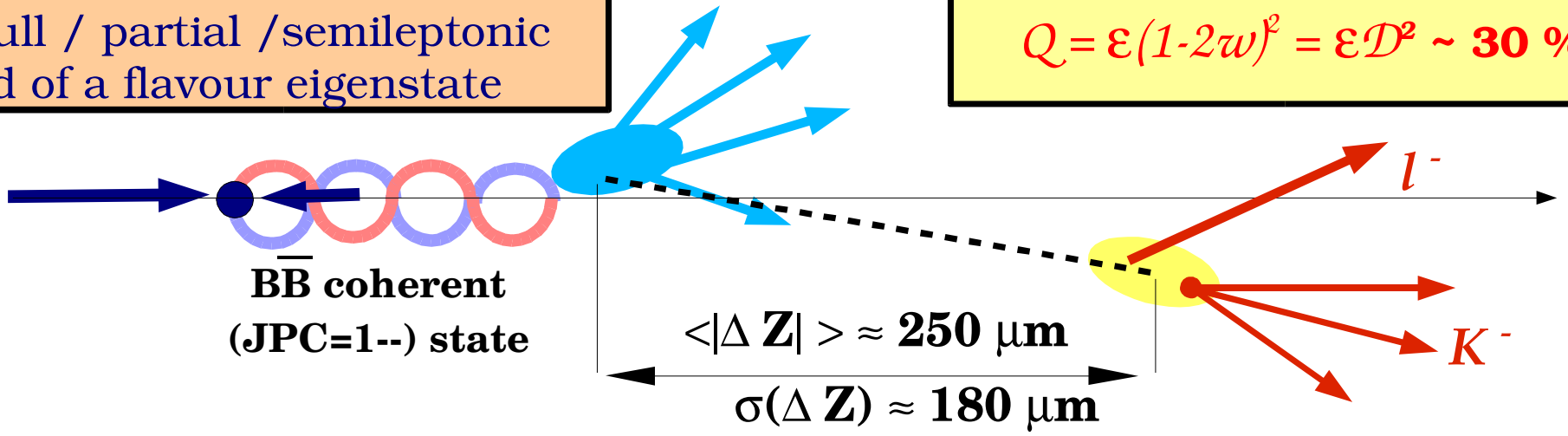
allow to determine the side of the Unitarity Triangle

complementary to CP asymmetry measurements (see Riccardo's talk)

τ & Δm_d: the method

B(flavour) :
flavour at clock start
full / partial /semileptonic
id of a flavour eigenstate

B(tag) :
flavour at other B decay
(l,K, soft/hard p) charge
Tagging quality factor:
$Q = \varepsilon(1-2w)^2 = \varepsilon \mathcal{D}^2 \sim$ **30 %**



Boost approx.: $\Delta t \approx \Delta Z / c\beta\gamma$

τ measurment: $dN/d(\Delta t)$

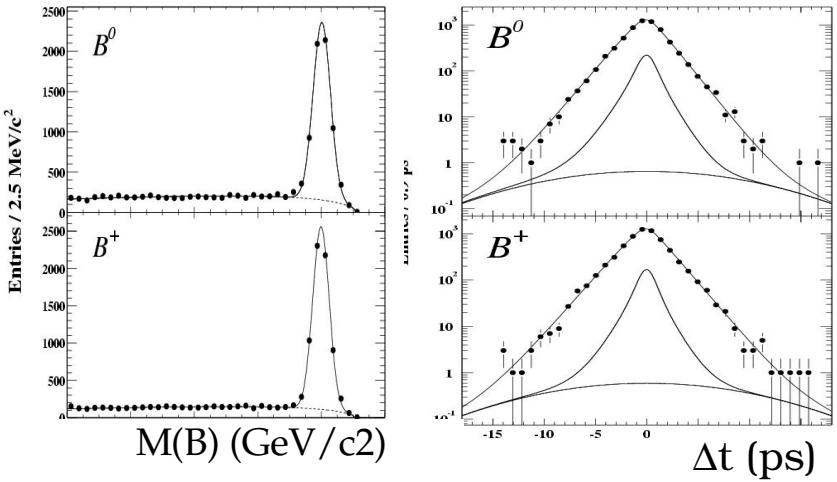
Δm_d measurment: $A_{mix}(\Delta t) = \dfrac{N(B\bar{B})-N(BB)}{N(B\bar{B})+N(BB)}$

0.56 (PEPII) :
$\sigma(\Delta t) \approx <\Delta t> << 2\pi / \Delta m_d$
is ~ same for all modes

τ & Δm_d :the samples

1) $B^{0/+} \rightarrow D^{(*)}\pi,\rho,a_1\ J/\Psi\ K^{(*)}$

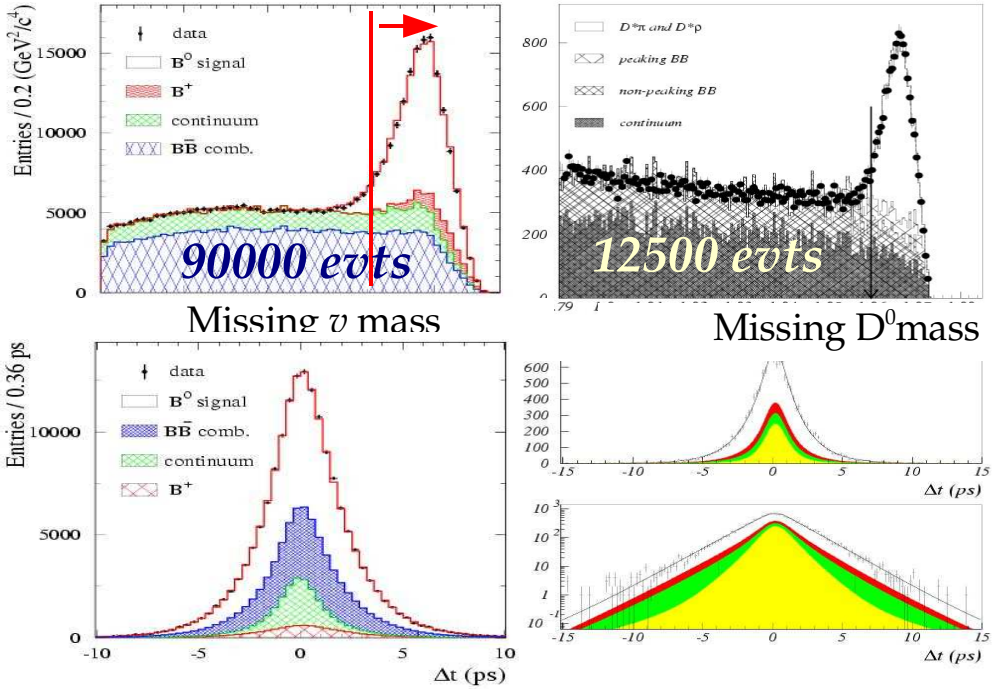
$\tau(B^{0/+})$ (PRL 87 2001) , Δm_d (PRL 88 2002)



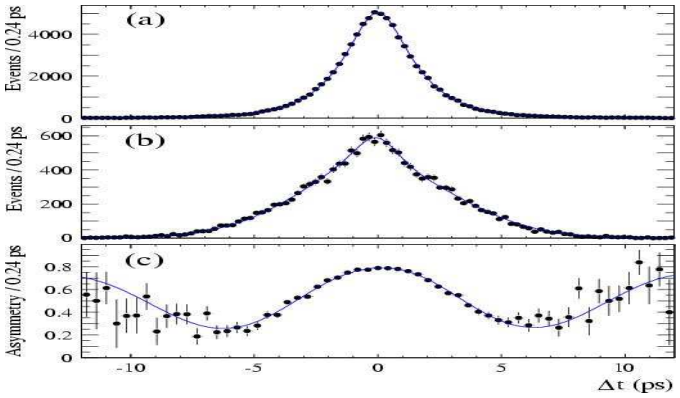
2) Partial B^0 Reconstruction: $\tau(B^0)$

$B^0 \rightarrow D^{*+}\ell^-\nu$ (PRL 89 2002)

$B^0 \rightarrow D^{*+}\pi/\rho$ (subm. to PRD)



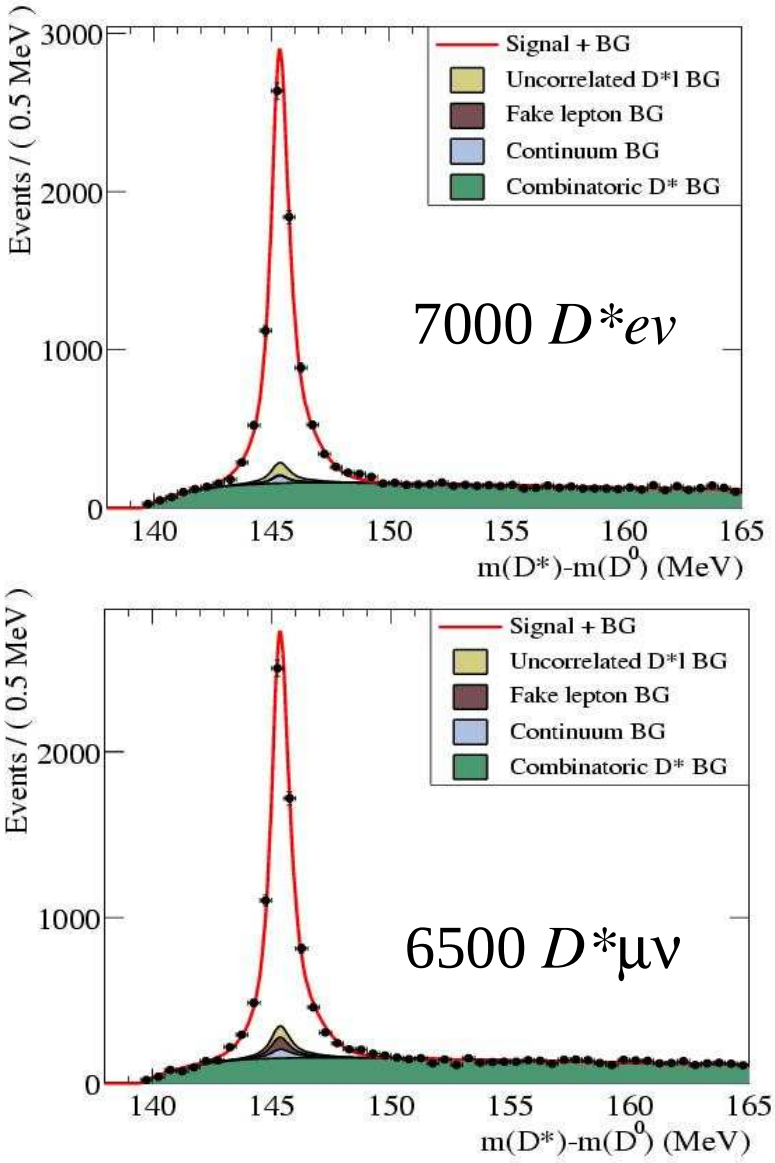
3) B B→ $\ell\ell$X: Δm_d (PRL 89 2002)



4) Simultaneous measurement of $\tau(B^0)$ and Δm using $B^0 \rightarrow D^{*+}\ell^-\nu$ decays

All results based on < 35 fb^{-1}

τ & Δm_d: $B^0 \rightarrow D^* l\nu$ selection



- High p lepton:

  e^-/μ^- $(p>1.2\ GeV/c)$

- + fully reconstructed D^{*+}:

  $D^{*+} \rightarrow \pi^+ D^0$,

  $D^0 \rightarrow K^-\pi^+, K3\pi, K^-\pi^+\pi^0, K_s\pi\pi$

- Consistency with kinematics:

  $\cos(\Theta_{D^*l}) < 0$

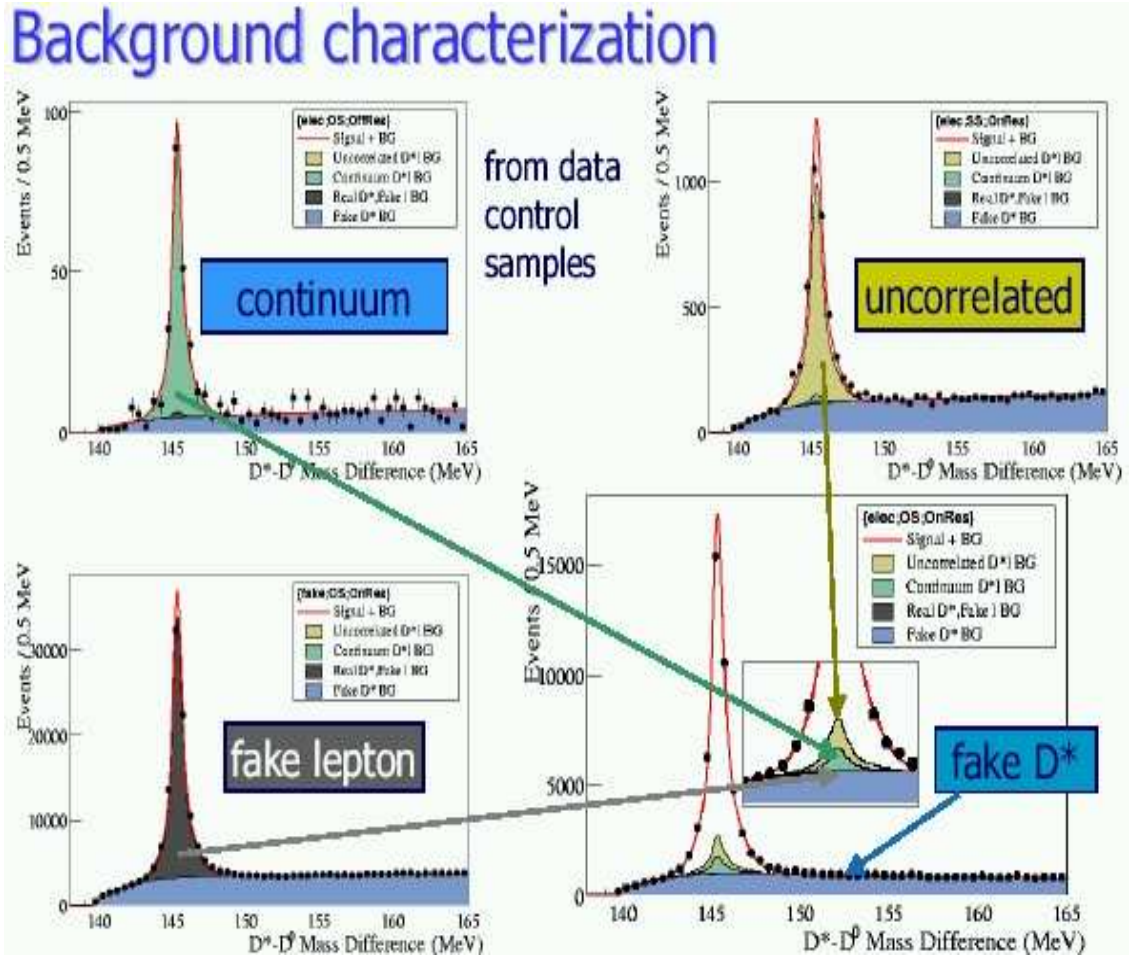
  $|\cos(\Theta_{B(D^*l)})| < 1.2$

- Background properties from data control samples

τ & Δm_d: $B^0 \rightarrow D^* l\nu$ sample

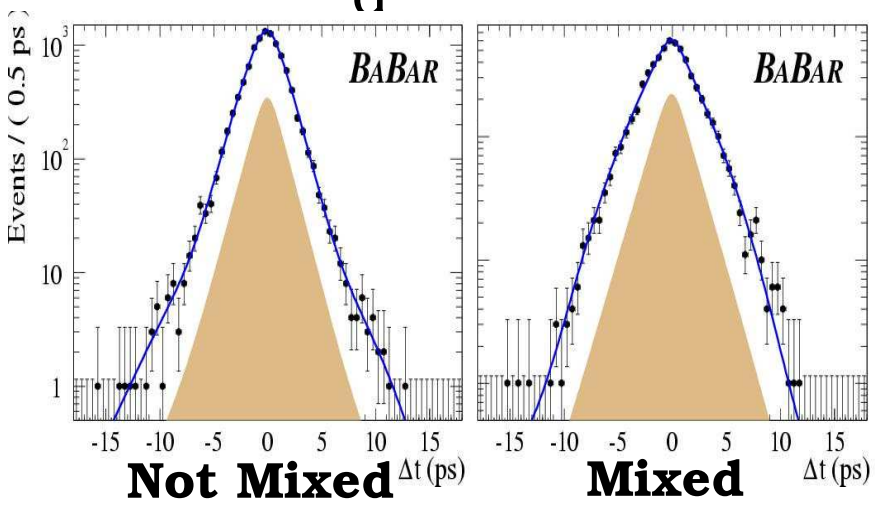
Backgrounds

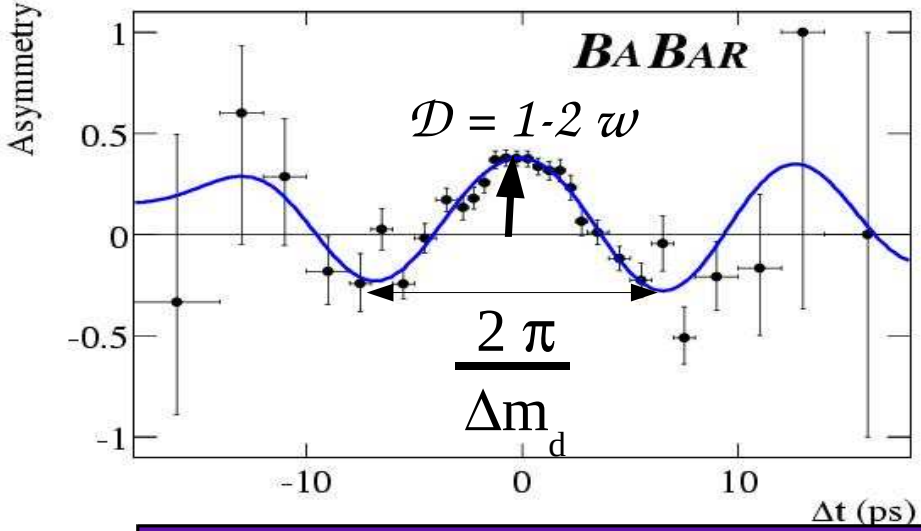
- combinatorics:
  - M_{D^*}-M_D side bands
- continuum:
  - off-peak runs
- $B_1 \rightarrow D^* X$, $B_2 \rightarrow l Y$ *(uncorrelated)*
  - flip: $\vec{p_l} \rightarrow -\vec{p_l}$
- fake leptons
  - tracks failing lepton-id
- $B^+ \rightarrow D^{*+} l^- \nu X$
  - fit itself



Any $B^0 \rightarrow D^{*+} l^- \nu (X)$ is signal for this analysis

τ & Δm_d: the fit





Flavour tag:

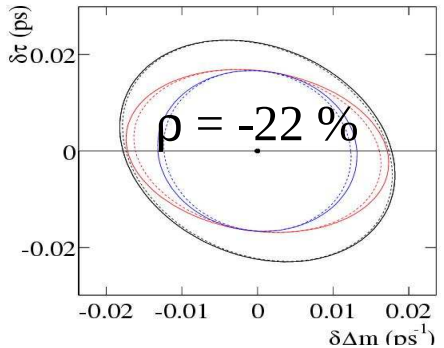
- *l,K,NN,*
- $Q = \varepsilon(1-2w)^2 \sim 24\ \%$

Fit simultaneously :

- tag Not Mixed,
- tag Mixed
- no tag (τ only, ~ 30%)

Determine τ , Δm_d + 29 parameters:

- resolution
- $f_{B+} = (8.2 \pm 2.9)\%$
- wrong tags

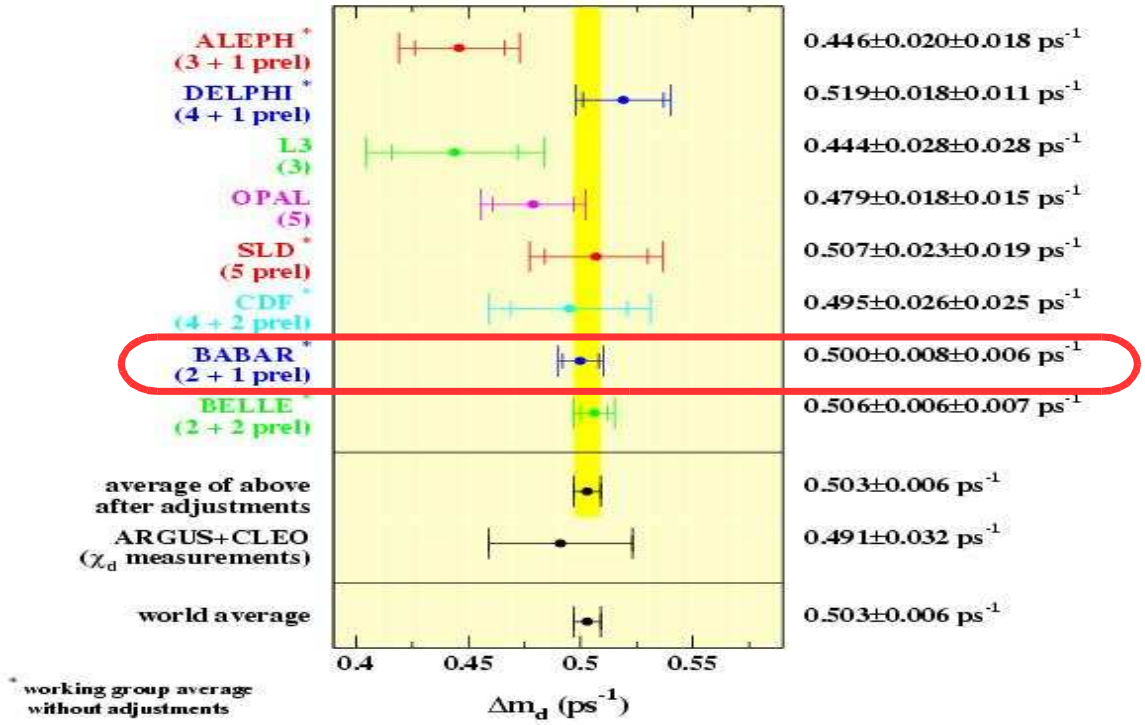


Δm_d = (0.492±0.018±0.013) ps^{-1}

$\tau(B^0)$ = (1.523±0.024±0.022) ps

τ & Δm_d:averages & comparisons

	Δmd	τ(B0)	R+/-
*D*lv (prel.)*	**0.492±0.018±0.013**	**1.523±0.023±0.022**	
D(*)h	**0.516±0.016±0.010**	**1.546±0.032±0.022**	**1.082±0.026±0.012**
ll	**0.492±0.012±0.009**		
Part.S.L		**1.529±0.012±0.029**	
Part.Had. (prel.)		**1.533±0.034±0.038**	
BaBar average	**0.500± 0.008±0.006**		
World average	**0.503±0.006**	**1.540± 0.014**	



BR($B^0 \to D^{*+} l^- \nu$)

- Same selection as above
- Use 2000+2001+2002 stat. (80 fb-1)
- Determine B.R. separately in

  2 (e/ μ) * 4 (D^0) * 3 (years) = 24 different modes
- 70 Kevts, purity 70 - 85 %

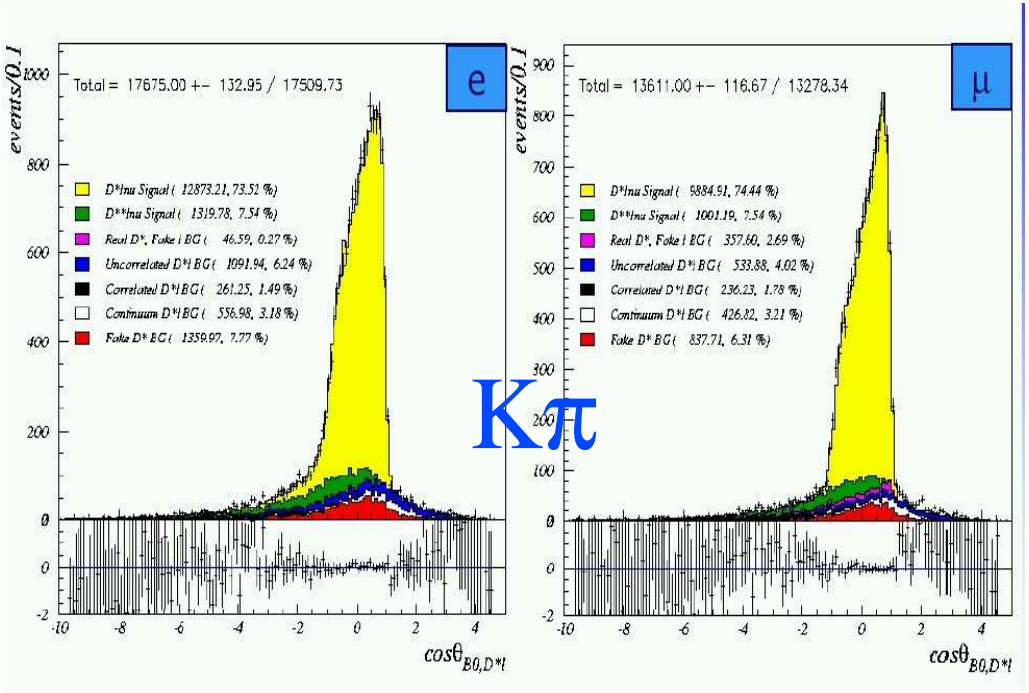
Channel	Efficiency (%)
$B^0 \to D^{*-}(K^+\pi^-)e^+\nu_e$	11.915 ± 0.102
$B^0 \to D^{*-}(K^+\pi^-\pi^+\pi^-)e^+\nu_e$	3.729 ± 0.038
$B^0 \to D^{*-}(K^+\pi^-\pi^0)e^+\nu_e$	2.860 ± 0.026
$B^0 \to D^{*-}(K^0_S\pi^+\pi^-)e^+\nu_e$	0.330 ± 0.014
$B^0 \to D^{*-}(K^+\pi^-)\mu^+\nu_\mu$	9.147 ± 0.089
$B^0 \to D^{*-}(K^+\pi^-\pi^+\pi^-)\mu^+\nu_\mu$	2.864 ± 0.033
$B^0 \to D^{*-}(K^+\pi^-\pi^0)\mu^+\nu_\mu$	2.183 ± 0.023
$B^0 \to D^{*-}(K^0_S\pi^+\pi^-)\mu^+\nu_\mu$	0.258 ± 0.013

D^0 : $\Sigma(\varepsilon\, Br) \sim 10\ \%$

Any $B^0 \to D^{*+}\, l\, X\, \nu$ is background for this analysis

Sample composition

- Combinatorics, continuum, uncorrelated, fake *l*
  - as above
- $B^0 \rightarrow D^* X_c/\tau,\ X_c/\tau \rightarrow l\, Y$
  - from MC (~ 1 %)
- $B^{0,+} \rightarrow l^+ \upsilon\ (D^*\pi)/\ D^{**},\ D^{**} \rightarrow D^{*-} X$
  - fit :



$$\cos(\Theta_{B\text{-}D^*l}) = \frac{-(m_B^2 + m_{D^*l}^2 - 2E_B E_{D^*l}) + m_{X\upsilon}^2}{2\,|\vec{p}_B|\,|\vec{p}_{D^*l}|}$$

Signal: = 0 → |cosΘ| <1
Backg.: > 0 → overflows

Results consistent with:

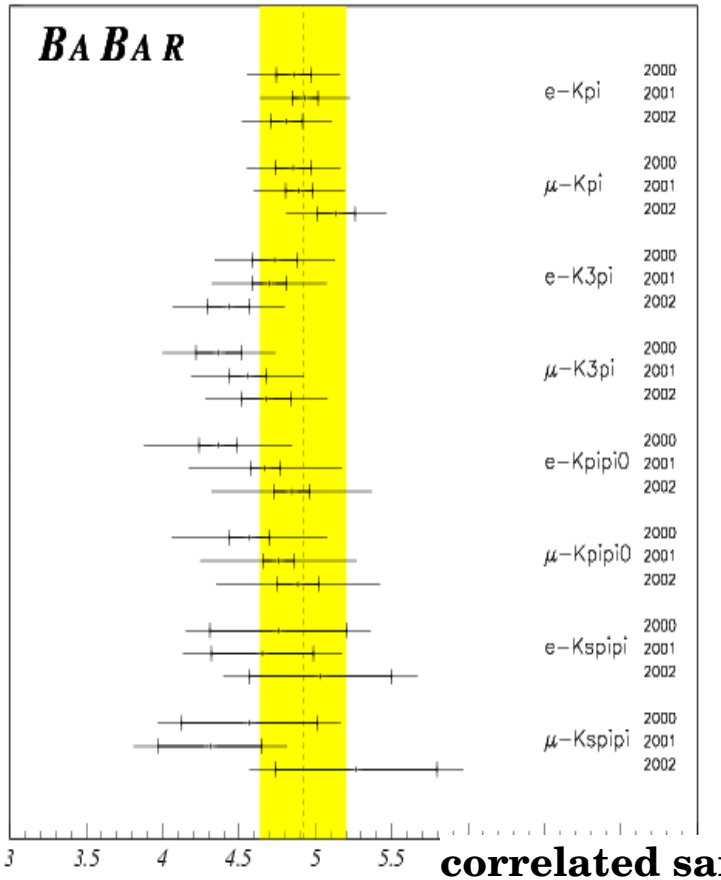
- f_{B+} from Δm_d analysis (+Isospin)
- $f_{D^{**}}$ from Moments analysis (see below)

Results

error contribution	$\delta\mathcal{B}/\mathcal{B}$ (%)
statistical data	0.6
statistical Monte Carlo	0.4
fraction of all backgrounds except $B \to D^{*-}\ell^+\nu_\ell X$	0.3
particle identification	0.9
reconstruction efficiency of slow pion from $D^{*-} \to \overline{D}^0\pi^-$ decay	1.9
particle reconstruction efficiency (all tracks but slow pion, including π^0 and K^0_S)	2.7
$D^{*-}\ell^+$ vertexing efficiency	1.0
lepton momentum cut	1.0
χ^2 fit binning	1.0
$B \to D^{*-}\ell^+\nu_\ell X$ background fraction error from χ^2 fit	0.2
$B \to D^{*-}\ell^+\nu_\ell X$ background composition	2.0
total number of B produced	1.1
$\Upsilon(4S)$ rest frame B momentum data/Monte Carlo disagreement	0.7
HQET parameter dependence	1.8
total systematic error	4.9
$\mathcal{B}(\overline{D}^0)$	2.0
$\mathcal{B}(D^{*-} \to \overline{D}^0\pi^-)$	0.7
$\mathcal{B}(\Upsilon(4S) \to B^0\overline{B}^0)$	2.7
total branching fractions error	3.5

PDG

χ^2/ndof = 21.3/23

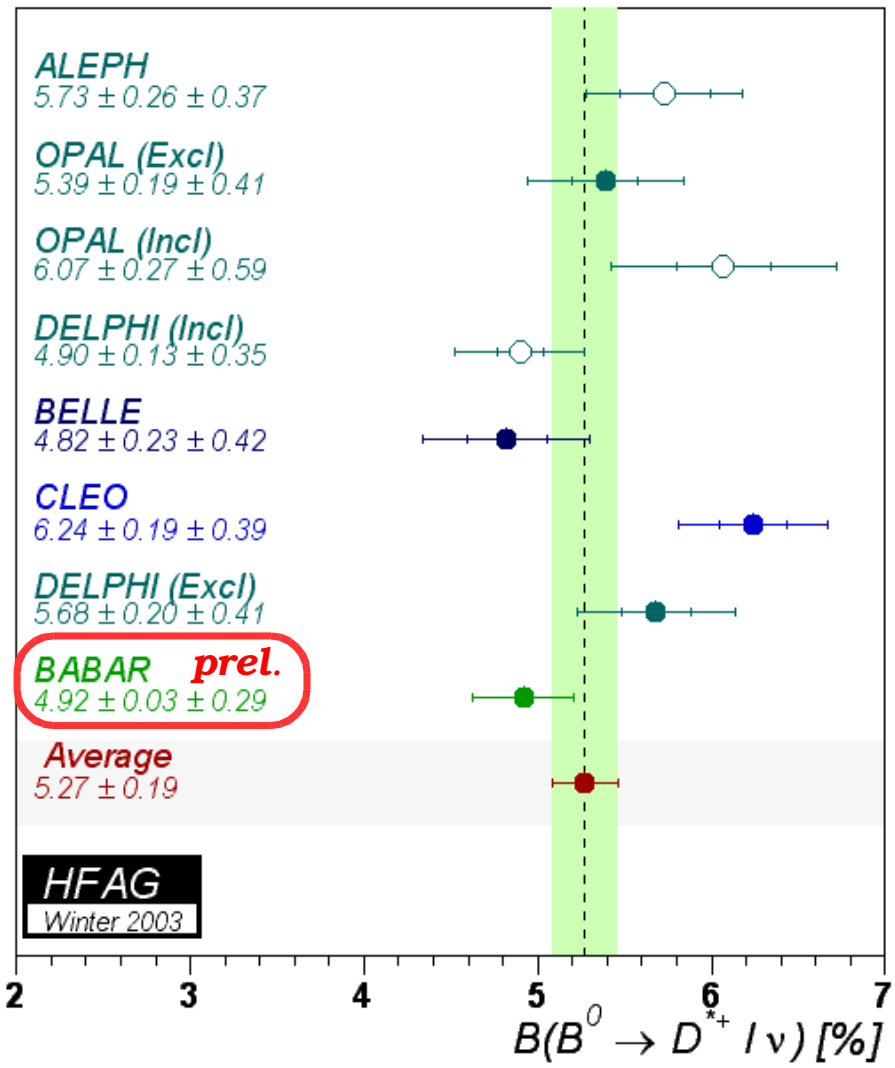


correlated samples (tracking,PID,B.R.)

BR($B^0 \to D^{*+} l^- \nu$) = ($4.92 \pm 0.03^{stat} \pm 0.02^{statMC} \pm 0.24^{exp} \pm 0.17^{BR}$)%

(BaBar Preliminary)

Comparisons & World Average



Results rescaled to common inputs:

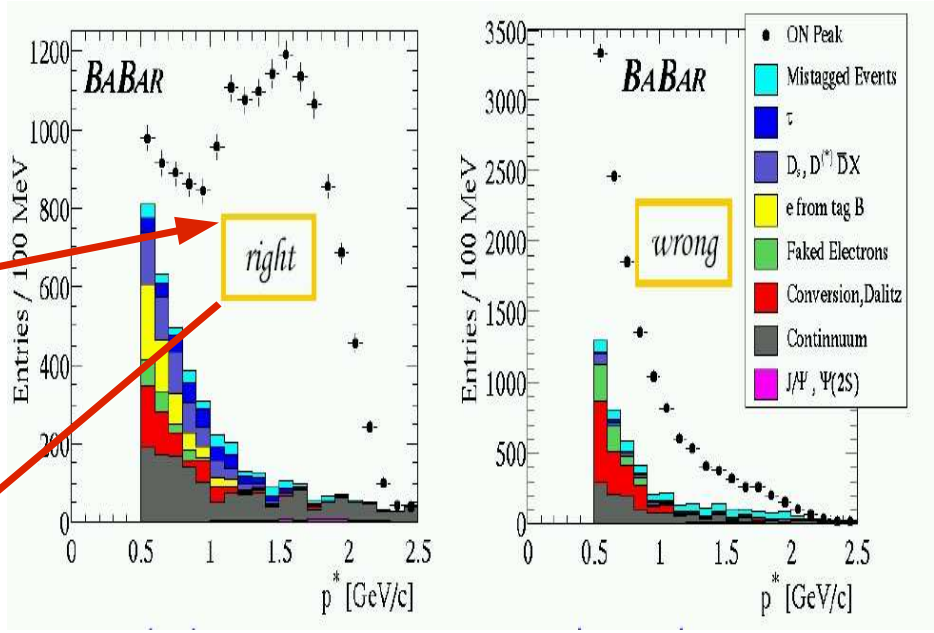
- BR = (5.27 ±0.19) %
- C.L. = 6.4 %

To come:

V_{cb} measurement with the same data sample

BR($B \to X_c l\nu$) and V_{cb}

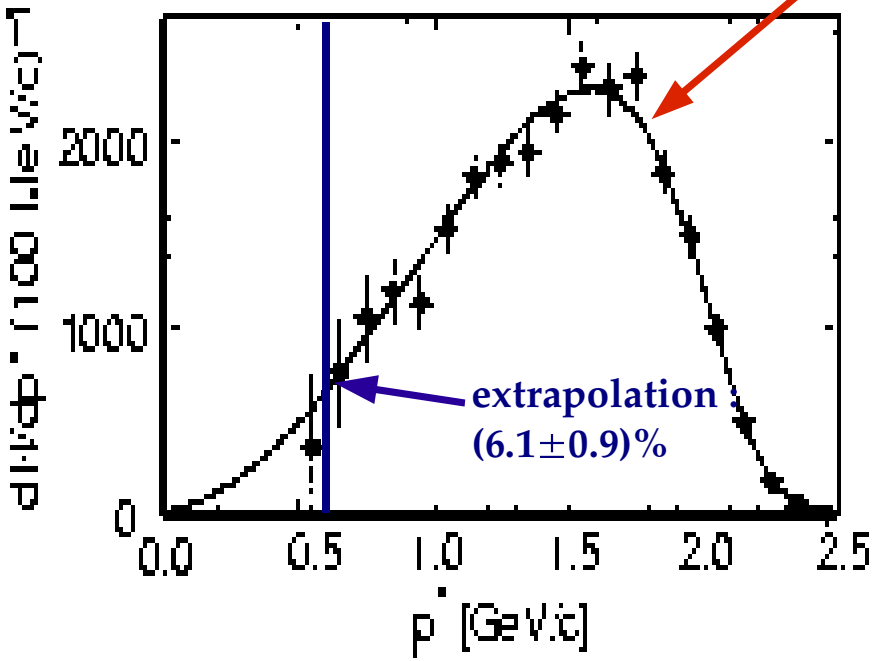
mostly $B \to l\nu X_c$ | mostly $B \to X_c \to l\nu Y$



selection

e-tag, p_{tag} >1.5 GeV

second e: Q { $e^{\mp}e^{\pm}$ / $e^{\pm}e^{\pm}$



measurement

fit p_e

- **bckg subtracted**
- **ε corrected**
- **mixing unfolded**

with sum of *ev (D+D*+D)* spectra**

BR($B \to X_c l\nu$) and V_{cb} : Results

$$BR = \tau(B)\ |V_{cb}|^2\ \gamma^{th} = (10.87 \pm 0.18 \pm 0.30)\ \%$$

$$|V_{cb}|^{incl} = (42.3 \pm 0.7_{exp} \pm 2.0_{th})\ 10^{-3}$$

BaBar Prel.

Perturbative & **non-perturbative** QCD

DETERMINATIONS OF BR($b \to X \ell \bar{\nu}$)

Expt.	BR	stat	syst
CLEO	10.49	±0.17	±0.43
BELLE (ℓ Tag)	10.90	±0.12	±0.49
BABAR (e Tag)	10.87	±0.18	±0.30
AVERAGE	10.63	±0.19	±0.16

Expt.	BR	stat	syst	model
ALEPH	10.70	±0.10	±0.23	±0.26
DELPHI	10.70	±0.08	±0.21	$^{+0.44}_{-0.30}$
L3	10.85	±0.12	±0.38	±0.26
L3 (double tag)	10.16	±0.13	±0.20	±0.22
OPAL	10.83	±0.10	±0.20	$^{+0.20}_{-0.13}$
AVERAGE	10.63	±0.09	±0.15	±0.18

$\Gamma(b \to X_c \ell \nu) = 0.434 \times (1 \pm 0.018) 10^{-10}$ MeV

LEP+$\Upsilon(4S)$ V_{cb} WG March 02

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Theoretically limited.
Experiment can drive theory !

$B \to X_c l\nu$:spectra

$\gamma^{th} = f(G_F, \alpha_s, \Lambda, \lambda_1, \ldots)$

OPE: Determine Λ, λ_1 from

First Hadronic Moment:

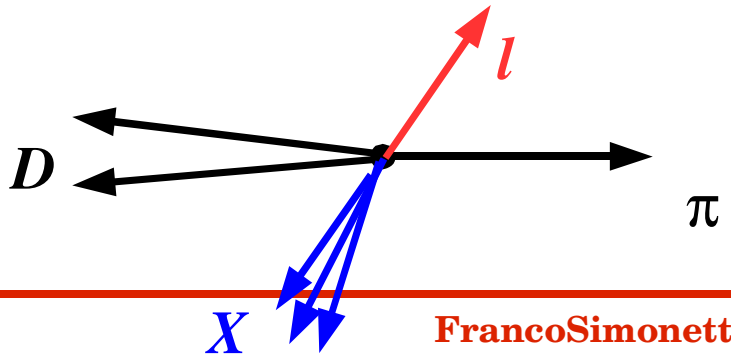
$$H_1 = f_D \langle M^2_D - M^2_{D(spin)} \rangle + f_{D^*} \langle M^2_{D^*} - M^2_{D(spin)} \rangle + f_{D^{**}} \langle M^2_{D^{**}} - M^2_{D(spin)} \rangle$$

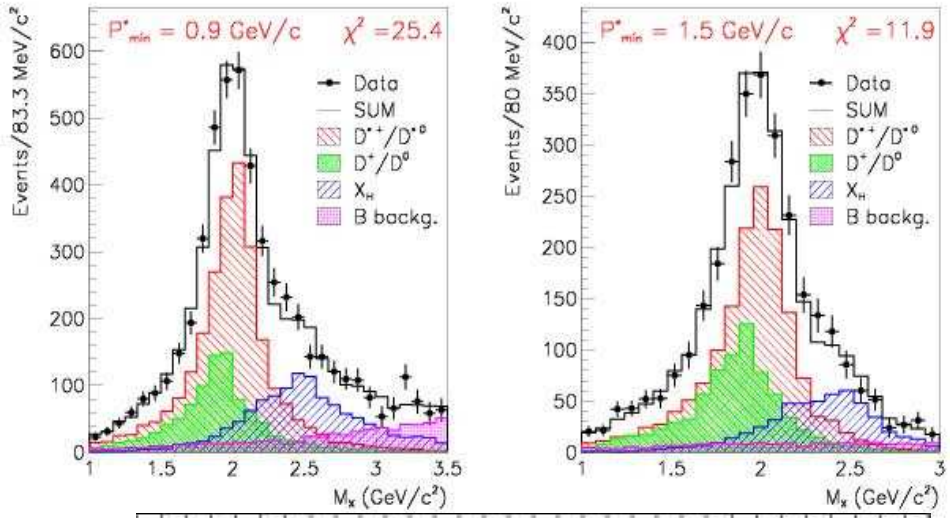
$$M_{D(spin)} = (M_D + 3M_{D^*})/4$$

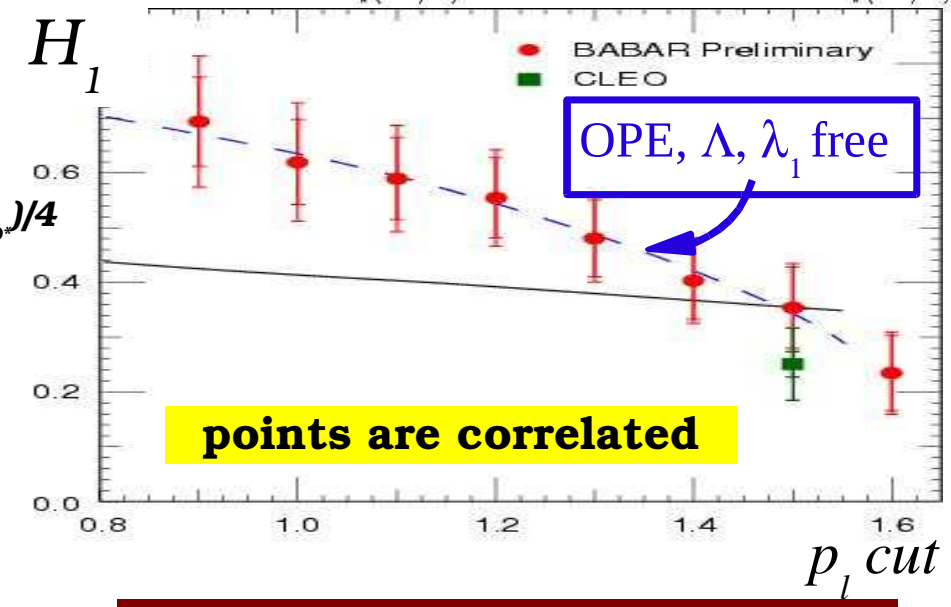
$B_1 \to lX$, $B_2 \to$ *fully reco.*

constrained kinematic fit to M_X

determine f_D , f_{D^*} , $f_{D^{**}}$







Need more x-checks:
higher moments,
lepton spectra …

V_{ub} :inclusive analysis

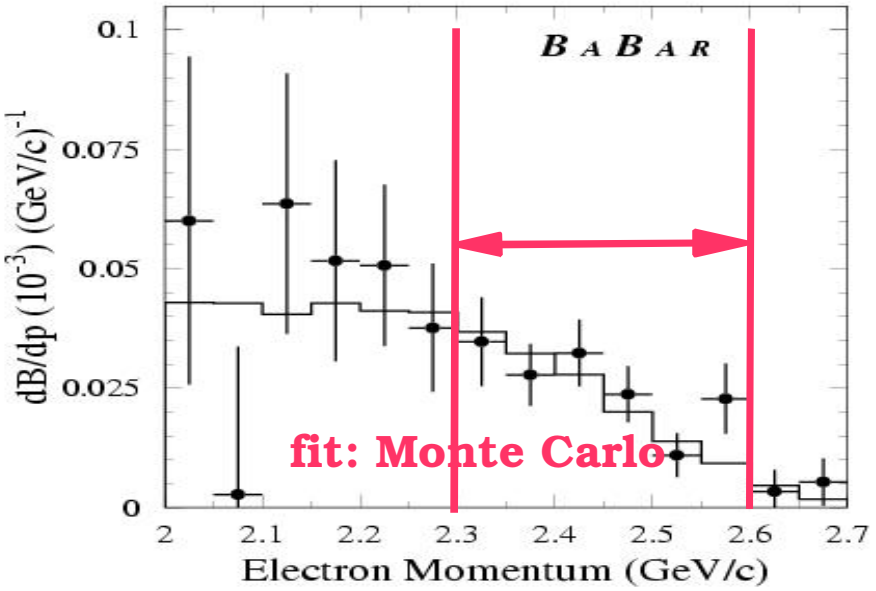
Main problem: $B \to X_c l\nu$ background: $\dfrac{B \to X_u l\nu}{B \to X_c l\nu} \sim 0.01$

Inclusive Analysis:

- p_l above $B \to X_c l\nu$ end point
- acceptance:

$f_u = 0.074 \pm 0.014 \pm 0.009$

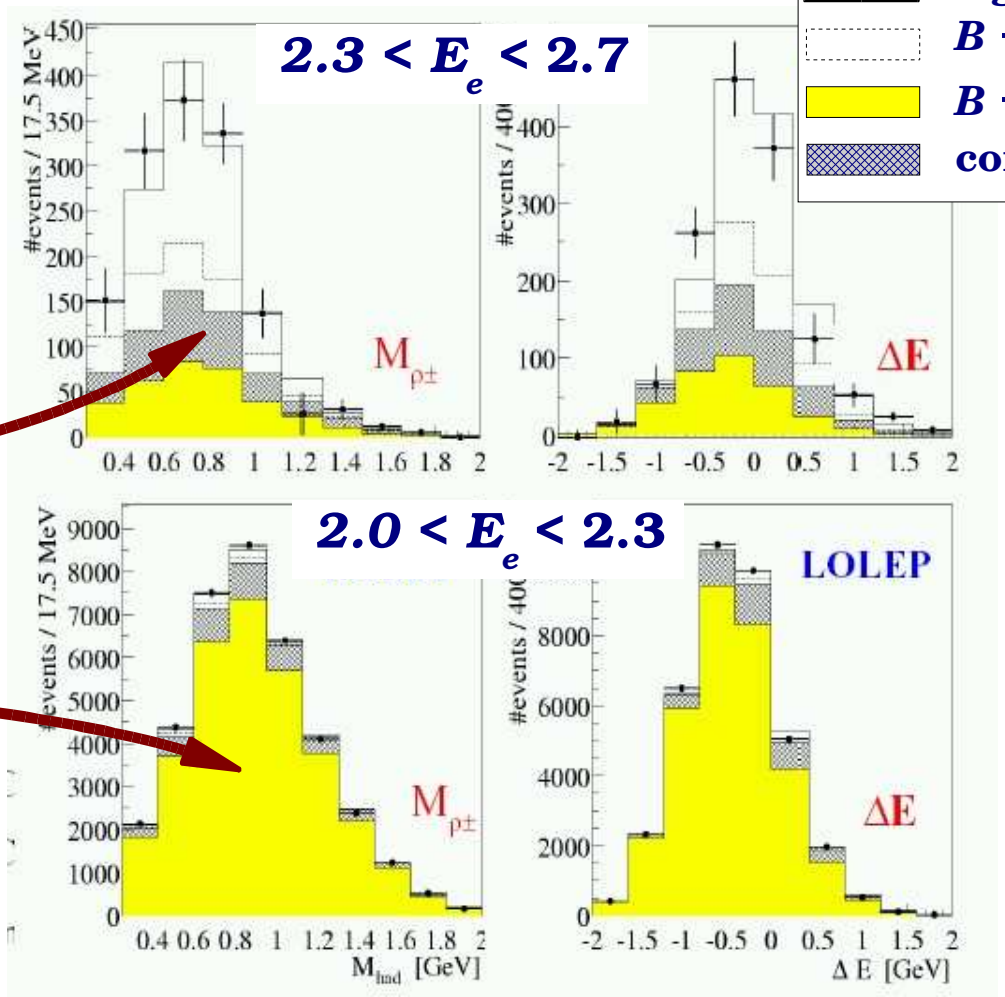
from CLEO $B \to s\gamma$ spectrum



$$|V_{ub}| = (4.43 \pm 0.29_{exp} \pm 0.25_{OPE} \pm 0.50_{fu} \pm 0.35_{s\gamma}) \times 10^{-3}$$

V_{ub} :exclusive $\rightarrow B^{+/0}\ \rho^{0/+} l\nu$

- ***ν* reconstruction**
  - **hermeticity**
- **constraints:**
  - $M_x = M_B,\ M_\nu = 0$
- $B \rightarrow \rho l\nu$:
  - $2.3 < E_e < 2.7$
- $B \rightarrow X_c l\nu$:
  - $2.0 < E_e < 2.3$



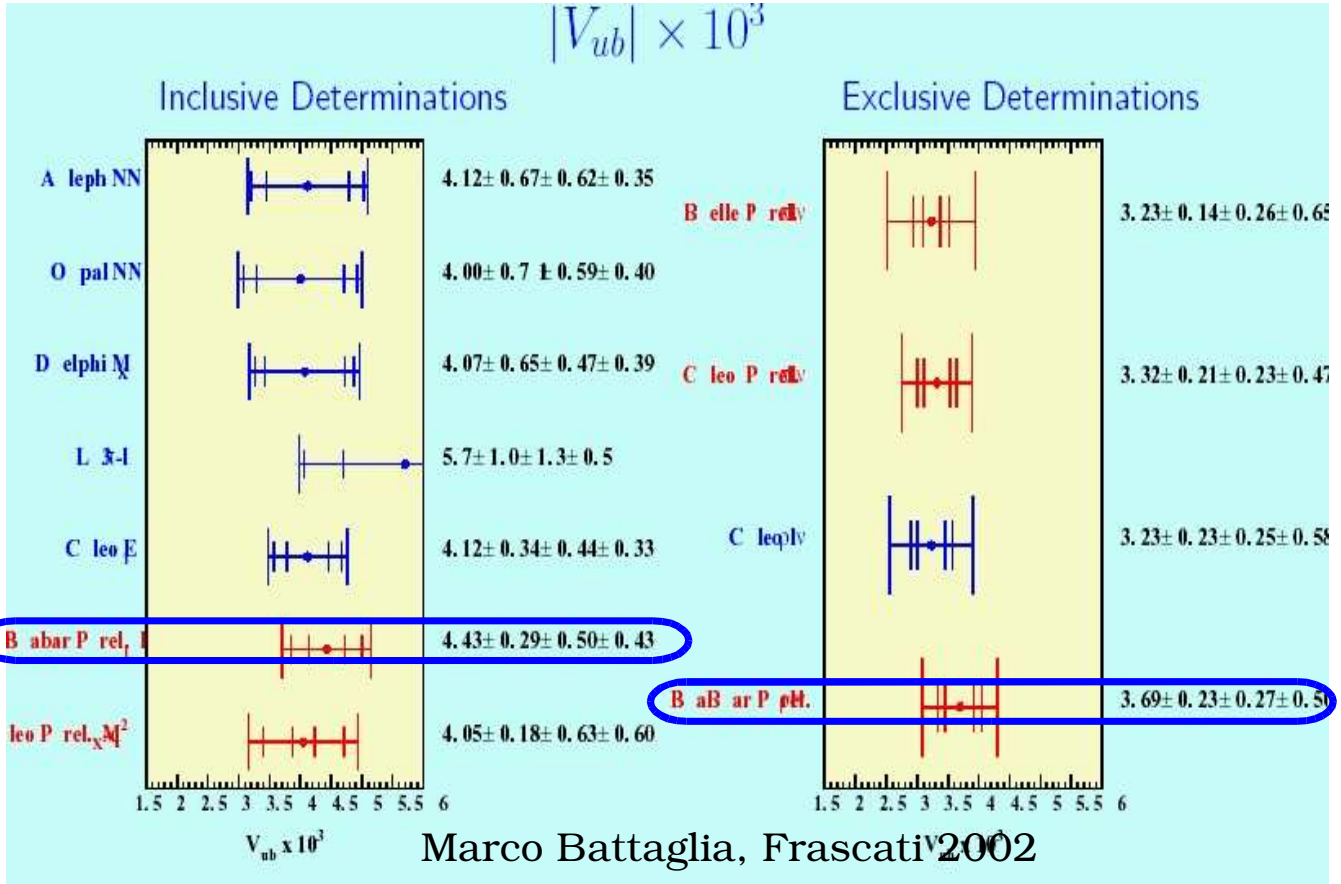
$$|V_{ub}| = (3.64 \pm 0.22_{st.} \pm 0.25_{sys.}\ {}^{+0.39}_{-0.56}{}_{th.}) \times 10^{-3}$$

V_{ub} comparison

BABAR preliminary

$$|V_{ub}|^{incl.} = (4.43 \pm 0.29_{exp} \pm 0.25_{OPE} \pm 0.50_{fu} \pm 0.35_{s\gamma}) \times 10^{-3}$$

$$|V_{ub}|^{excl.} = (3.64 \pm 0.22_{st.} \pm 0.25_{sys.} {}^{+0.39}_{-0.56\ th.}) \times 10^{-3}$$



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Good consistency among experiments

Consistency between incl./excl.techniques ?

Conclusion

- BABar and BELLE push B Physics into high-precision era:
  - **τ,Δm_d, V_{cb} ~ o(%) level**
- V_{td},V_{cb} & V_{ub} are theoretically limited
  - **end of the game ?**
- New experimental handles:
  - **Δm_s (Tevatron only ☹, V_{td} ~1 %)**
  - **lepton & hadron spectra (V_{cb} < 1%)** ☺
  - **more measurement + spectra (V_{ub} ~ 5 %)** ☺
- Much more to come ...