Results on hadronic and semileptonic B decays from BaBar

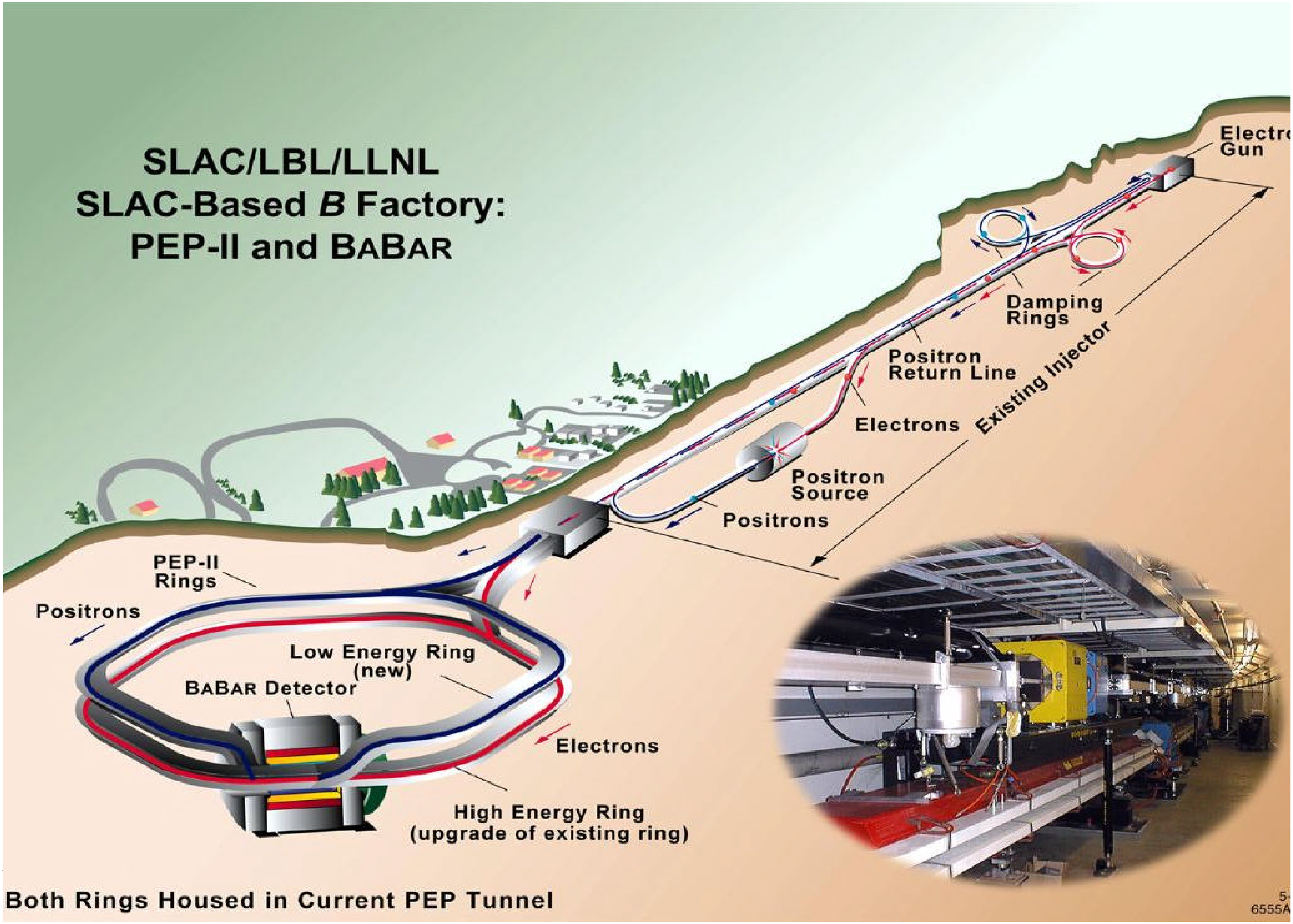
Stefania Xella Hansen

Rutherford Appleton Lab, UK

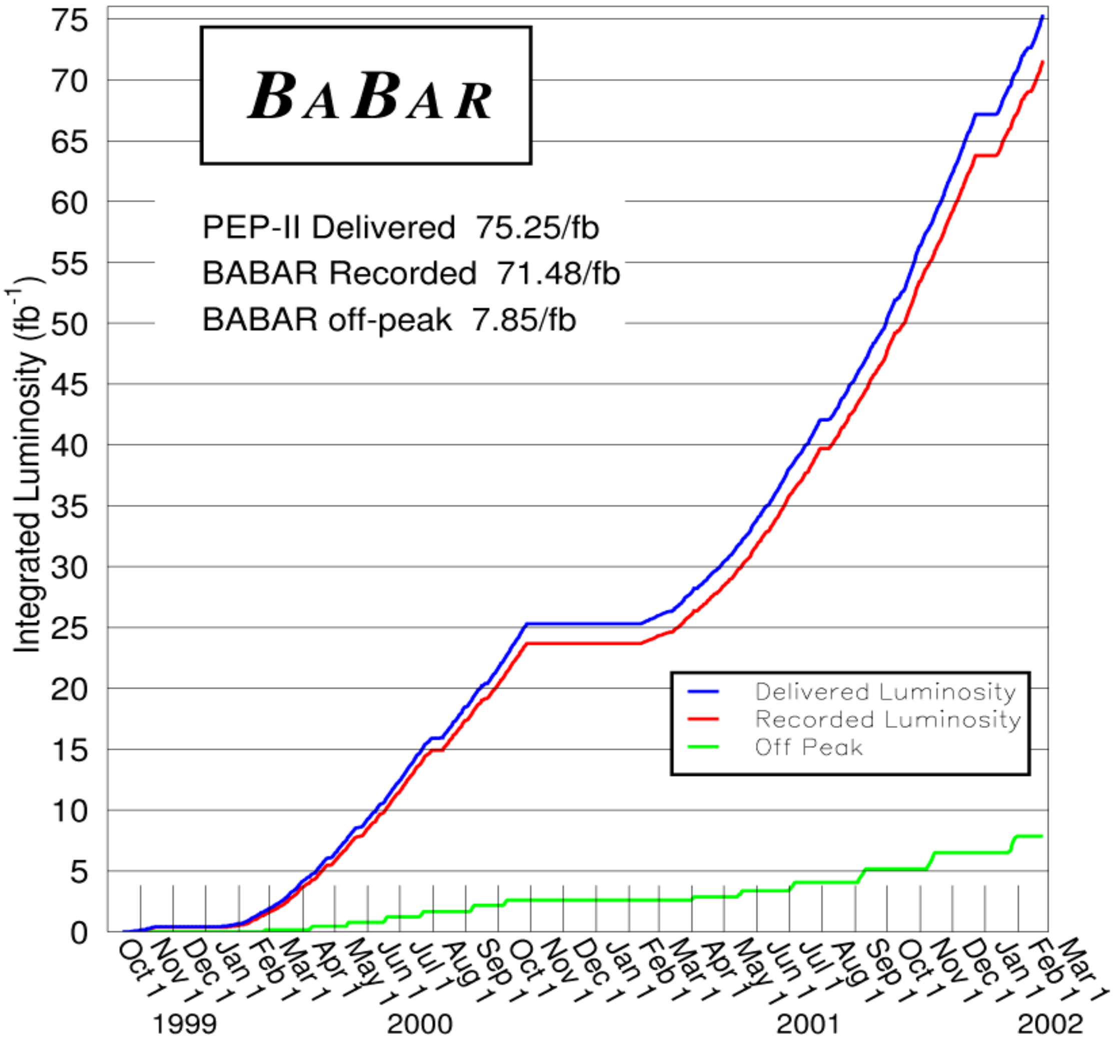
On Behalf of the BaBar Collaboration

March 3-9, 2002

La Thuile, Val d'Aosta


SLAC/LBL/LLNL
SLAC-Based B Factory:
PEP-II and BABAR
Electr
Gun
Damping
Rings
Positron
Return Line
Existing Injector
Electrons
Positron
Source
Positrons
PEP-II
Rings
Positrons
Low Energy Ring
(new)
BABAR Detector
Electrons
High Energy Ring
(upgrade of existing ring)
Both Rings Housed in Current PEP Tunnel
5-
6555A

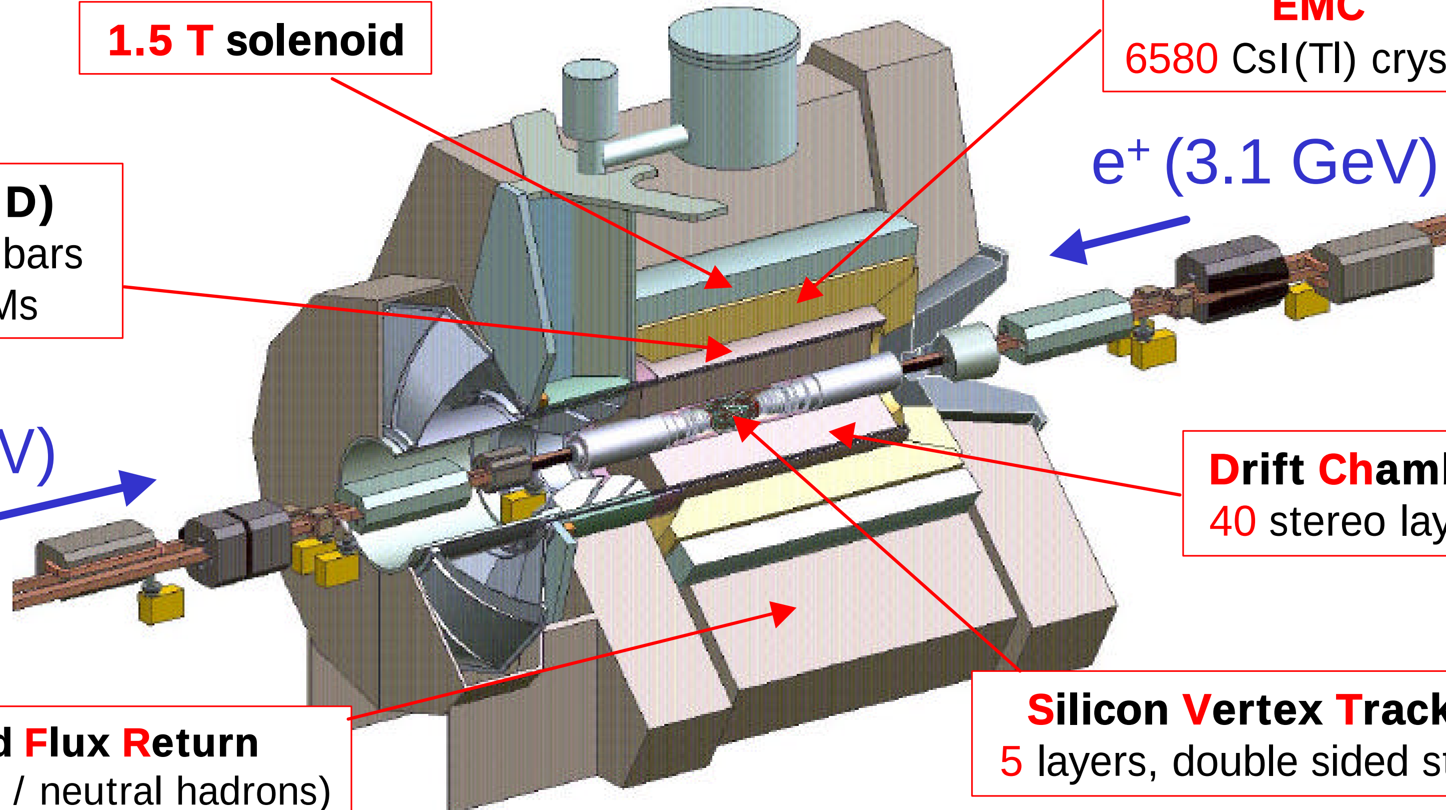
B factory performance



- PEP-II top luminosity: $4.51 \times 10^{33} \mathrm{cm}^{-2}\mathrm{s}^{-1}$ (design 3.0×10^{33})
- Top recorded L/24h: 303.4 pb^{-1}

Analyses shown here use maximum 20/fb (run1+run2)

The BaBar detector



SVT: 97% efficiency, 15 μm z hit resolution (inner layers, perp. tracks)

SVT+DCH: $\sigma(p_T)/p_T = 0.13\ \% \times p_T \oplus 0.45\ \%$, $\sigma(z_0) = 65$ @ 1 GeV/c

DIRC: K-π separation 4.2 σ @ 3.0 GeV/c → 2.5 σ @ 4.0 GeV/c

EMC: $\sigma_E/E = 2.3\ \% \cdot E^{-1/4} \oplus 1.9\ \%$

Physics results presented

Semileptonic B decays

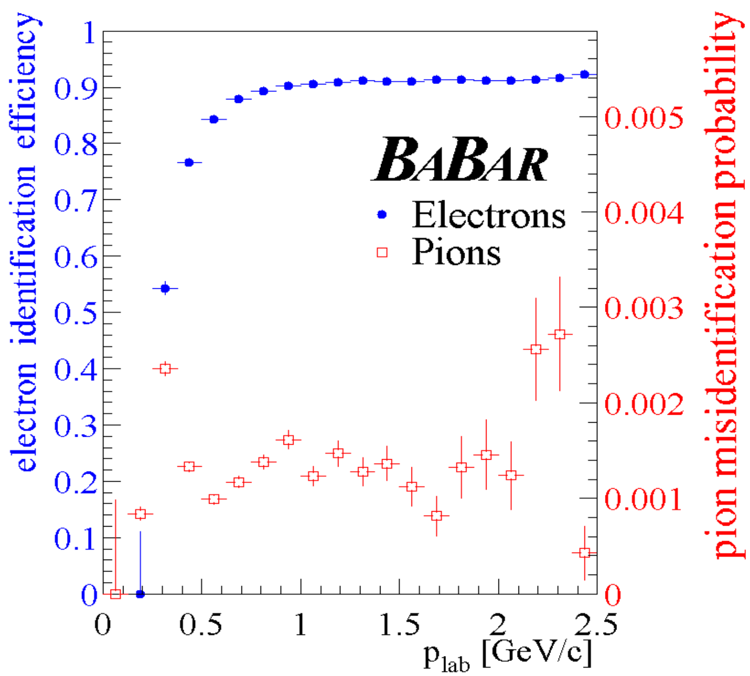
- Measurement of $Br(B^0 \to \rho^- e^+ \nu)$
- Measurement of $|V_{ub}|$
- Measurement of inclusive spectrum and branching ratio
- Measurement of $|V_{cb}|$

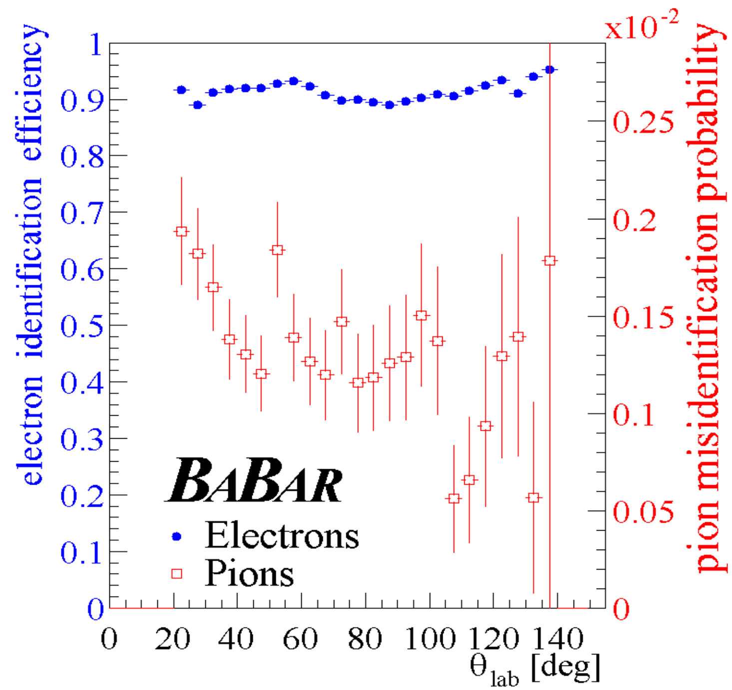
Hadronic B decays

- Measurement of $Br(B^- \to D^0\pi^-)/Br(B^- \to D^0K^-)$
- Measurement of $Br(B^0 \to D^{*+} D^{*-})$ and R_t

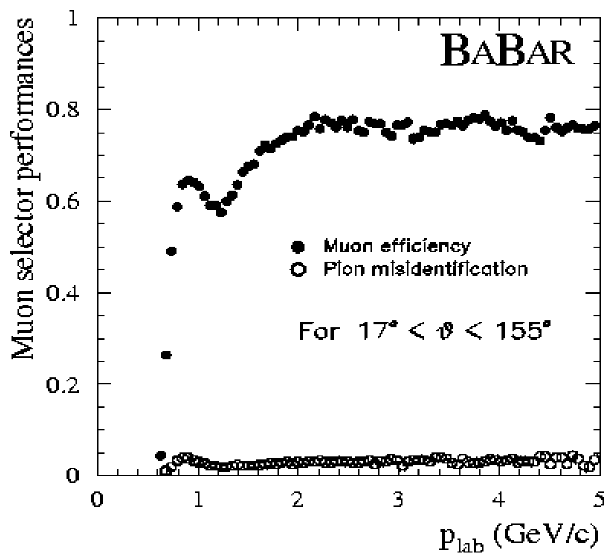
Electron ID in BaBar

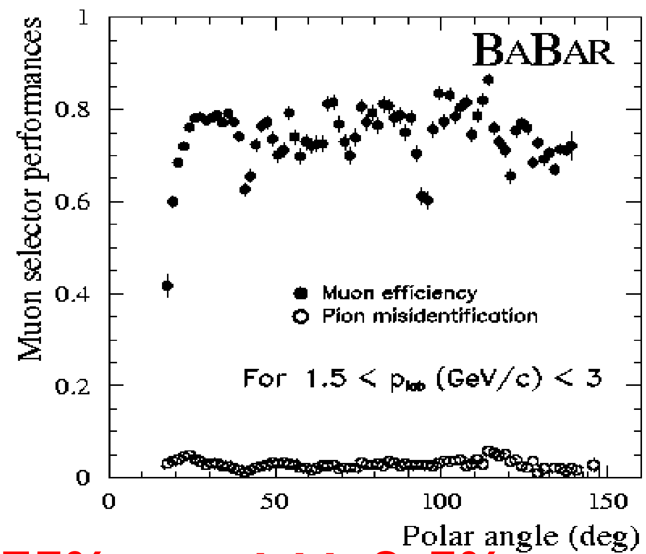
- Electron ID   eff e=91%, π misid=0.13%
  - Match track to EMC cluster
  - 0.89<E/p<1.2
  - EM shower shape requirements
  - dE/dx and DIRC angle consistent with electron hypothesis





Muon ID in BaBar





- **Muon ID**

eff μ=75%, π misid=2.5%

  - **# interaction lenghts in IFR >2.2**
  - **Difference in measured and expected int. Length <1**
  - **Match between extrapolated track and IFR hits**
  - **Requirements on average and spread of # of IFR hits per layer**

$B^0 \rightarrow \rho^- e^+ \nu$

This mode allows to access the CKM element |Vub| rather cleanly, wrt to an inclusive B->$X_u e\nu$ analysis, where strong interactions have a big impact

The theoretical challenge for the extraction of Vub is the calculation of the form factors describing the spectrum of the decay

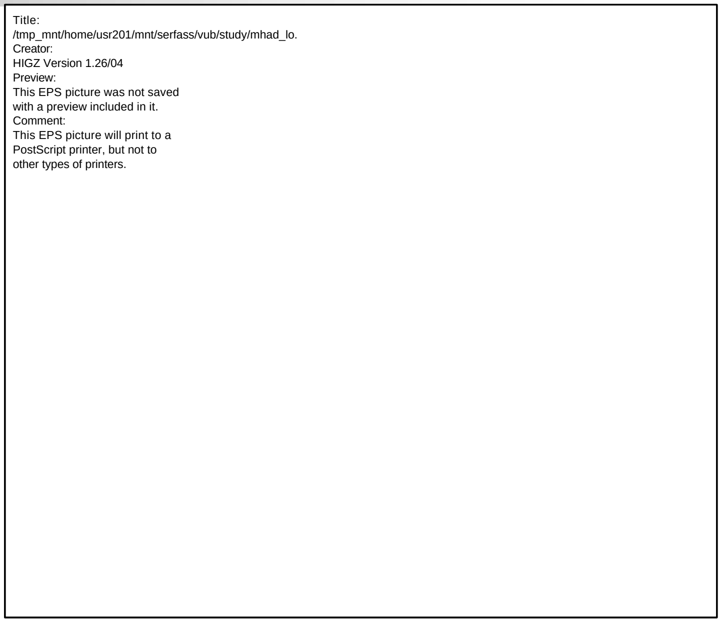
The experimental challenge is the rather large background, from $b \rightarrow c$ in E_{lept}<2.35 GeV and from continuum in E_{lept}>2.35 GeV

For this reason, analysis split in two energy ranges:

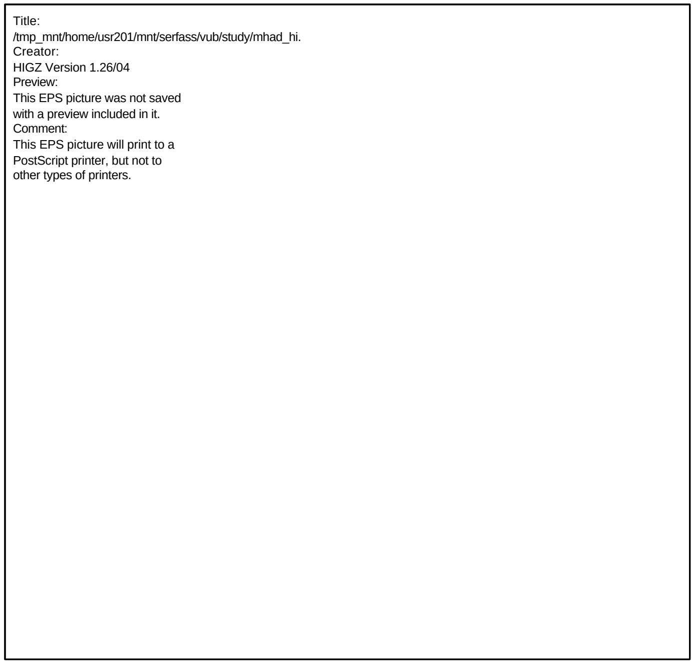
HILEP 2.35GeV<E*e<2.7GeV
LOLEP 2.0GeV<E*e<2.35GeV

$B^0 \rightarrow \rho^- e^+ \nu$

LOLEP



Analysis based on the 1999-2000 statistics:
20.2 fb^{-1} (on peak) and 2.6 fb^{-1} (off peak)



HILEP

2-dim extended maximum likelihood fit on data on and off peak and on MC data on HILEP,LOLEP and on the 5 channels (ρ^+,ρ^0, ω, π^0,π^+) in the variables ΔE=Ehad+Ee+|pν|-Ebeam (with |pν|~p miss), or M($\pi\pi$)/M($\pi\pi\pi$)

9 free parameters, among which Br($B^0 \rightarrow \rho e \nu$),Br($B^0 \rightarrow \pi e \nu$)

$B^0 \rightarrow \rho^- e^+ \nu$

Title:
/tmp_mnt/home/usr201/mnt/serfass/vub/study/q2_hi.ep
Creator:
HIGZ Version 1.26/04
Preview:
This EPS picture was not saved
with a preview included in it.
Comment:
This EPS picture will print to a
PostScript printer, but not to
other types of printers.

Results of the fit:

$Br(B^0 \rightarrow \rho e \nu) = (2.97 \pm 0.56)\ 10^{-4}$

$Br(B^0 \rightarrow \pi e \nu) = (0.34 \pm 1.02)\ 10^{-4}$

Systematics about 16%, main contribution from data cuts and background b->u description

The results need to be extrapolated to the full energy range for leptons (using a theoretical model, hence introducing a theory dependent uncertainty)

$$Br(B0 \rightarrow \rho\text{-}e+\ \nu) = (3.26 \pm 0.65(\mathrm{stat})^{+0.63}_{-0.65}(\mathrm{syst})\ \pm 0.33(\mathrm{theo}))\ 10^{-4}$$

$$|V_{ub}| = (3.57 \pm 0.36^{+0.33}_{-0.38} \pm 0.60)\ 10^{-3}$$

$B \to Xe\nu$

Inclusive Semileptonic B decays provide a straight forward way to measure the coupling to the charged weak current via V_{cb}

Theory prediction for branching ratio does not reproduce the measured values. Any other precise measurement of this inclusive Br is most valuable

Tag electron

Signal electron

N. of tagged events

Incl B secondaries spectrum

$$dN(t\pm e\mp)/dp^* = \varepsilon(p^*)\ Te\ (dB_b/dp^*(1-f^0\chi^0) + dB_c/dp^*\ f^0\chi^0 + dBc/dp^*{}_{same})$$

$$dN(t\pm e\pm)/dp^* = \varepsilon(p^*)\ Te\ (dB_b/dp^*\ f^0\chi^0 + dB_c/dp^*\ (1-f^0\chi^0)$$

Inclusive B semilept spectrum !

e from Btag decay

A measurement of like & un-like sign ee pairs gives model independent measurement of inclusive B semileptonic spectrum

$B \to Xe\nu$

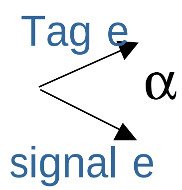
Analysis based on the 1999-2000 statistics: 4.13 fb^{-1} (on peak) and 1 fb^{-1} (off peak)

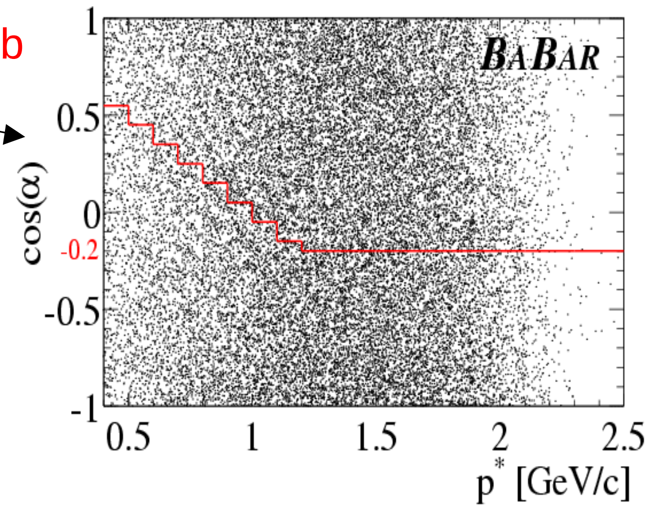
- tag electron 1.4 GeV<p*<2.3GeV
- signal electron p*>0.4 GeV

+ $\cos\alpha > -0.2$ & $\cos\alpha + p^* > 1.0$

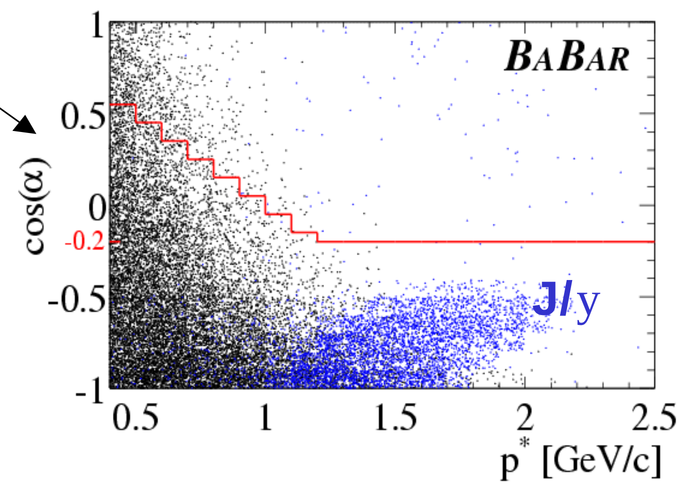
- average efficiency 54.5%

e from primary b decay





To remove
e from secondary
decay of Btag



Backgrounds are

. $\gamma \to e^+e^-$, $\pi^0 \to \gamma e^+e^-$, $J/\psi \to e^+e^-$

. Misidentified hadrons

. Cascades producing right-sign electrons

$B \to X \tau^+ \nu_\tau$, $\tau^+ \to e^+ \nu_e \nu_\tau$

$B \to D^+_s D$, $D^+_s \to X' e^+ \nu_e$

$B \to D^{(*)} D^{(*)} K$, $D \to X' e^+ \nu_e$

. mistagged events

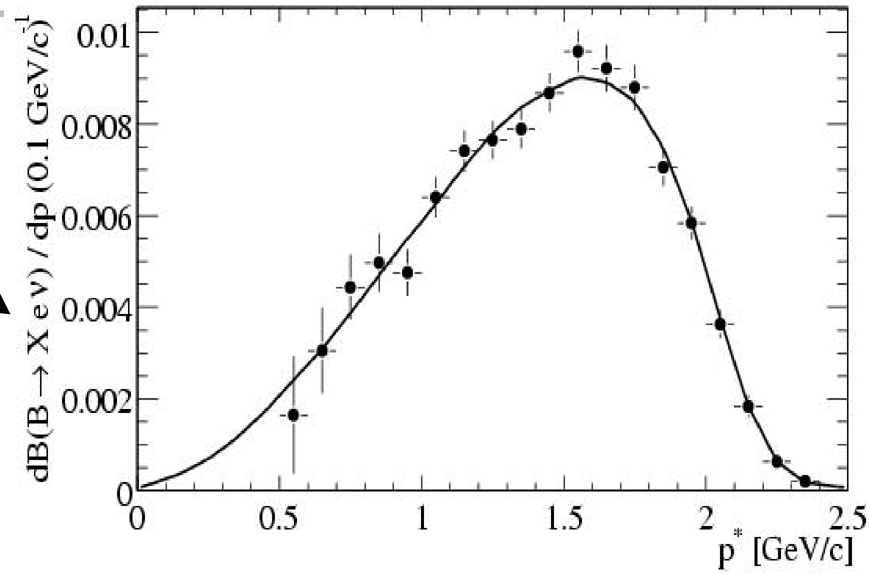
$B \to Xe\nu$

Fully corrected electron spectrum

$Br(B \to X\, e\, \nu)$ =

$(10.82 \pm 0.21_{stat} \pm 0.38_{sys})\,\%$

Systematics dominated by unknown $c\bar{c}s$ cascade Br



$$|V_{cb}| = 0.0411 \left(\frac{Br(B \to X_c\, e\, n)}{0.105} \; \frac{1.55\, ps}{t_B} \right)^{1/2} (1.0 \pm 0.015_{pert} \pm 0.010_{m_b} \pm 0.012_{1/m_Q^3}) \quad [1]$$

With PDG - value for τ_B and $Br(B \to X_u\, e\, \nu) = (1.7 \pm 0.5) \times 10^{-3}$:

$|V_{cb}| = 0.0408 \pm 0.0004_{stat} \pm 0.0008_{sys} \pm 0.0020_{theory}$

[1] See Bigi, Shifman, Uraltsev, Ann. Rev. Nucl. Part. Science 47 (1997) 591.

Hadronic B decays

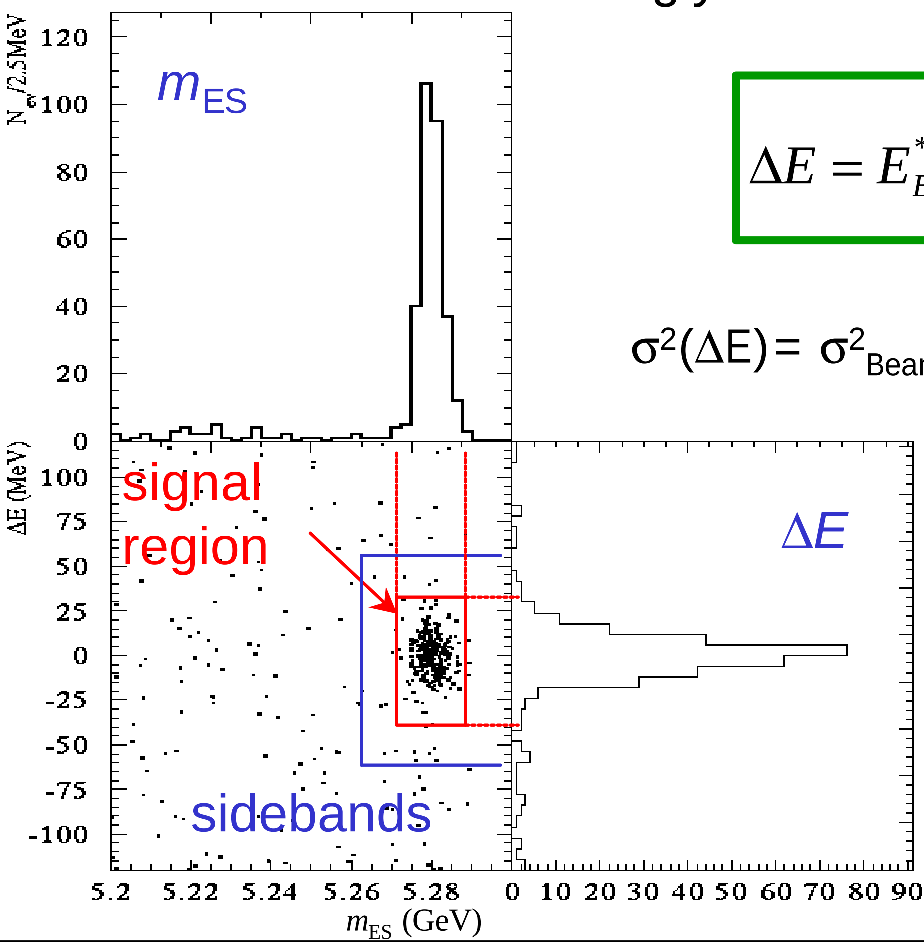
In the hadronic exclusive reconstruction,two higly uncorrelated kinematic variables are used

$$\Delta E = E_B^* - \frac{\sqrt{s}}{2}$$

$$m_{ES} = \sqrt{\frac{s}{4} - p_B^{*\,2}}$$

$\sigma^2(\Delta E) = \sigma^2_{Beam} + \sigma^2_E \sim \sigma^2_E$

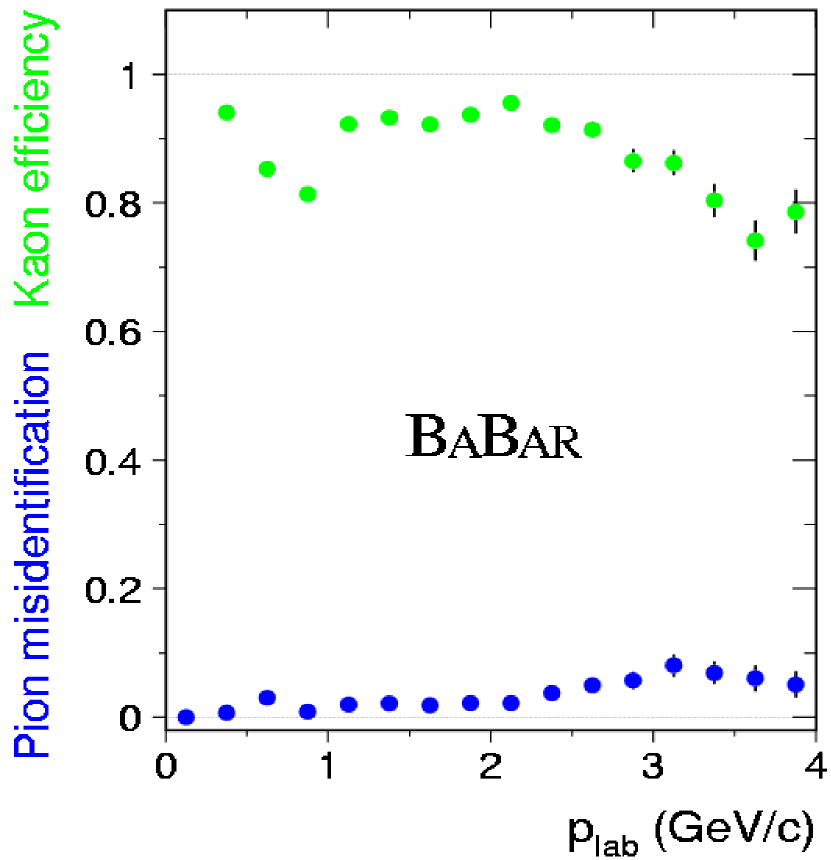
$\sigma^2 m_{ES} = \sigma^2_{Beam} + (p/m_B)^2 \sigma^2_p \sim \sigma^2_{Beam}$



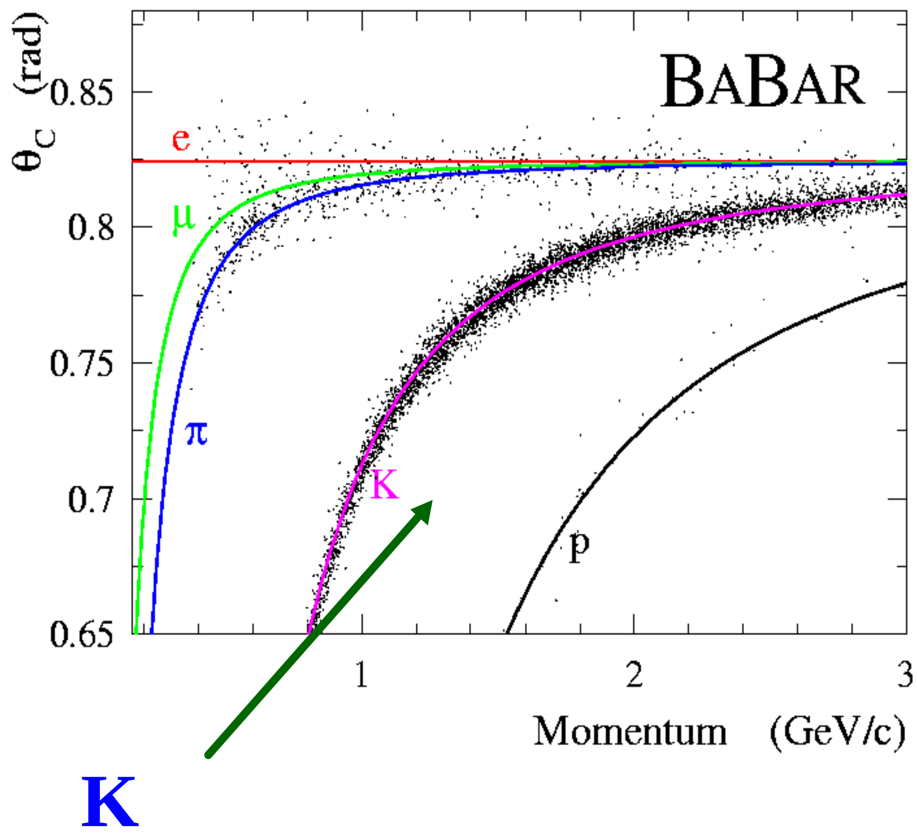
- A *signal region* is defined around the central value of ΔE and m_{ES} (2.5 or 3 σ) to extract the signal yield
- *Sidebands* are defined outside the signal region in order to estimate background contribution

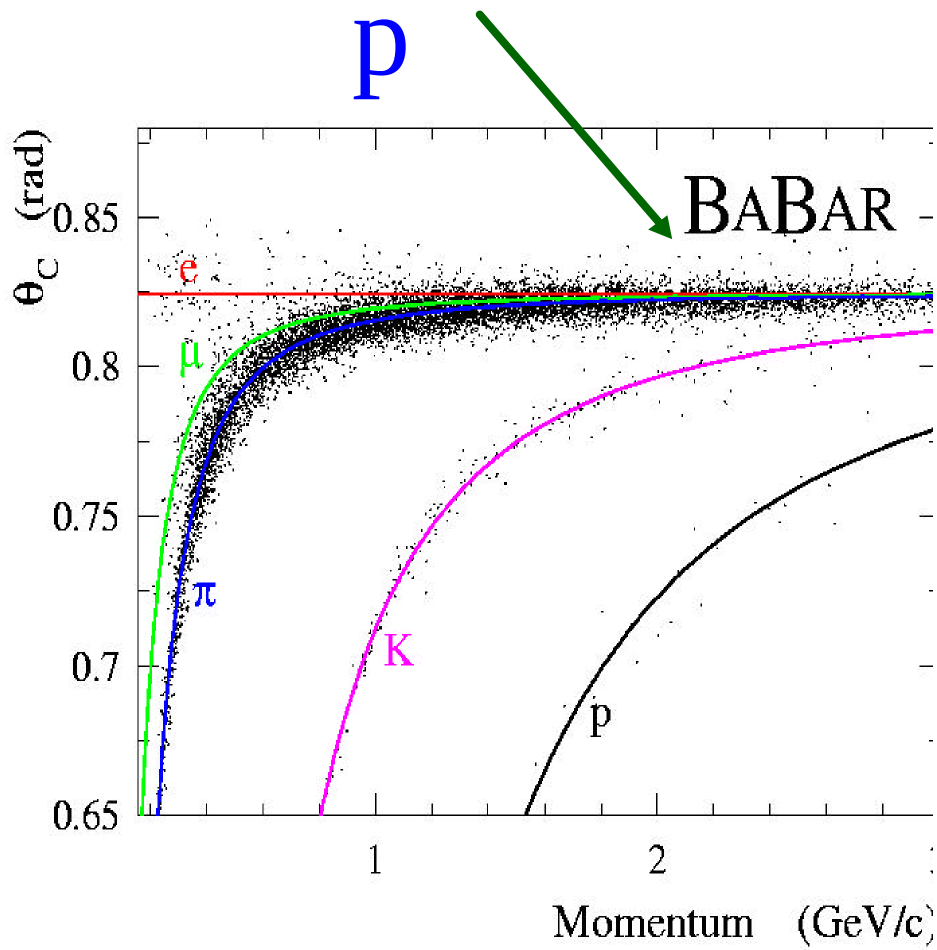
Kaon ID in BaBar

- **Kaon ID** **effK=85%, p misid=5%**
  - **NN based on likelihood ratios in DCH and SVT (dE/dx), and in DIRC (compare single hits with expected pattern of cherenkov light)**
  - **>3s K/p separation @ 0.25<p<3.4GeV**



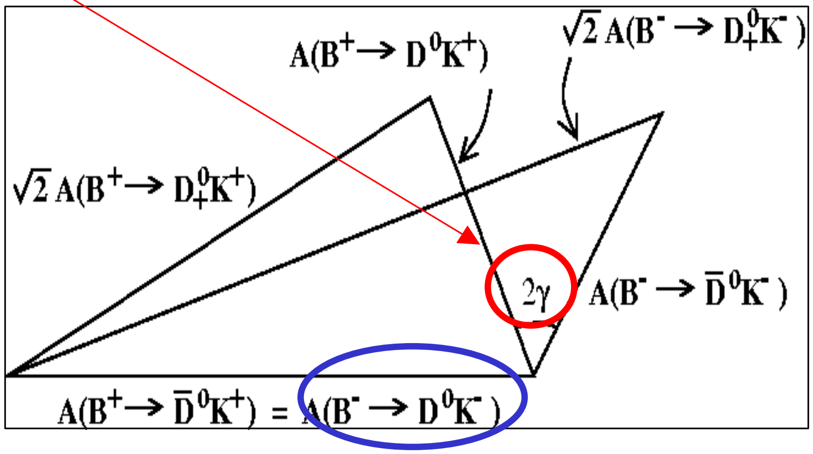
Cherenkov angles for π and K





$Br(B^- \to D^0 K^-)$ / $Br(B^- \to D^0 \pi^-)$

$Br(B^- \to D^0 K^-)$ is an ingredient of a number of methods proposed to extract the CKM angle γ in a theoretically clean way



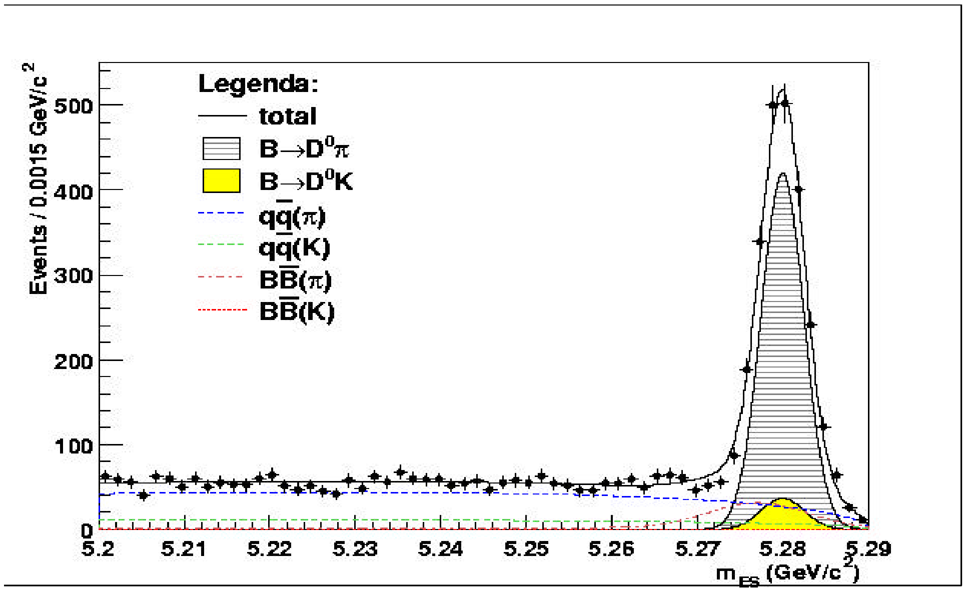
Measurement of
$Br(B^- \to D^0 K^-)$ / $Br(B^- \to D^0 \pi^-)$
allows a precise measurement of $Br(B^- \to D^0 K^-)$

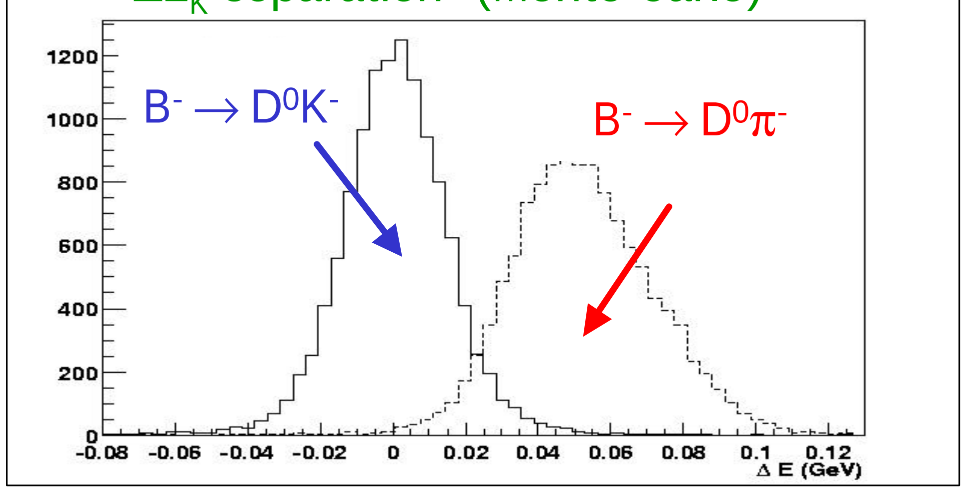
$Br(B^- \to D^0 K^-)$ / $Br(B^- \to D^0 \pi^-)$

Analysis based on the 1999-2000 statistics:

20.7 fb^{-1} (on peak) + 2.62 fb^{-1} (off peak)

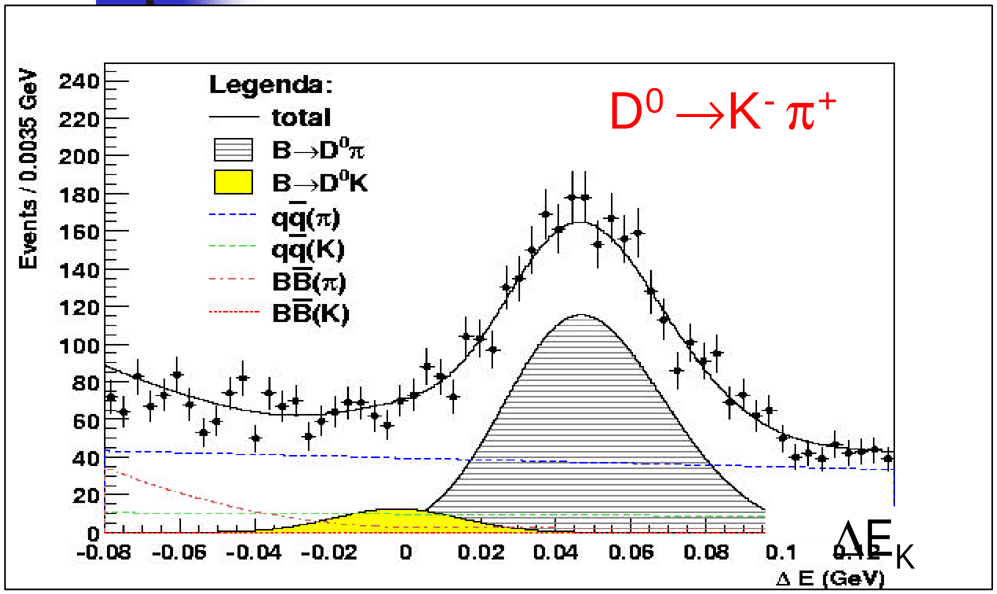
- D^0 is selected in the modes: $D^0 \to K\pi$, $D^0 \to K3\pi$, $D^0 \to K\pi\pi^0$
- No PID required on bachelor h-
- ΔE is calculated assigning the Kaon mass to the prompt track

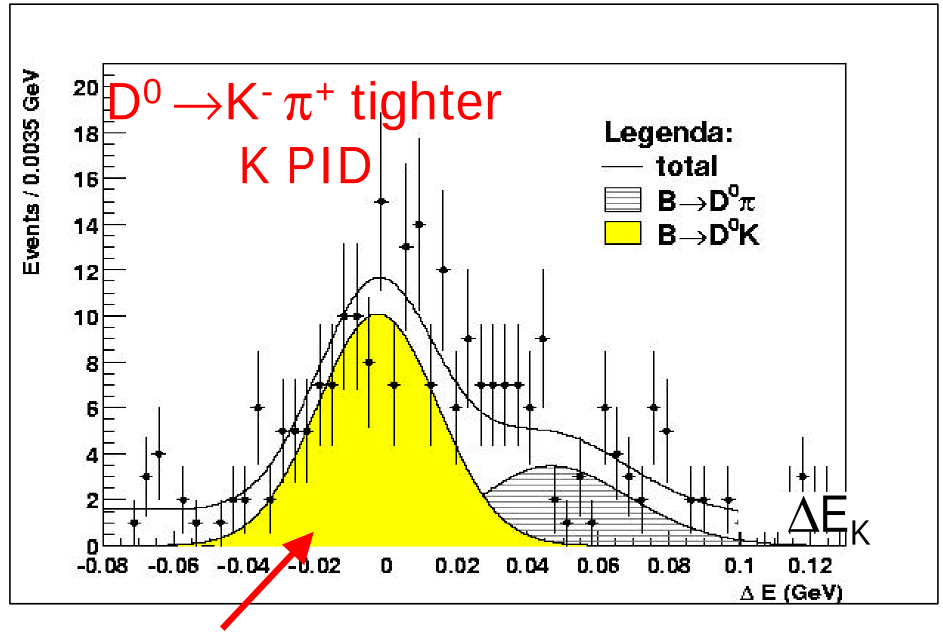




- N_{DK}, $N_{D\pi}$ and the background extracted with a unbinned maximum likelihood fit
- Likelihood function depends on ΔE_K, m_{ES} and Θ_C information from DIRC

$Br(B^- \to D^0 K^-) / Br(B^- \to D^0 \pi^-)$





The presence of the signal $B \to D^0K^-$ is evident when a Kaon PID requirement is applied to the prompt track ("h")

Averaging over the three D^0 modes:

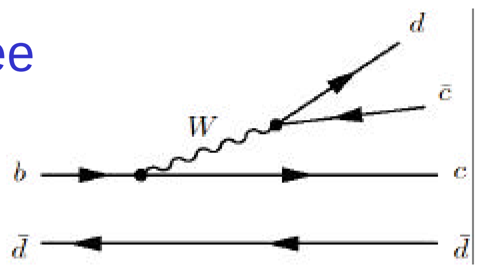
$$R = BR(B^- \to D^0 K^-) / BR(B^- \to D^0 \pi^-) = (8.3 \pm 0.6 \pm 0.3)\%$$

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

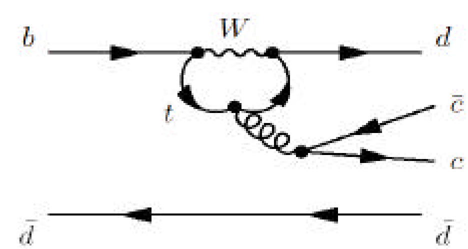
This channel can be used to measure CP violation (sin2β).

Several extensions to the SM predict possible different CP asymmetry in this channel and in the charmonium one, so this decay is most valuable for performing stringent tests of CP in the SM.

Tree



Penguin



But $D^{*+}D^{*-}$ is a mixture of P-even and P-odd components (A_0, $A_{||}$, $A_\perp$), so the CP asymmetry is diluted. One needs to measure:

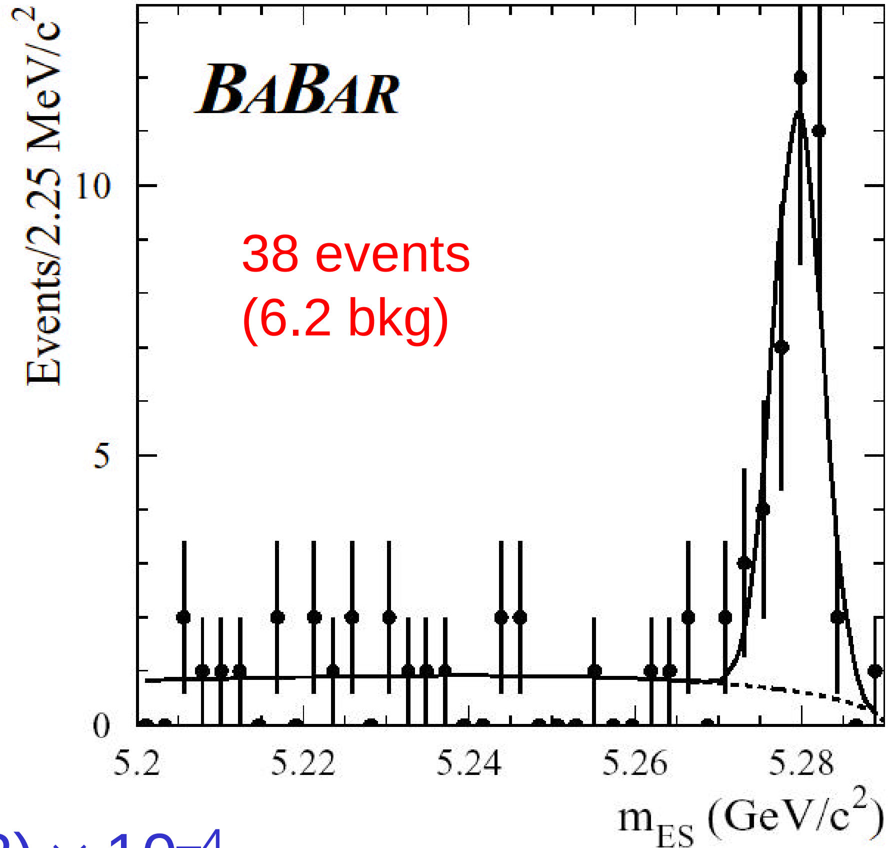
$$R_t \equiv \frac{|A_\perp|^2}{|A_0|^2 + |A_\parallel|^2 + |A_\perp|^2}$$

which tells how much P-odd component exists. This is done via angular analysis

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

Analysis based on the 1999-2000 statistics:
20.7 fb^{-1} (on peak) + 2.4 fb^{-1} (off peak)

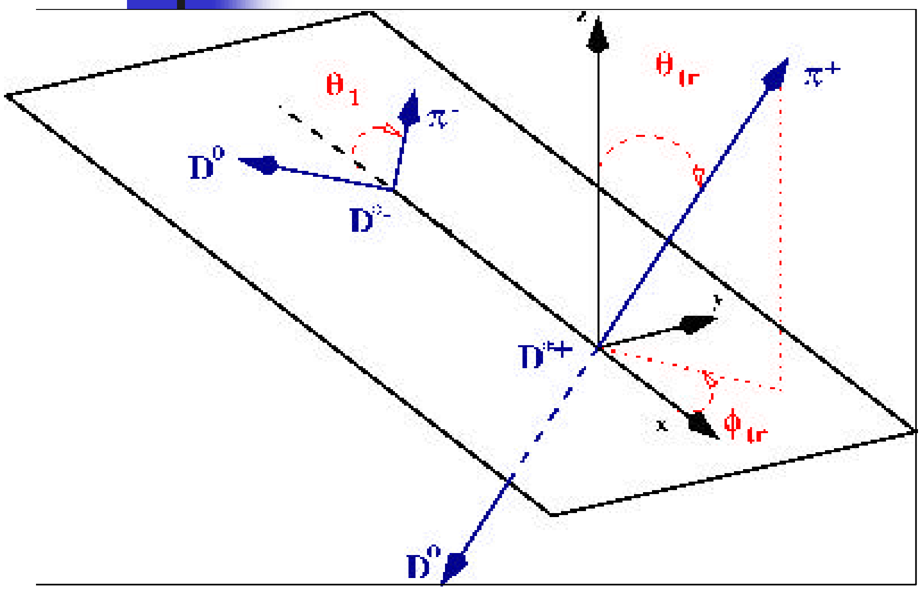
- D^* reconstructed via $D^0 \pi$ and $D \pi^0$
- D reconstrcuted via $K\pi, K2\pi, K3\pi, K\pi\pi^0$
- signal box defined as
  $|\Delta E| < 25$MeV
  and
  $5.273\ GeV/c^2 < M_{es} < 5.285\ GeV/c^2$



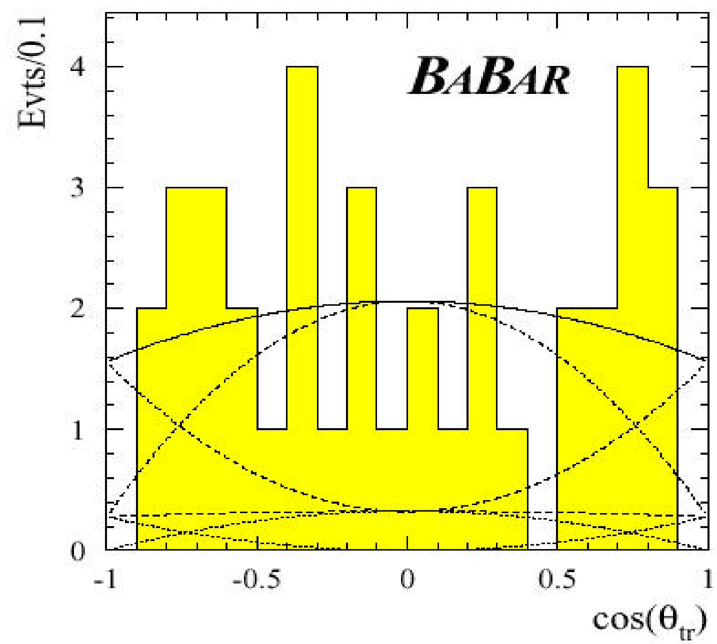
Main systematic:
Tracking efficiency (9.4%)

$$Br(B^0 \to D^{*+} D^{*-}) = (8.3 \pm 1.6 \pm 1.2) \times 10^{-4}$$

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



$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_{tr}} = \frac{3}{4}(1-R_t)\sin^2\theta_{tr} + \frac{3}{2}R_t\cos^2\theta_{tr}$$



An unbinned maximum likelihood fit is performed to the 38 found signal events. Background description from sidebands. θ_{tr} distribution from MC

$R_t = 0.22 \pm 0.18 \pm 0.03$

Summary of results

From semileptonic B decays

$Br(B0\text{-}> \rho\text{-}e+ \nu)=(3.26\pm0.65(stat)^{+0.63}_{-0.65}(syst)\ \pm0.33(theo))\ 10^{-4}$

$|Vub| = (3.57 \pm 0.36^{+0.33}_{-0.38}\pm0.60)\ 10^{-3}$

$Br(B\rightarrow X\ e\ \nu) = (10.82 \pm0.21_{stat}\pm0.38_{sys})\%$

$|V_{cb}| = 0.0408 \pm0.0004_{stat} \pm0.0008_{sys} \pm 0.0020_{theory}$

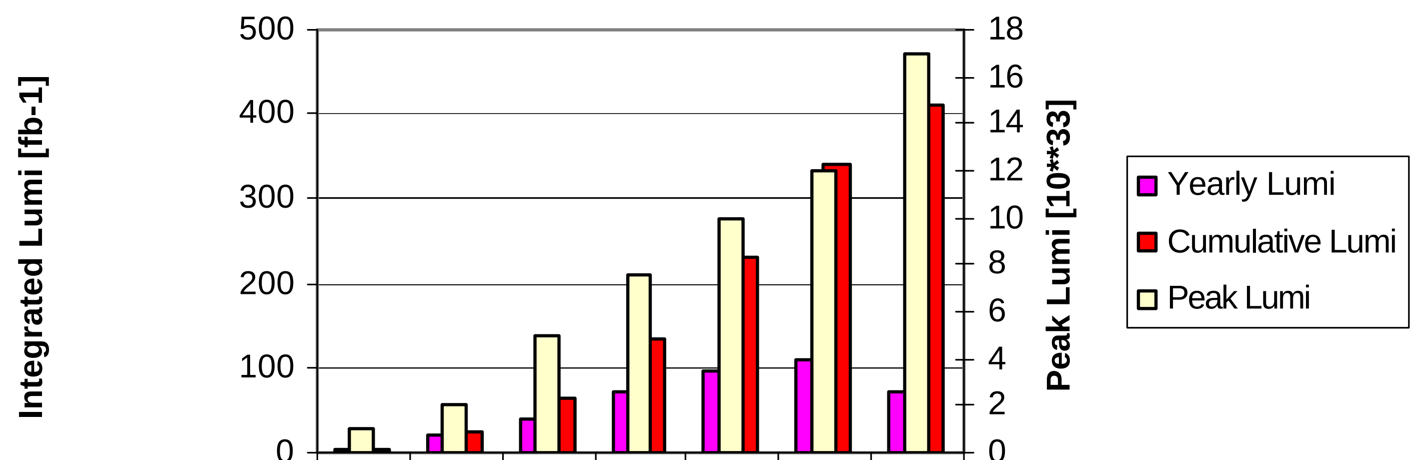
From hadronic B decays

$R=BR(B^-\rightarrow D^0\ K^-)/\ BR(B^-\rightarrow D^0\ \pi^-) = (8.3 \pm 0.6 \pm 0.3)\%$

$Br(B^0 \rightarrow D^{*+}D^{*-}) = (8.3 \pm 1.6 \pm 1.2) \times 10^{-4}$

$R_t = 0.22 \pm 0.18 \pm 0.03$

Luminosity Plans for BABAR & PEP II



	1999	2000	2001	2002	2003	2004	mid 2005
Yearly Lumi	2	23	40	70	95	110	70
Cumulative Lumi	2	25	65	135	230	340	410
Peak Lumi	1	2	5	7.5	10	12	17

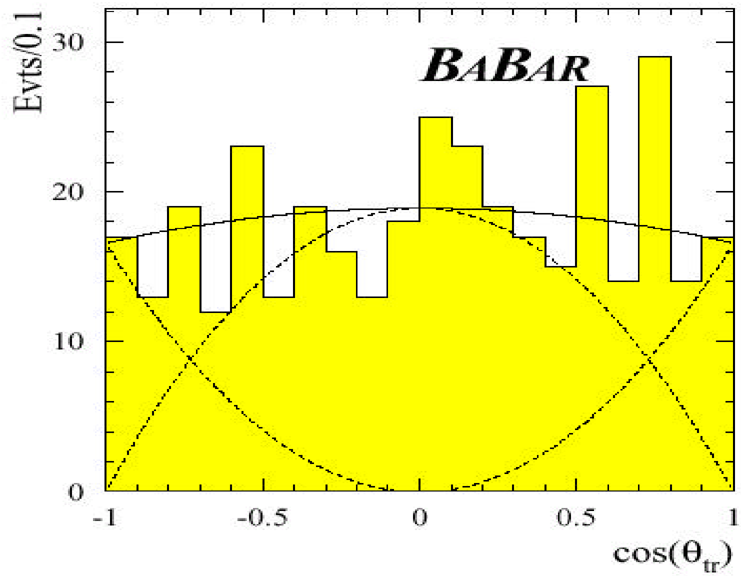
Year

$Br(B^- \to D^0 K^-)$ / $Br(B^- \to D^0 \pi^-)$

effic	$D^0 \to K\pi$	$D^0 \to K3\pi$	$D^0 \to K\pi\pi^0$
$D^0 \pi^-$	49.2 0.5	17.4 0.4	10.2 0.3
$D^0 K$	48.1 0.7	16.8 0.4	10.1 0.3

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

$R_t^{(bkg)} = 0.29 \pm 0.04$



Events from sidebands
Are giving a value compatible with
flat distribution Rt=1/3