Semileptonic Branching Ratios and Moments

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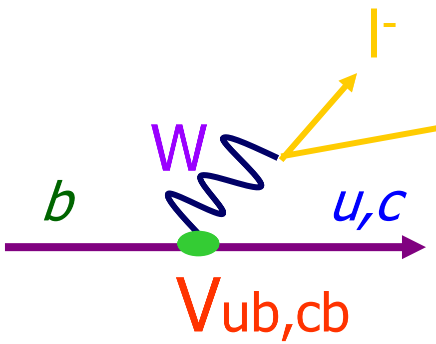
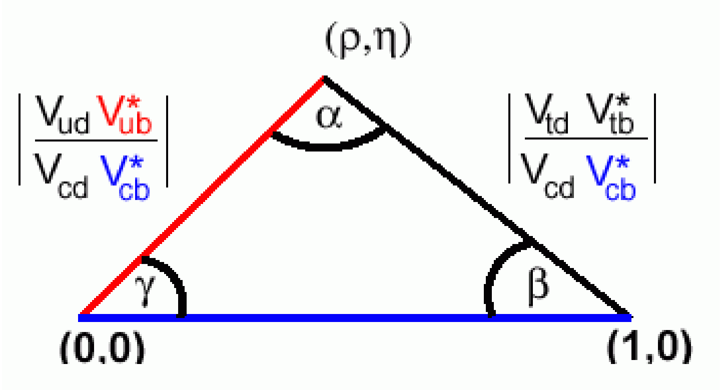
Motivations

- semileptonic decays are
  - relatively simple theoretically at parton level
  - accessible experimentally
  - sensitive to quark couplings to $W^{\pm}$
    (i.e. CKM matrix elements $|V_{ub}|$ and $|V_{cb}|$)
  - probe the dynamics of the decay
  - probe the impact of strong interactions



- two possible approaches
  - exclusive measurements
    - need form-factors to describe the transition of the B meson to a lighter one
  - inclusive measurements
    - need OPE and b-quark mass to extract $|V_{xb}|$ from the total rate



Target

in naïve spectator picture the process is analogous to muon decay

$$\Gamma(b \to ul\overline{\nu}, cl\overline{\nu}) \approx \frac{G_F^2 m_b^5}{192\pi^3} \left|V_{ub,cb}\right|^2 \Rightarrow f(\text{parameters}) \times \left|V_{ub,cb}\right|^2$$

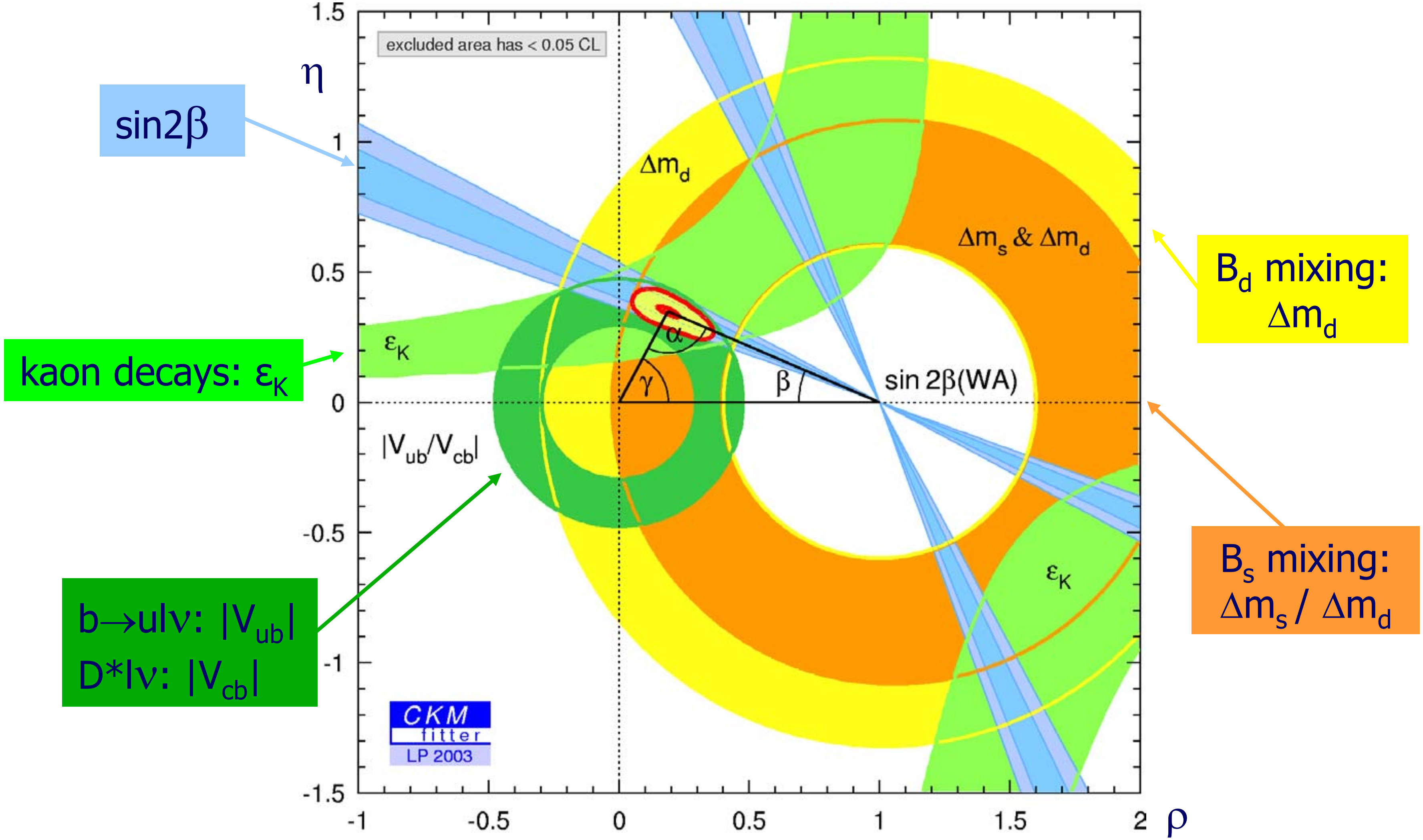
but QCD (perturbative and non-perturbative) corrections are needed to extract weak decay physics

comparison of results from different measurements provides a test of the consistency of OPE predictions and of underlying assumptions

use many different approaches/techniques

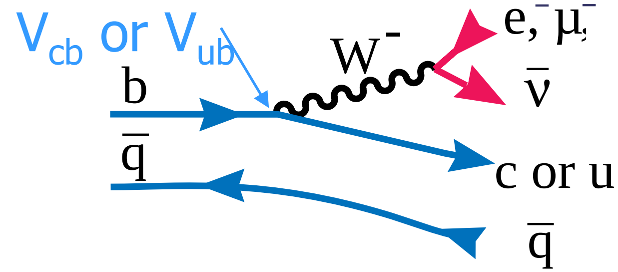
CKM'02 @ CERN

Framework



measurements of $|V_{ub}|$ and $|V_{cb}|$ provide stringent tests of the unitarity triangle

Outline



- exclusive measurements
  - BR($B\to\rho e\nu$) [BaBar]
  - BR($B\to\pi l\nu$), BR($B\to$"ρ"$l\nu$), BR($B\to\omega l\nu$) [BaBar, Belle, Cleo]
  - BR($B\to D^* l\nu$) [BaBar]
  - BR($B\to\pi l\nu$) [Cleo]
  - BR($B\to D^{**0} l\nu X$) [Opal]

far too much interesting material to include in 20 min [apologies in advance]

- inclusive measurements
  - $<M_x^n>$, $<E_l^n>$ in $B\to X_c l\nu$ [BaBar, Cleo, Delphi]
  - BR($B\to X_u l\nu$) [BaBar]
  - ΔBR($B\to X_u l\nu$) [Belle]

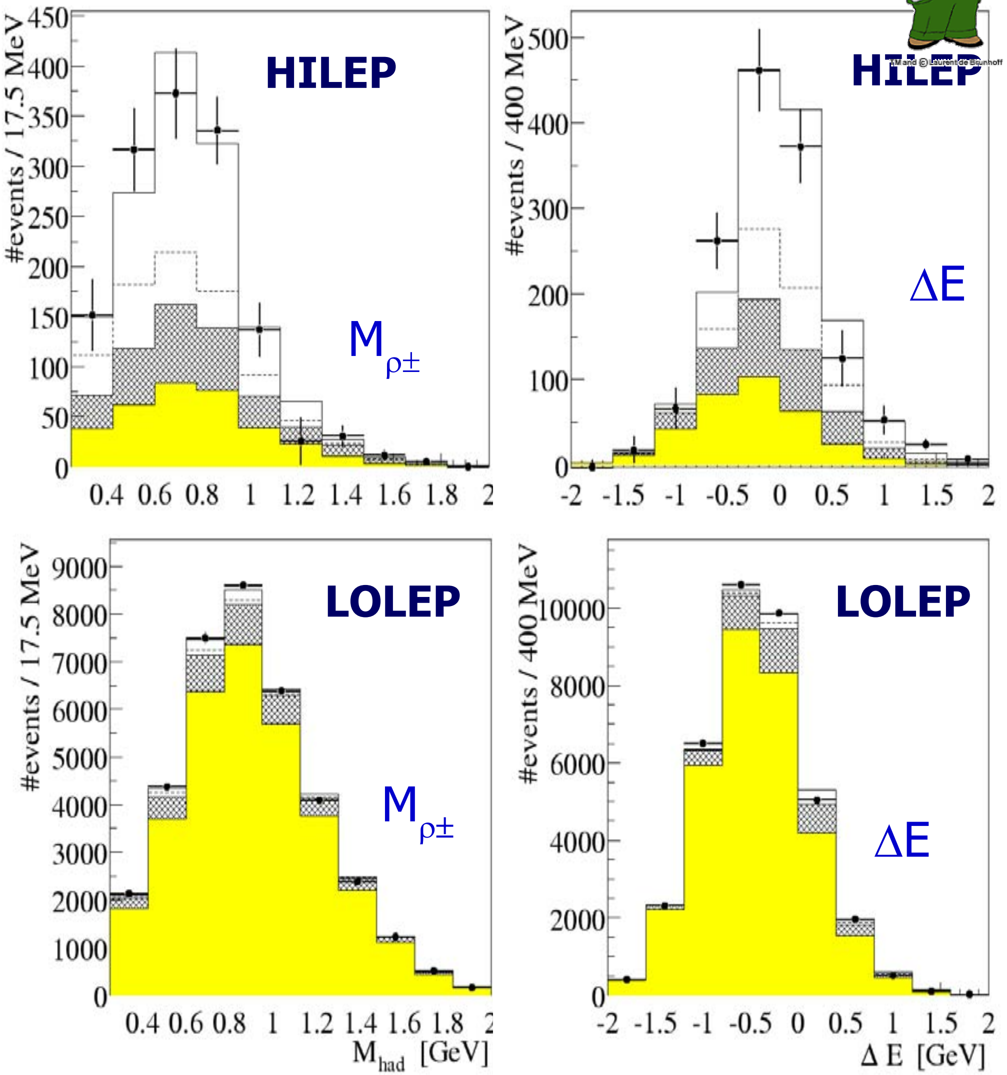
my own selection of recent result

$BR(B^0 \to \rho^+ e^- \nu)$ [1]

- signal (ISGW2)
- crossfeed
- $b \to u e \nu$ downfeed (ISGW2+DeFazio Neubert)
- $b \to c e \nu$ (HQET + Goity Roberts)

HILEP:
$2.3 < E_{electron} < 2.7$ GeV
(large continuum backgrounds)

LOLEP:
$2.0 < E_{electron} < 2.3$ GeV
(large $b \to c e \nu$ backgrounds)



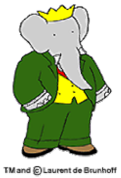
$\Gamma(B^0 \to \rho^- e^+ \nu) = 2\,\Gamma(B^+ \to \rho^0 e^+ \nu)$

$\Gamma(B^0 \to \pi^- e^+ \nu) = 2\,\Gamma(B^+ \to \pi^0 e^+ \nu)$

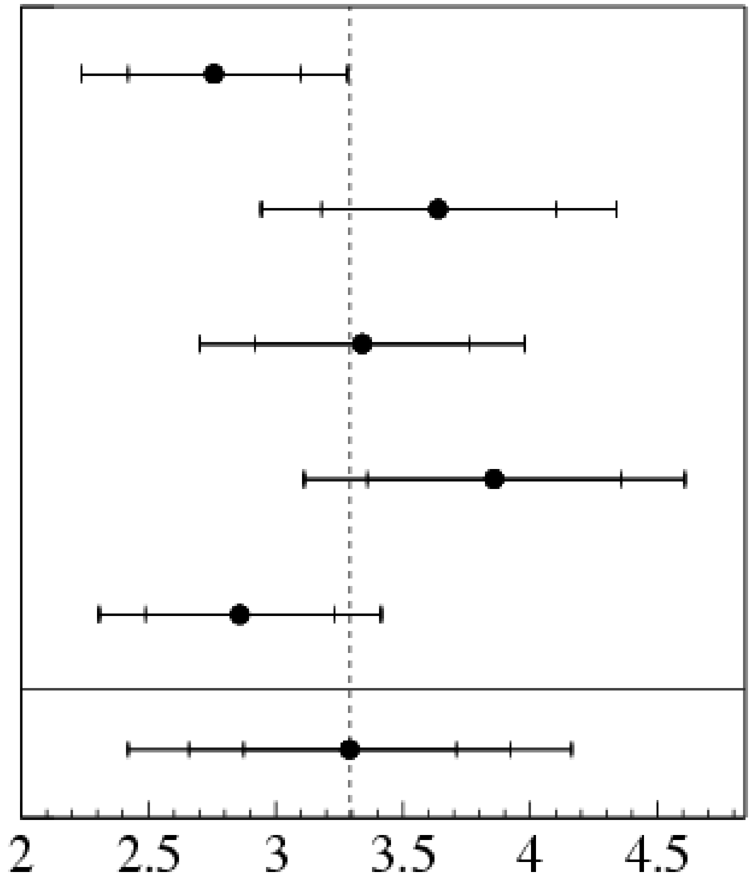
$\Gamma(B^+ \to \rho^0 e^+ \nu) = \Gamma(B^+ \to \omega e^+ \nu)$

(isospin-constrained average of $\rho^\pm$ and ρ^0)

BR($B^0 \to \rho^+ e^- \nu$) [2]



extrapolate partial branching fraction to entire lepton-energy spectrum using five different form-factor calculations



ISGW2:
$2.76 \pm 0.34 \pm 0.40$

Beyer/Melikhov:
$3.64 \pm 0.46 \pm 0.52$

UKQCD:
$3.34 \pm 0.42 \pm 0.48$

LCSR:
$3.86 \pm 0.50 \pm 0.56$

Ligeti/Wise:
$2.86 \pm 0.37 \pm 0.41$

Combined:
$3.29 \pm 0.42 \pm 0.47 \pm 0.60$

combined result: unweighted mean

theoretical error on the combined result:

full spread seen between the different form-factors

combined result (unweighted mean):

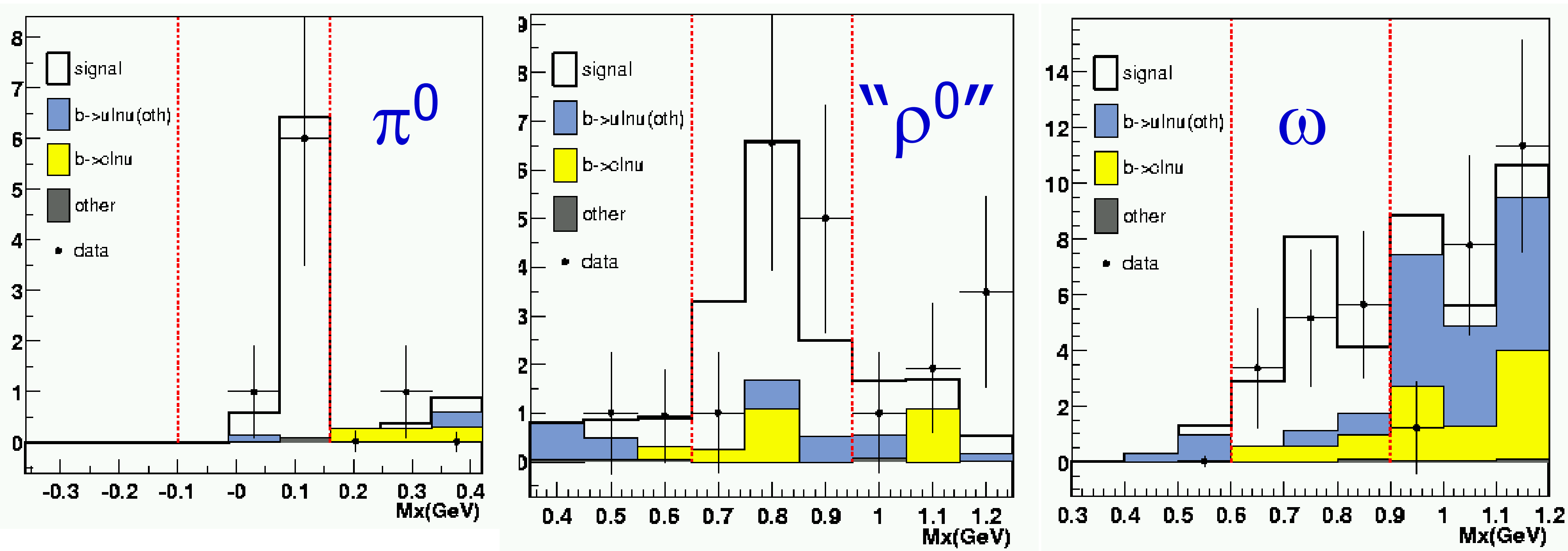
$$BR=(3.29 \pm 0.42 \pm 0.47 \pm 0.55) \times 10^{-4}$$

PRL 90 (2003) 181801

BR($B\to\pi^0 l\nu$, "ρ^0"$l\nu$, $\omega l\nu$)

very high purity but small statistics
loose cuts: small model dependence

"ρ^0" : $0.65 < m_{\pi\pi} < 0.95$ GeV/c^2



$$BR(B\to\pi^0 l\nu) = (0.78 \pm 0.32 \pm 0.13\ ) \times 10^{-4}$$
$$BR(B\to\text{"}\rho^0\text{"}l\nu) = (0.99 \pm 0.37 \pm 0.19\ ) \times 10^{-4}$$
$$BR(B\to\omega l\nu) = (2.20 \pm 0.92 \pm 0.57\ ) \times 10^{-4}$$

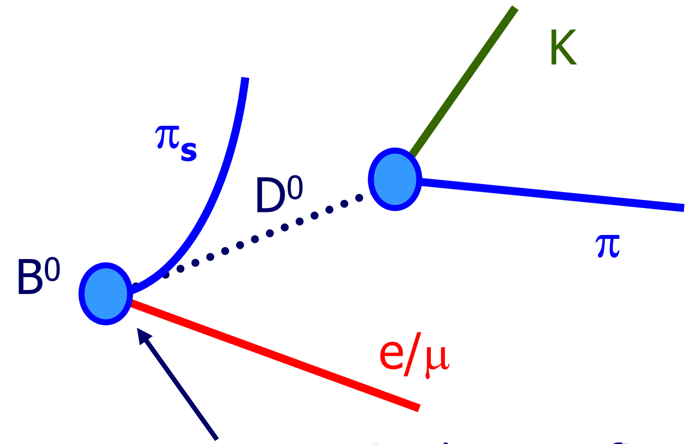
new CLEO results: see next talk !

preliminary

$B \to D^* l \nu$: motivations

$B \to D^* l \nu$ represents 10% (5% e +5% μ channel) of the total B^0 decays, so a precise understanding of this decay improves the overall knowledge of the B branching ratios

the study of the differential decay rate can be used to extract $|V_{cb}|$



constrained vertex fit on D^0 decay products, soft pion and lepton

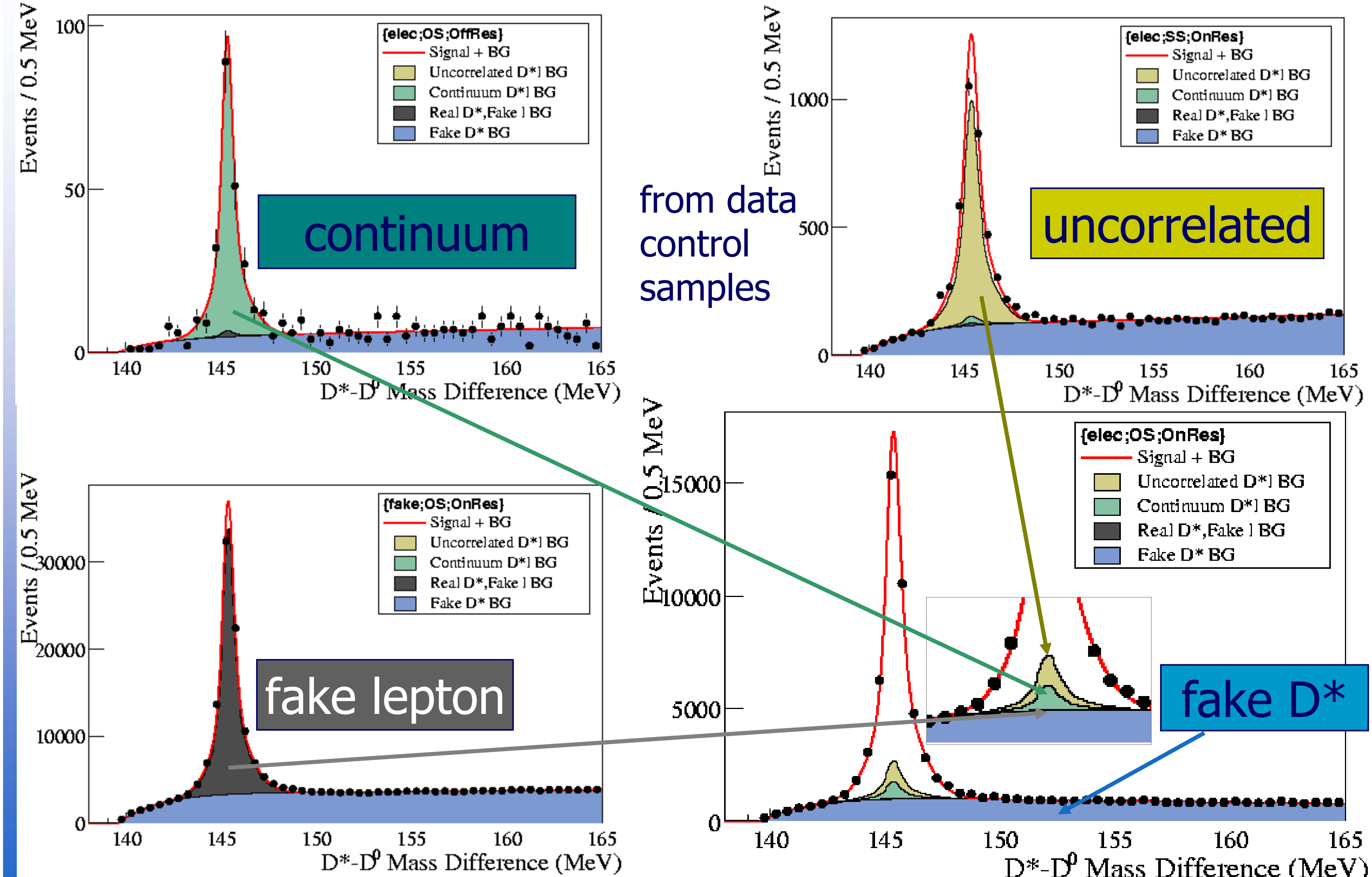
$D^{*\pm} \to D^0 \pi^\pm$

$D^0 \to K\pi,\ K_s\pi\pi,\ K\pi\pi^0,\ K\pi\pi\pi$

δM [= $M(D^*)-M(D^0)$] used to fit signal and background components (except D^{**})

data control samples are used to estimate the background components (72 samples)

Background characterization: fit to δM [= $M(D^*)-M(D^0)$]



Separation of D** component

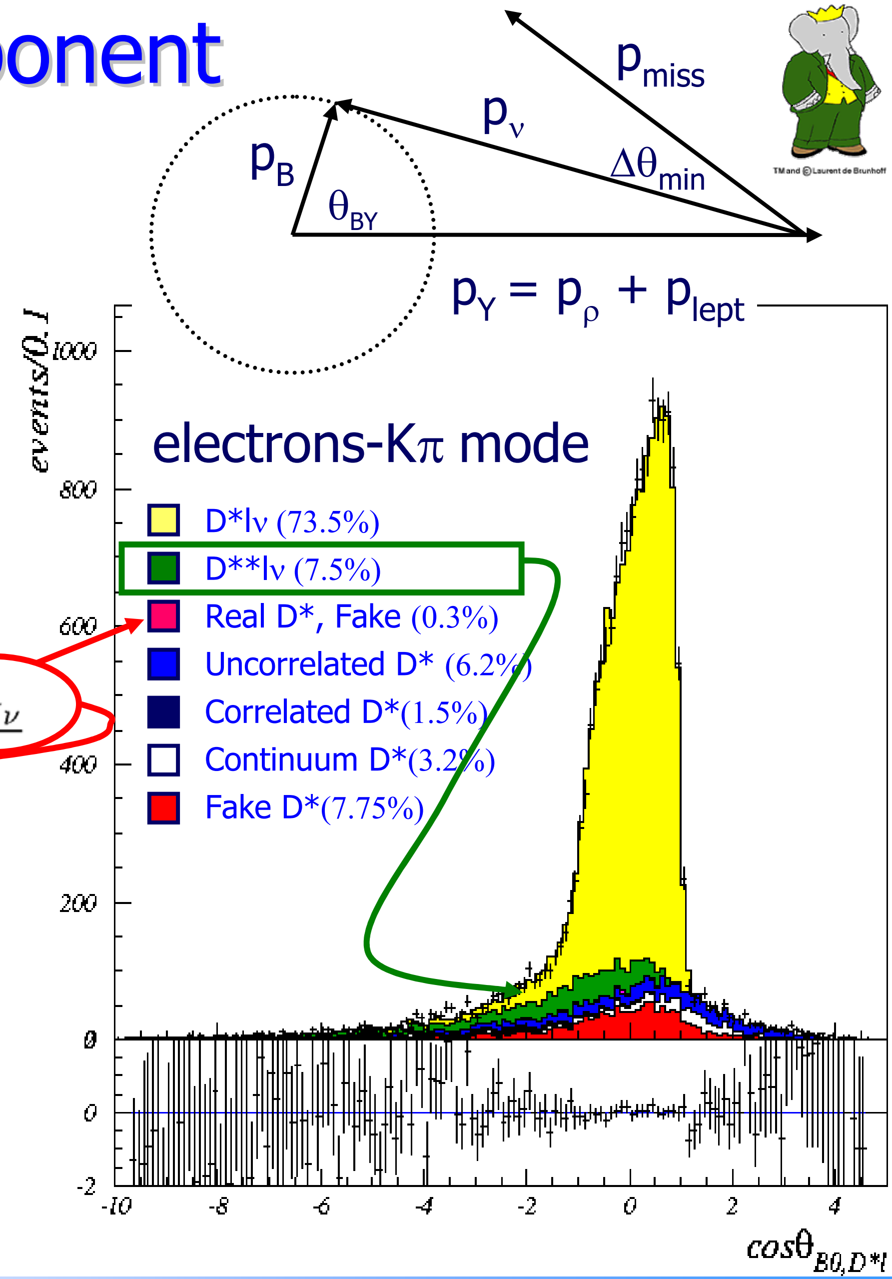
once other backgrounds are estimated from the global fit, $B^{0(+)} \to D^*Xl\nu$ events are separated using the angle between the B^0 and the D^*l direction.

can be written as:

$$\cos\theta_{B^0,D^*\ell} = \frac{-(m_{B^0}^2 + m_{D^*\ell}^2 - 2\,E_{B^0}E_{D^*\ell}) + m_{X\nu}^2}{2\,|\vec{p}_{B^0}||\vec{p}_{D^*\ell}|}$$

$m_{X\nu}^2 = 0$ if $B^0 \to D^*l\nu$

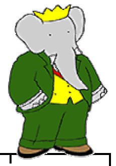
$m_{X\nu}^2 > 0$ if $B^{0(+)} \to D^*Xl\nu$



D^{**} shape different from the D^* one fitted in each D^0 mode and e/μ subsample

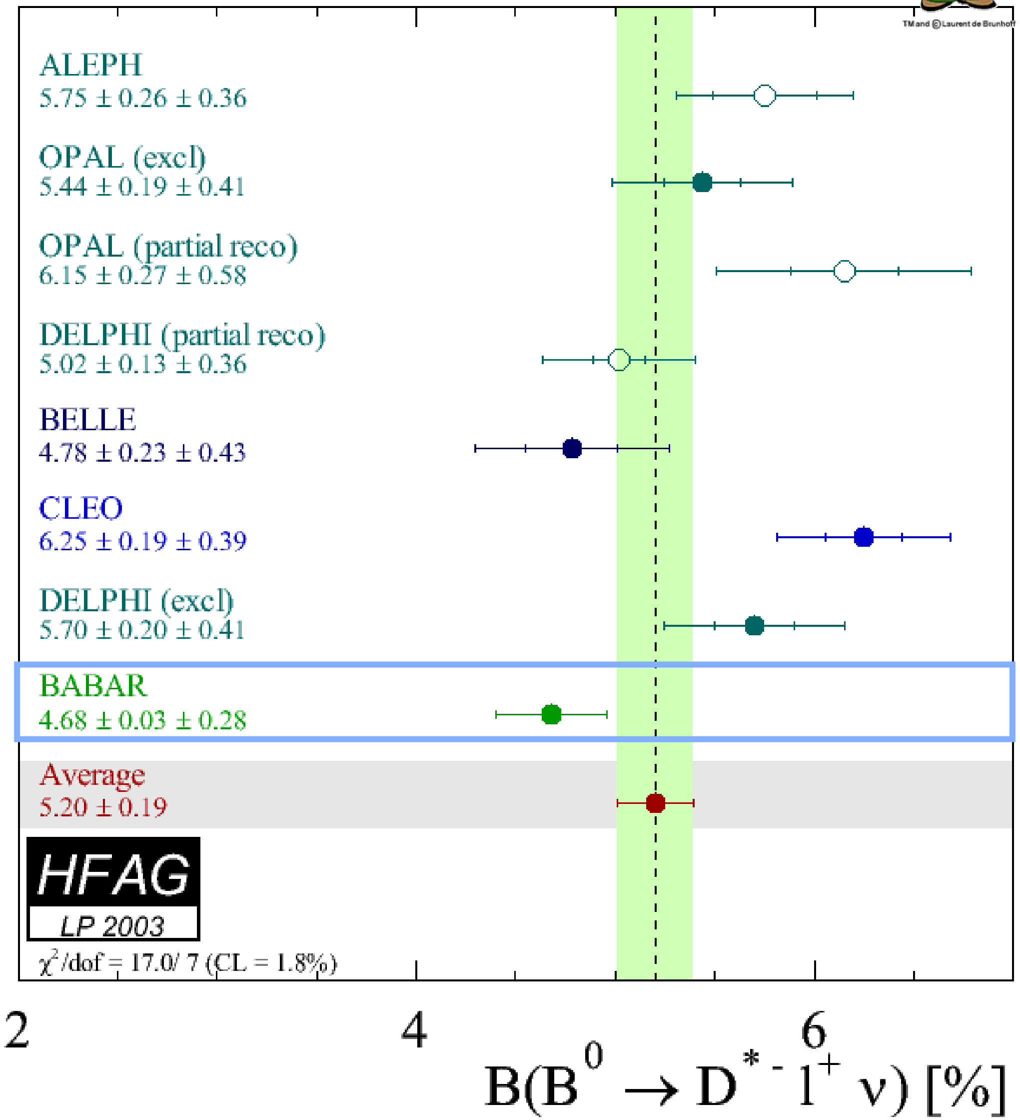
Results for BR($B \rightarrow D^* l \nu$)

hep-ex/0308027



$BR(B^0 \rightarrow D^{*-} l^+ \nu) =$
$(4.69 \pm 0.02_{stat.data}$
$\pm 0.02_{stat.MC}$
$\pm 0.24_{syst.data})\%$

comparison with other results



Orbitally excited D mesons (D^{**})

- D^{**0} are L=1 orbitally excited charm mesons
  - narrow $J_q = 3/2$, $J^P=1^+,2^+$ states (D_1^0, D_2^{*0})
  - wide $J_q = 1/2$, $J^P=0^+,1^+$ states (not visible with statistics)

motivation

- investigate the difference between measured inclusive and exclusive semileptonic branching ratios
- reduce uncertainty in $|V_{cb}|$
- test HQET predictions

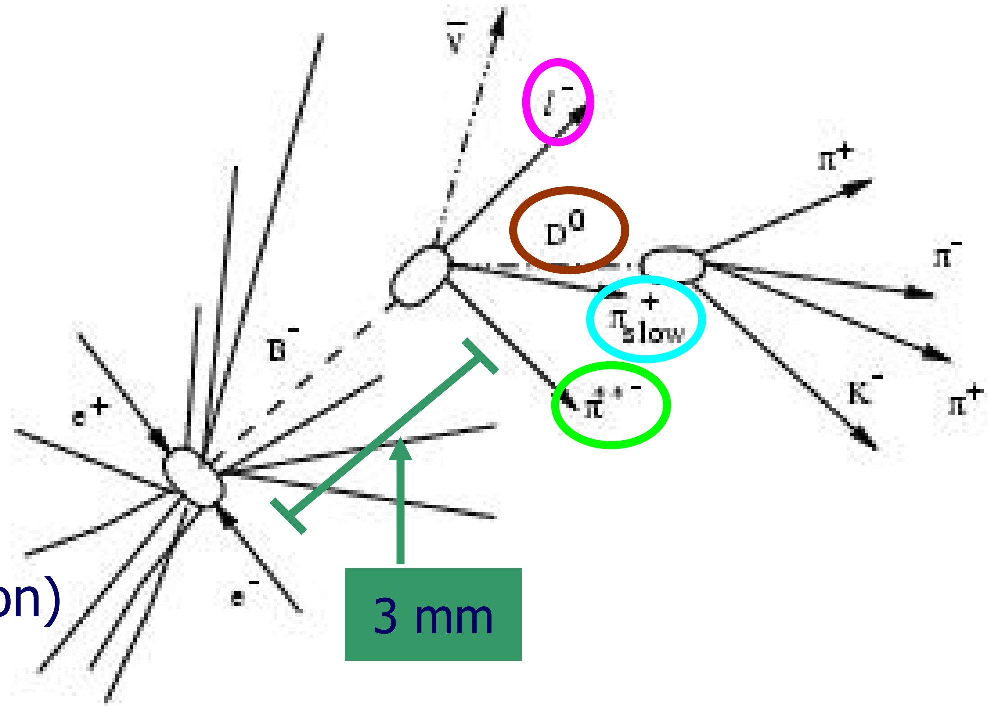
Method

- identify high p lepton (μ,e)
  - high efficiency and purity for p_{μ}> 3 GeV/c, p_e> 2 GeV/c
- exclusively reconstruct D^{**0}

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

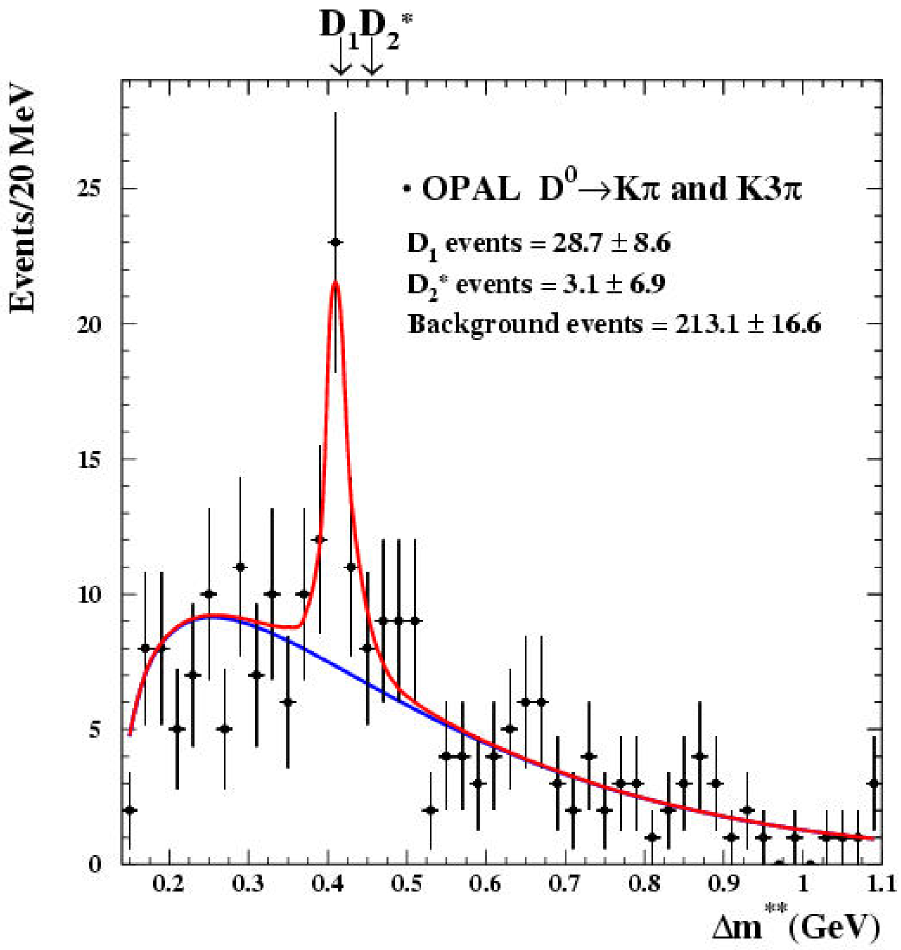
$\quad \hookrightarrow D^0 \pi^+_{slow}$

$\quad\quad \hookrightarrow K^-\pi^+(\pi^+ \pi^-)$



- background cuts to remove fake π^{**-} (π from fragmentation)
  - main background from $b \rightarrow D^{*0} \ell \bar{\nu}_{\ell} X$ decays plus fake π^{**-}
  - ANN (p, p_T, $d0/\sigma_{d0}$) to select π^{**-}

$D^{**0} - D^{*+}$ mass difference



combine $D^0 \to K\pi$ and $K3\pi$ channels to reduce uncertainty due to background

unbinned ML fit to determine number of D_1 and D_2^* events (B.-W. ⊗ Gaussian)

$$BR(b \to \bar{B}) \times BR(\bar{B} \to D_1^0 \ell^- \bar{\nu} X) \times BR(D_1^0 \to D^{*+}\pi^-) =$$
$$= (2.64 \pm 0.79(stat) \pm 0.39(syst)) \times 10^{-3}$$

$$BR(b \to \bar{B}) \times BR(\bar{B} \to D_2^{*0} \ell^- \bar{\nu} X) \times BR(D_2^{*0} \to D^{*+}\pi^-)$$
$$\leq 1.4 \times 10^{-3} \quad (95\% \text{ C.L.})$$

number of wrong sign and right sign background events fit simultaneously

CERN-EP-2002-094

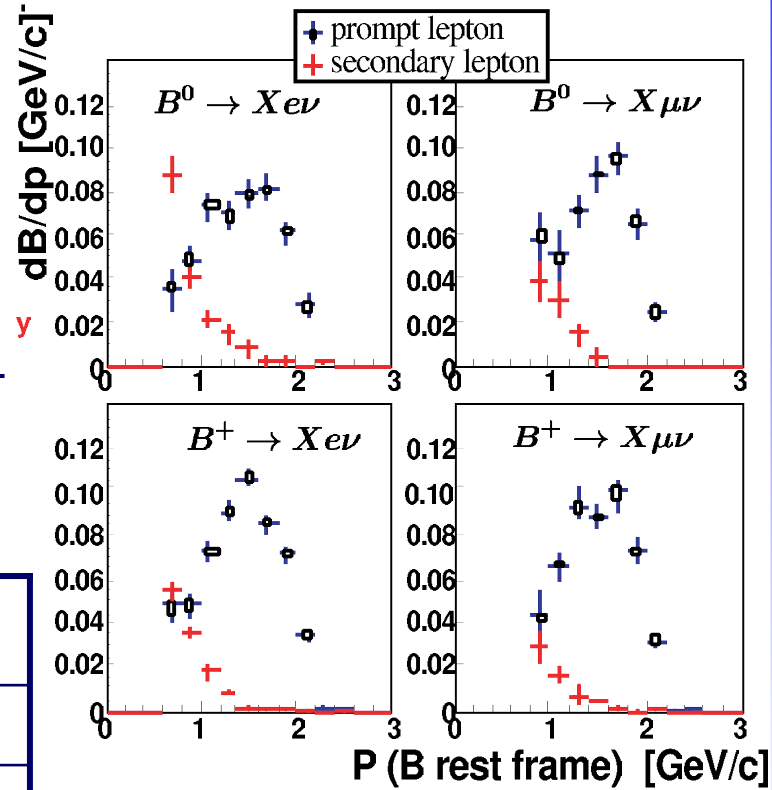
B^o & B^+ semileptonic decays

accurate, separate BR_{sl} for B^o & B^+, tagged by fully reconstructing one B

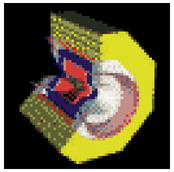
$BR(B^+ \to X l \nu)/B(B^0 \to X l \nu) = 1.14 \pm 0.04 \pm 0.01$

preliminary

	$BR_{sl}(\%)$	$\Gamma_{sl}(ns^{-1})$
B^o	10.32±0.32±0.29	67.0±2.8
B^+	11.77±0.26±0.32	71.1±2.5
½(B^o+B^+)	11.19±0.20±0.31	69.0±1.9
Y(4S)	10.89 ±0.24	67.7±1.8

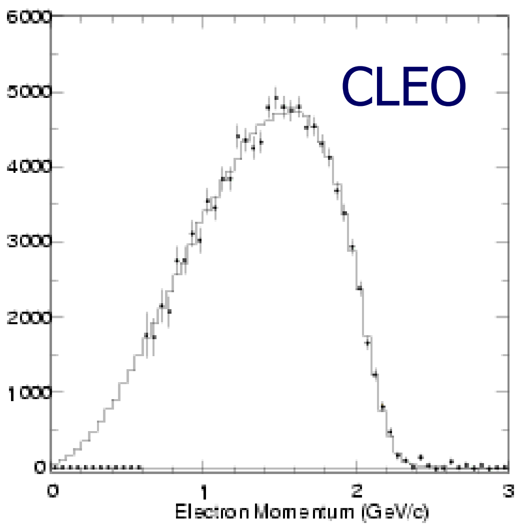


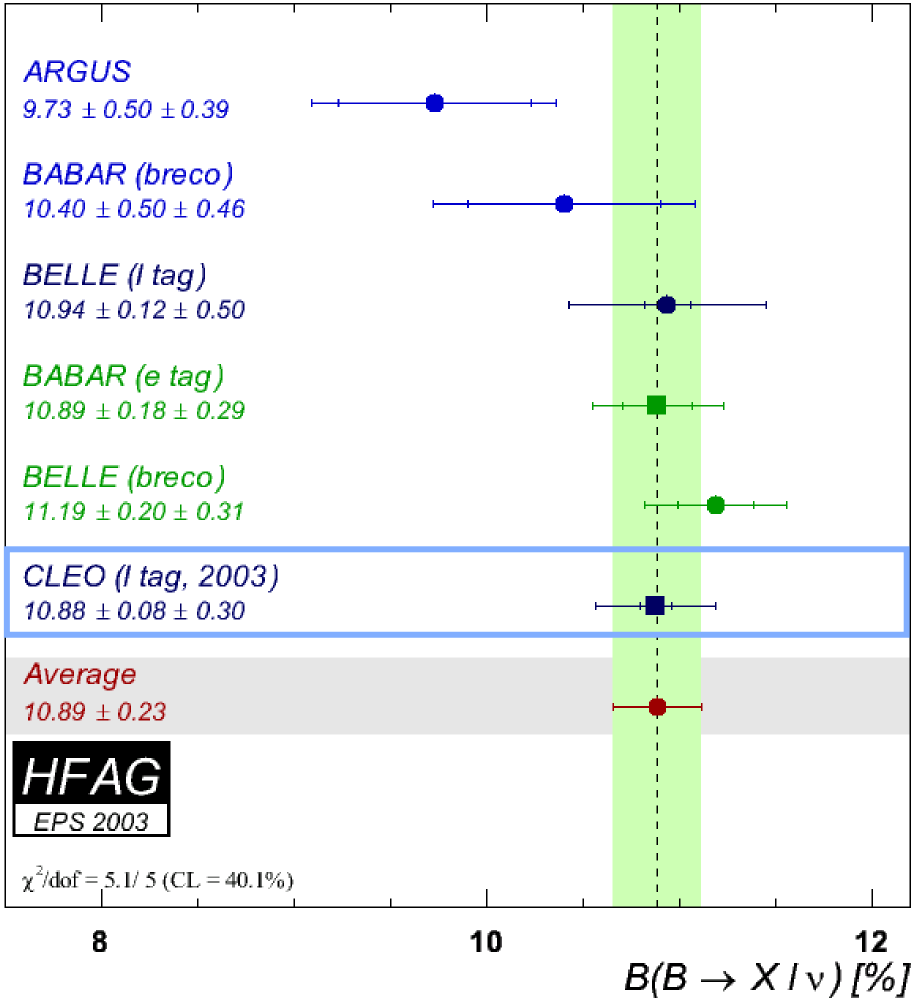
$\Gamma_{sl}(B^+)/\Gamma_{sl}(B^o) = 1.063 \pm 0.038$



Semileptonic B decays average BR_{sl}

on Y(4S), use high momentum lepton to tag flavor of 1st B





$BR(B \to Xe\nu)=$
$(10.89 \pm 0.08_{stat} \pm 0.33_{syst})\%$

preliminary, EPS'03 272

LEP(most recent EW fit)=$(10.59 \pm 0.22)\% \to 10.76\%$ at Y(4S)

Parameters of HQE

parameterization of decay rate in terms of Operator Product Expansion in HQET in powers of $\alpha_s(m_b)\beta_0$ and Λ/m_B:

$$\Gamma_{sl} = \frac{G_F^2 |V_{cb}|^2}{192\pi^3} m_B^5 c_1 \left\{ 1 - c_2 \frac{\alpha_s}{\pi} + \frac{c_3}{m_B} \bar{\Lambda} \left(1 - c_4 \frac{\alpha_s}{\pi}\right) + \frac{c_5}{m_B^2} \left(\bar{\Lambda}^2 + c_6 \lambda_1 + c_7 \lambda_2\right) + O\left(\frac{1}{m_B^3}\right) + O\left(\frac{\alpha_s^2}{\pi}\right) \cdots \right\}$$

pole mass expansion

$\bar{\Lambda}$, λ_1, λ_2, are non-perturbative parameters

- λ_1: (-) kinetic energy of the motion of the b-quark
- λ_2: chromo-magnetic coupling of b-quark spin to gluon (from B*-B mass difference, $\lambda_2 = 0.12 \text{GeV}^2$)
- $\bar{\Lambda} = m_B - m_b + (\lambda_1 - 3\lambda_2)/2m_B + \ldots$

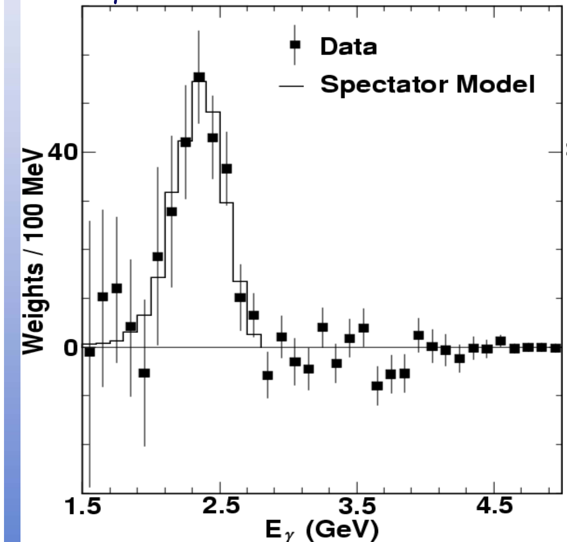
  + additional parameters enter at higher orders (ρ_1, ρ_2, τ_1, τ_2, τ_3, τ_4)

  use theoretical estimates $-1/m_B^3$

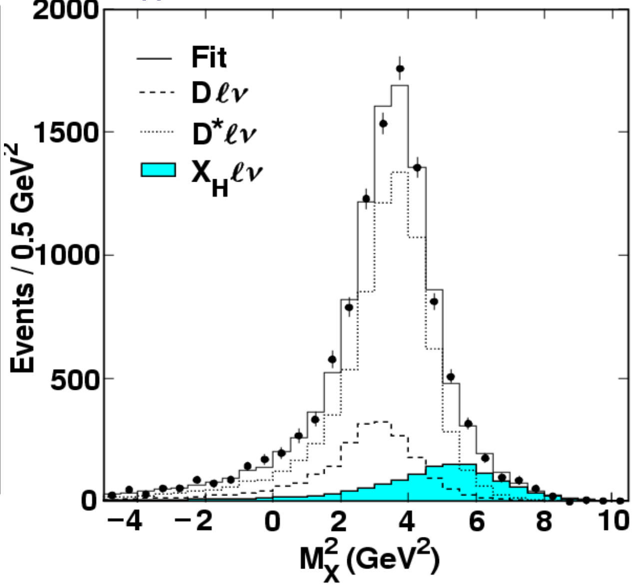
OPE parameter extraction

first derivations of OPE parameters from spectral moments used the pole mass expansion and photon energy spectrum in $B \to X_s\gamma$, hadronic mass spectrum and lepton energy spectrum in $B \to X_c l \nu$

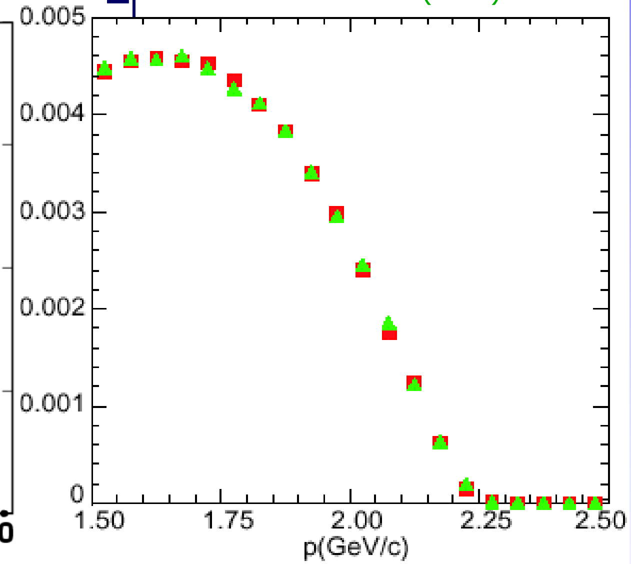
E_γ PRL 87 (2001) 251807



M_X^2 PRL 87 (2001) 251808



E_l PRD 67 (2001) 072001

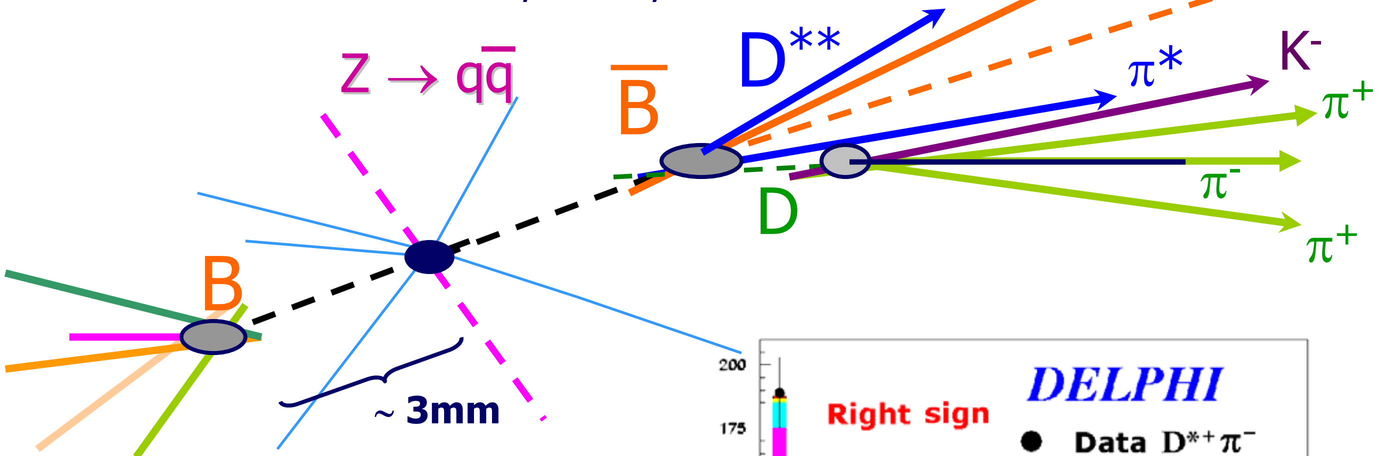


$$E_\gamma = \frac{m_B - \bar{\Lambda}}{2} + \dots$$

$$\frac{1}{m_B^2}\left\langle (M_X^2 - \bar{m}_D^2) \right\rangle = \mathcal{M}_0 + \frac{1}{m_B}\mathcal{M}_1(\bar{\Lambda}, \lambda_1, \lambda_2) + \dots$$

Moments of lepton energy spectrum and hadronic mass spectrum in $Z \rightarrow b\bar{b}$ events

$B_d^0 \rightarrow D^{**} l \nu$ decays exclusively reconstructed in three channels: $D^{**} \rightarrow D^{*+}\pi^-$, $D^0\pi^+$, $D^+\pi^-$

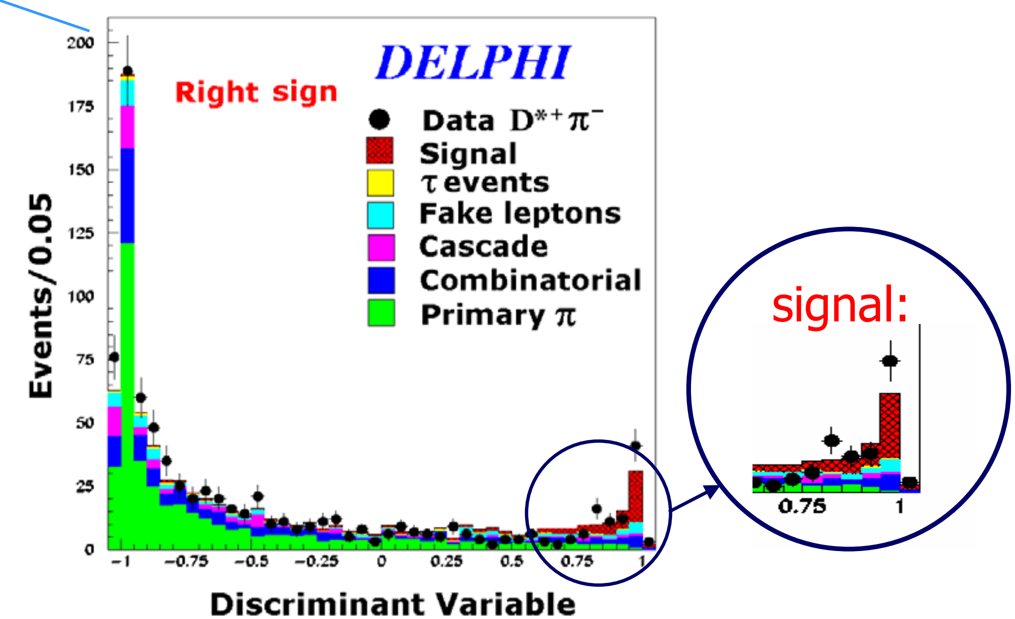


first measurements of moments performed at LEP exploiting advantage of Z^0 kinematics

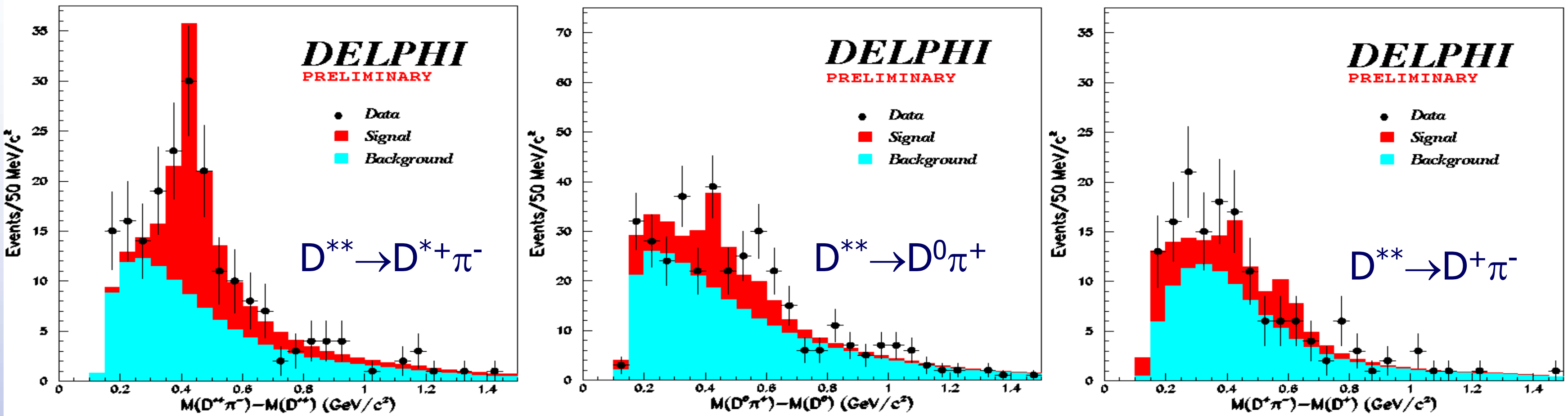
good secondary vertex reconstruction and signal/background separation

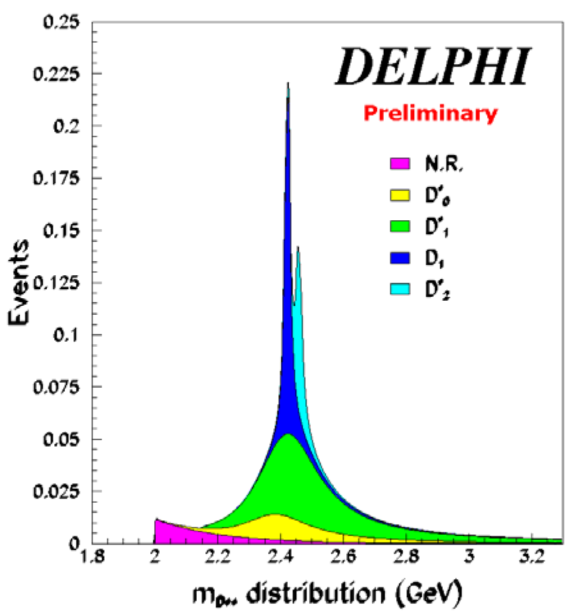
$\Gamma_{b\bar{b}} / \Gamma_{hadrons} \sim 22\%$

$E_B \sim 0.7\, E_{beam} \sim 30$ GeV



Hadronic mass spectrum in $B \rightarrow D^{**} l \nu$





$\Delta_M = M(D^{(*)}\pi) - M(D^{(*)})$ distributions fitted including contributions of resonant (narrow, broad) and non resonant states, $D^* X l \nu$ floating

$BR(B^0 \rightarrow D^{**} l \nu) = (2.7 \pm 0.7 \pm 0.2)\ \%$

DELPHI'03-28

Interpretations

moments of hadronic mass spectrum and of lepton energy spectrum are sensitive to the non-perturbative parameters of the Heavy Quark Expansion.

at order $1/m_b^2 \Rightarrow \overline{\Lambda}, \lambda_1, \lambda_2$ ($\lambda_2 \approx 0.12$ GeV^2) , at order $1/m_b^3 \Rightarrow \rho_1, \rho_2, T_{1\text{-}4}$

two possible approaches:

1) pole mass expansions $$M_n = f_n(\lambda_1, \overline{\Lambda}, \lambda_2, T_1, T_2, \ldots)$$

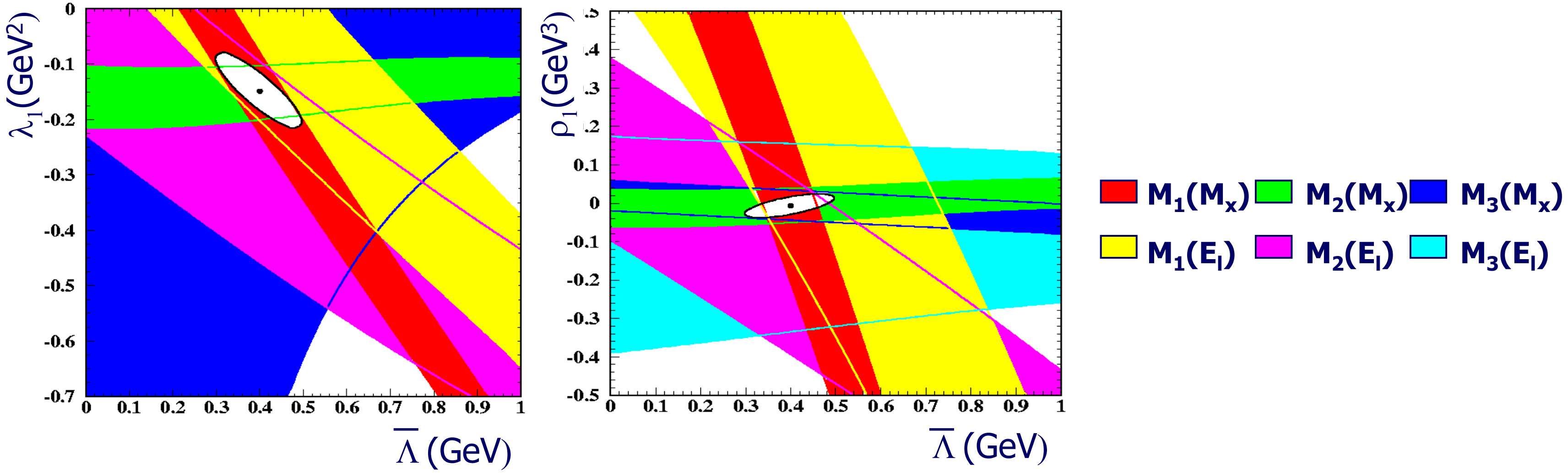
(Falk, Luke, Gambino)

2) running quark masses $$M_n = f_n(\mu_\pi^2, m_b(1\ \text{GeV}), \mu_G^2, \rho_D^3, \rho_{LS}^3, \ldots)$$

(Bigi, Shifman, Uraltsev, Vainshtein)

Pole mass scheme

multi-parameter fit:



$\bar{\Lambda} = 0.542 \pm 0.065_{fit} \pm 0.090_{sys}$ GeV
$\lambda_1 = -0.238 \pm 0.055_{fit} \pm 0.030_{sys} GeV^2$
$\rho_1 = 0.030 \pm 0.028_{fit} \pm 0.010_{sys} GeV^3$
$\rho_2 = 0.066 \pm 0.025_{fit} \pm 0.192_{sys} GeV^3$

good consistency of all measurements (χ^2/d.o.f.=0.4)
results compatible with CLEO

similar results with m_b^{1S}-λ_1 formalism applied to CLEO and DELPHI data
(C.W.Bauer, Z.Ligeti, M.Luke, A.V.Manohar hep-ph/0210027)

Non-perturbative parameter extraction

makes use of low scale running quark masses and does not rely on a $1/m_c$ expansion

$$M_n(E_l) = \left(\frac{m_b}{2}\right)^n \left(\varphi_n(r) + a_n(r)\frac{\alpha_s}{\pi} + b_n(r)\frac{\mu_\pi^2}{m_b^2} + c_n(r)\frac{\mu_G^2}{m_b^2} + d_n(r)\frac{\rho_D^3}{m_b^3} + s_n(r)\frac{\rho_{LS}^3}{m_b^3} + \ldots \right)$$

$m_b(\mu)$, $m_c(\mu)$ are independent parameters and two operators only contribute to $1/m_b^3$ corrections : ρ_D^3, ρ_{LS}^3

$$r = \frac{m_c^2(\mu)}{m_b^2(\mu)}$$

first applied to fit DELPHI data

- multi-parameter χ^2 fit to first three moments of lepton energy spectra and hadronic mass spectra
  (higher moments used to get sensitivity to $1/m_b^3$ parameters)
- use expressions for non-truncated lepton spectra
- simultaneous use of leptonic and hadronic moments in order to leave enough free parameters in the fit

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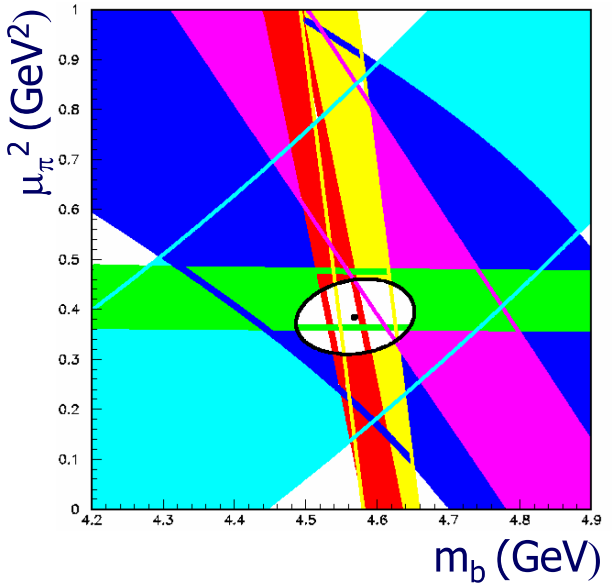
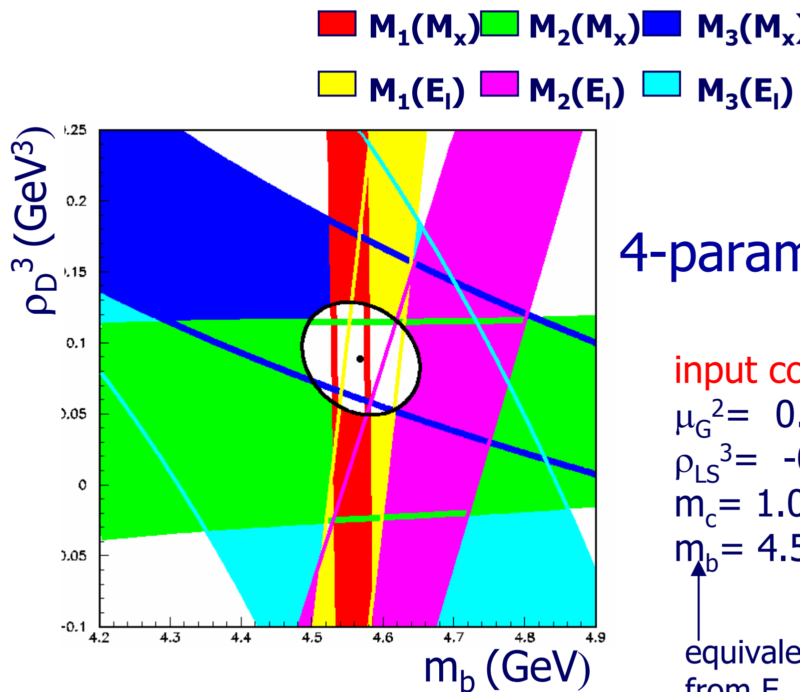
Kinetic mass scheme





4-parameter fit

input constraints:

$\mu_G^2 = 0.35 \pm 0.05$ GeV^2

$\rho_{LS}^3 = -0.15 \pm 0.15$ GeV^3

$m_c = 1.05 \pm 0.30$ GeV

$m_b = 4.57 \pm 0.10$ GeV

equivalent to that derived from E_γ in $B \to X_s\gamma$

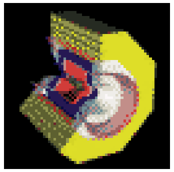
$$m_{b,kin}\,(1\text{GeV}) = 4.570 \pm 0.082_{fit} \pm 0.010_{sys}\ \text{GeV}$$
$$m_{c,kin}\,(1\text{GeV}) = 1.133 \pm 0.134_{fit} \pm 0.030_{sys}\ \text{GeV}$$
$$\mu_\pi^2\,(1\text{GeV}) = 0.382 \pm 0.070_{fit} \pm 0.030_{sys}\ \text{GeV}^2$$
$$\rho_D^3\,(1\text{GeV}) = 0.089 \pm 0.039_{fit} \pm 0.010_{sys}\ \text{GeV}^3$$

good consistency of all measurements (χ^2/d.o.f.=0.9)

within present accuracy no need to introduce higher order terms to establish agreement with data

Generalized energy moments

hep-ex/0212051

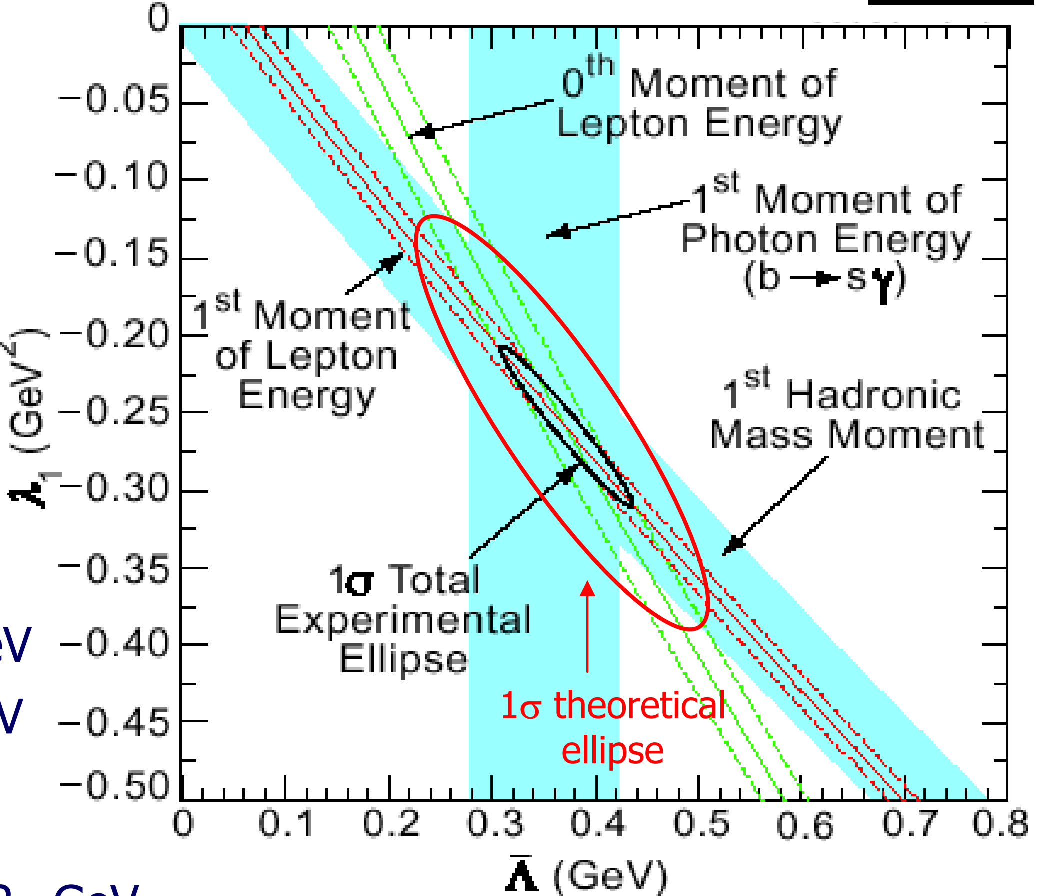


using ratios of truncated lepton spectra (Gremm et al. PRL77 20 '96)

$$R_0 = \frac{\int_{1.7\,\text{GeV}} \frac{d\Gamma_{sl}}{dE_l} dE_l}{\int_{1.5\,\text{GeV}} \frac{d\Gamma_{sl}}{dE_l} dE_l} \quad R_1 = \frac{\int_{1.5\,\text{GeV}} E_l \frac{d\Gamma_{sl}}{dE_l} dE_l}{\int_{1.5\,\text{GeV}} \frac{d\Gamma_{sl}}{dE_l} dE_l}$$

$$R_0 = 0.6187 \pm 0.0014 \pm 0.0016 \text{ GeV}$$

$$R_1 = 1.7810 \pm 0.0007 \pm 0.0009 \text{ GeV}$$



$$\bar{\Lambda} = 0.39 \pm 0.03_{stat} \pm 0.06_{sys} \pm 0.12_{th} \text{ GeV}$$

$$\lambda_1 = -0.25 \pm 0.02_{stat} \pm 0.05_{sys} \pm 0.14_{th} \text{ GeV}^2$$

parameters extracted from lepton spectra are in agreement with those extracted from M_X^2 and E_γ

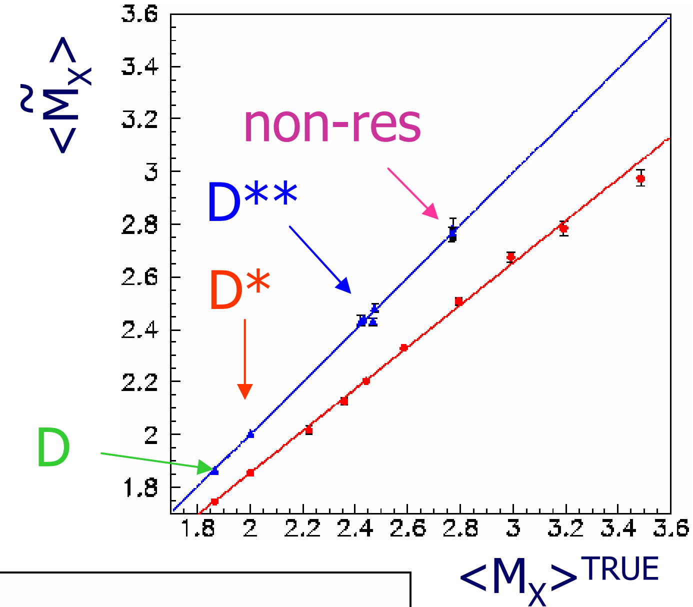
Hadronic mass moments [1]

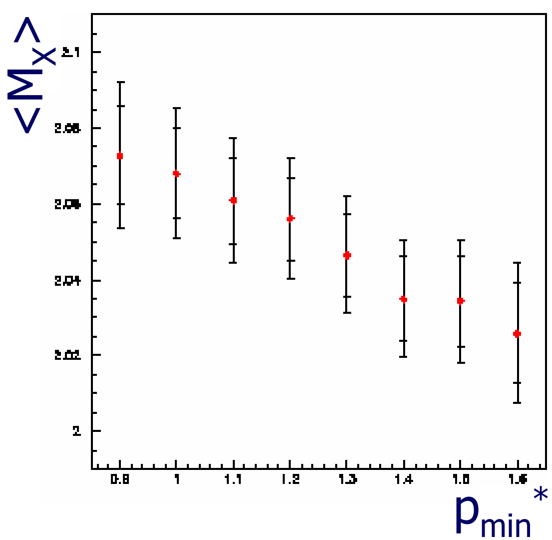
measured $\tilde{M}_X$ differs from true M_X

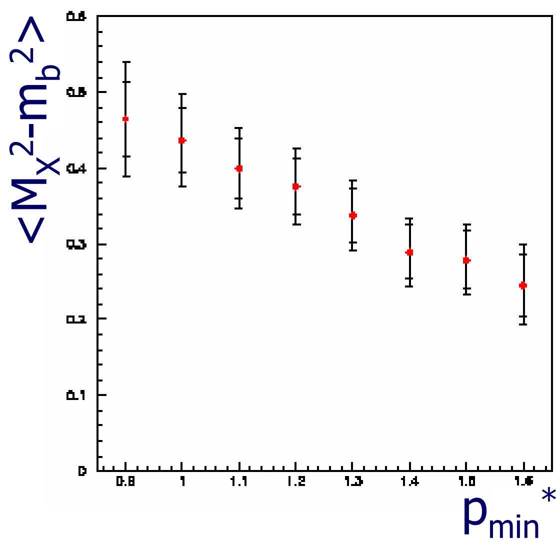
for each interval in M_X, full detector simulation gives $\langle M_X \rangle$ and $\langle \tilde{M}_X \rangle$

calibration curves applied to data: no model dependence !

p_{min}^* dependence study

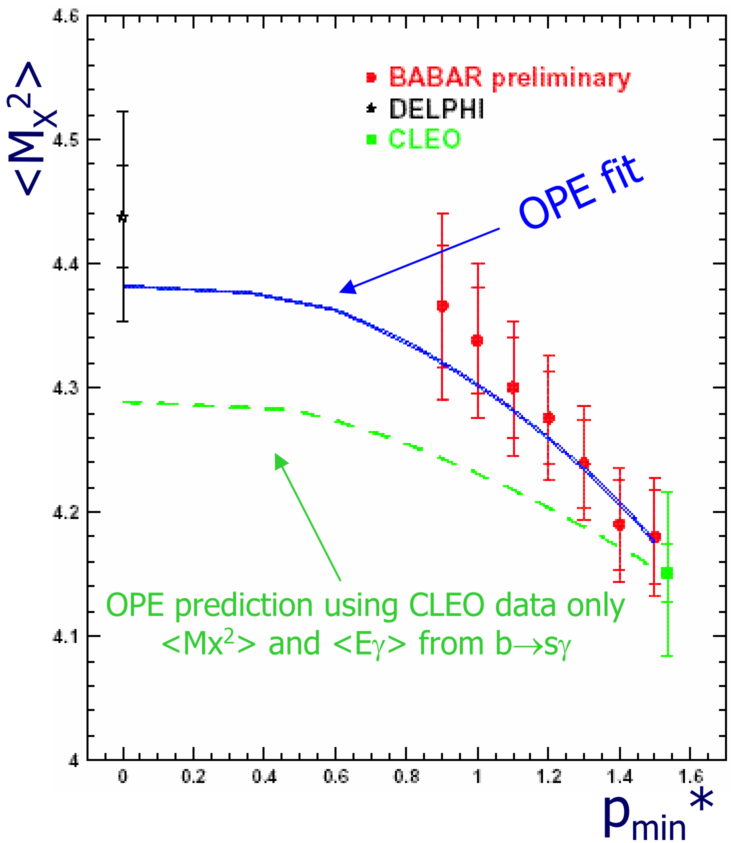


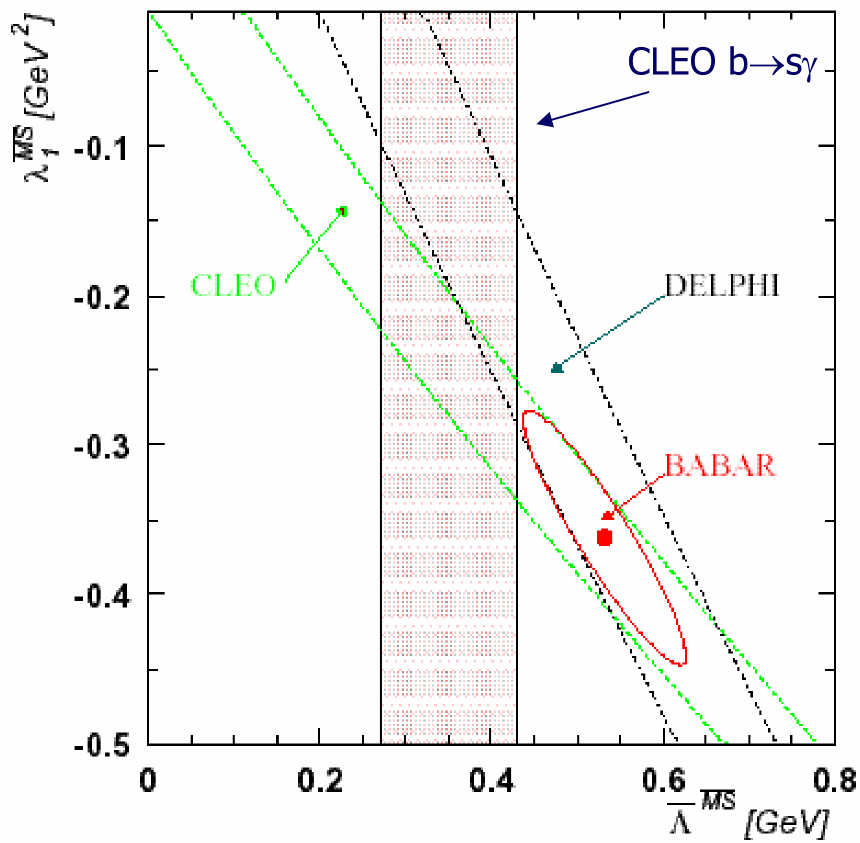




Hadronic mass moments [2]

fit OPE for $<M_X^2>$ to data and extract the two leading HQE parameters $\overline{\Lambda}$ and λ_1 (MS scheme) → all correlations taken into account

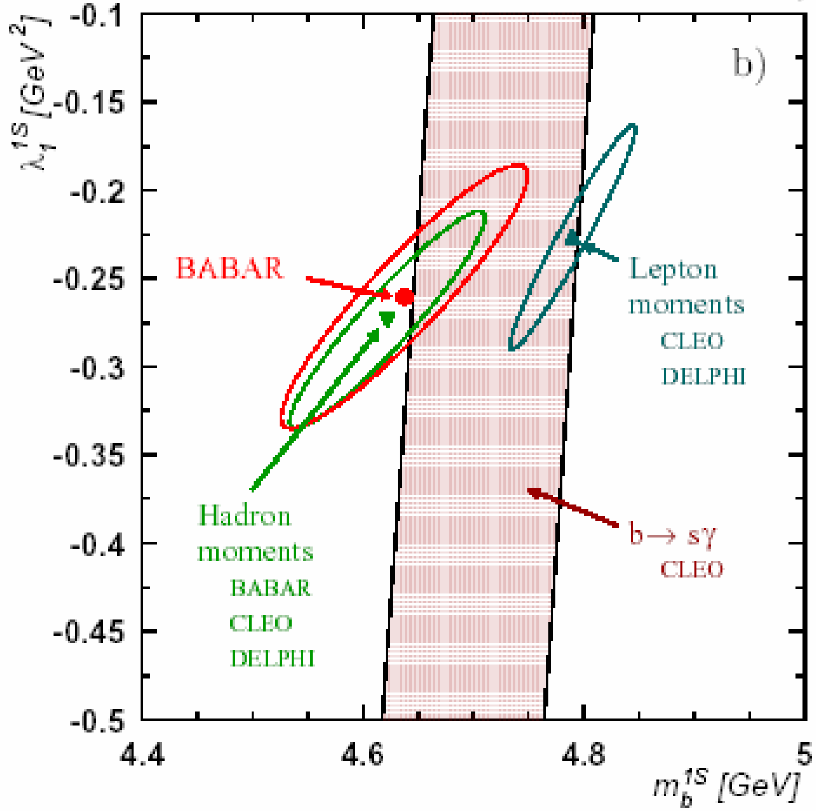




all hadron mass moments are consistent (overlap from bands and BABAR ellipse) but $\Delta\chi^2$=1 contour does not overlap with <Eγ> band from CLEO b→sγ

Hadronic mass moments [3]

extraction of m_b^{1s}, and λ_1^{1s} from a fit to the HQE in the 1s mass scheme ($O(1/m_b^3)$ parameters are fixed in the fit)



$\Delta\chi^2=1$ contour of hadron moments and lepton moments do not overlap

indication for large $O(1/m_b^3)$ corrections, duality violation, or maybe even more …?

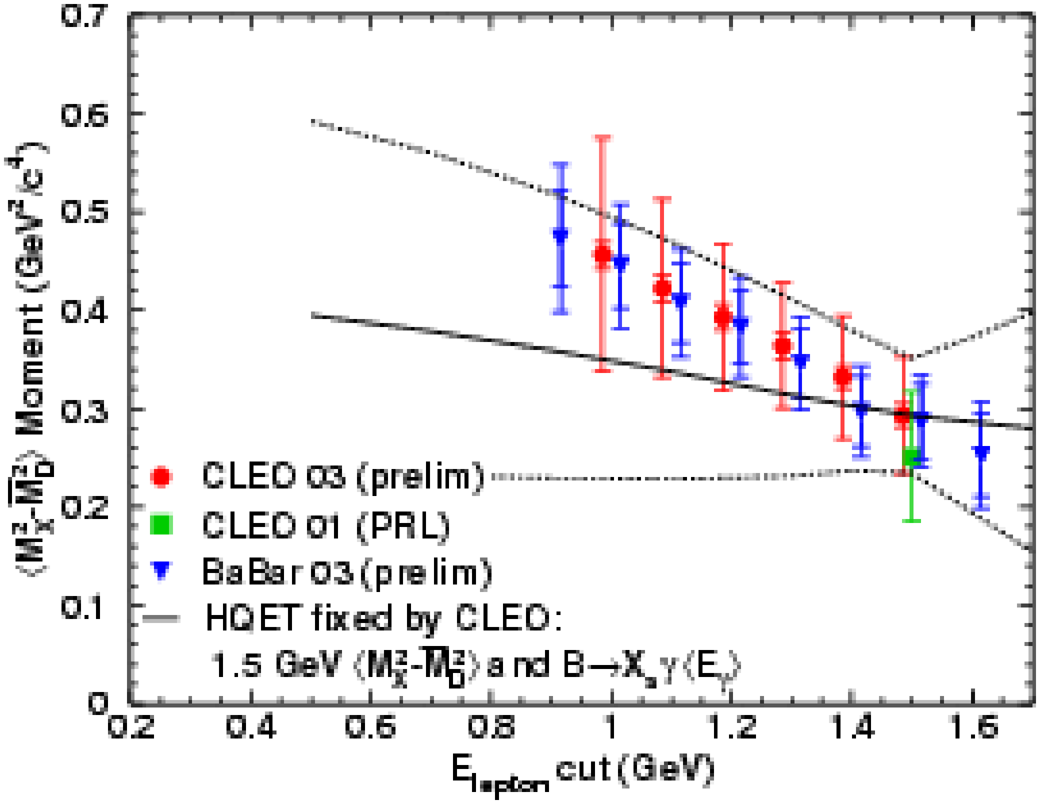
$$m_b^{1s} = 4.638 \pm 0.094_{exp} \pm 0.062_{dim \oplus BLM} \pm 0.065_{1/m_B^3} \text{ GeV}$$

$$\lambda_1 = -0.26 \pm 0.06_{exp} \pm 0.04_{dim \oplus BLM} \pm 0.04_{1/m_B^3} \text{ GeV}^2$$

hep-ex/0307046

Hadronic mass moments

the neutrino 4-vector is inferred using the detector hermeticity



$$\langle M^2_X - \overline{M}^2_D \rangle_{El>1.0\ GeV} = 0.456 \pm 0.014 \pm 0.045 \pm 0.109\ (GeV/c^2)^2$$

$$\langle M^2_X - \overline{M}^2_D \rangle_{El>1.5\ GeV} = 0.293 \pm 0.012 \pm 0.033 \pm 0.048\ (GeV/c^2)^4$$

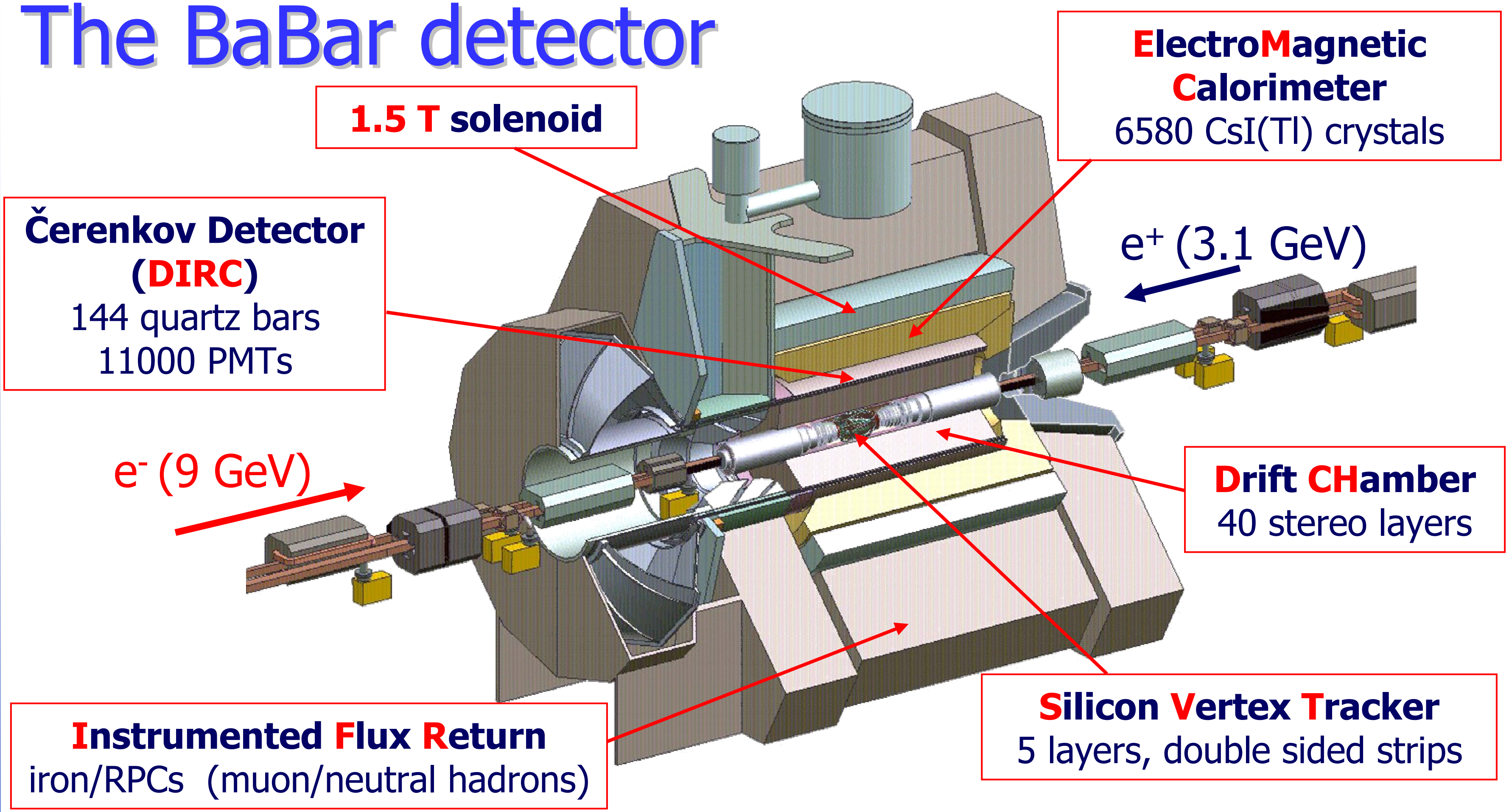
hep-ex/0307081

Summary

- Huge efforts/progress in this area !!
- Large theoretical progress over the last decade (HQET & OPE)
- Fully reconstructed B meson recoil tag, neutrino reconstruction
- Many complementary observables
- Inclusive studies yield crucial informations for Heavy Quark physics, even for exclusive decays

Start of Backup Slides

The BaBar detector



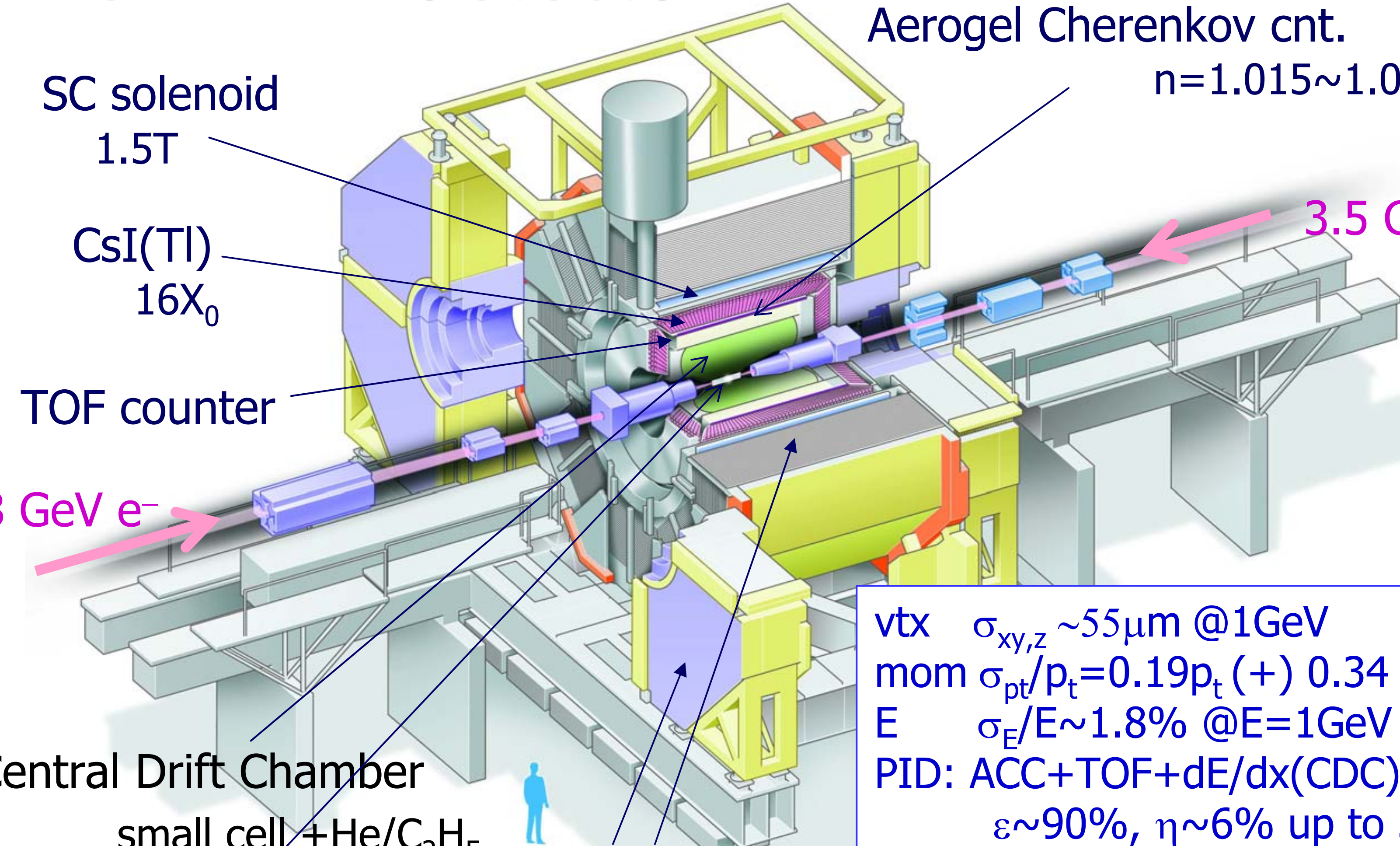
SVT: 97% efficiency, 15 μm z hit resolution (inner layers, $\perp$ tracks)

SVT+DCH: $\sigma(p_T)/p_T = 0.13\ \% \times p_T + 0.45\ \%$

DIRC: K-π separation 4.2σ @ 3.0 GeV/c $\rightarrow$ $>3.0\sigma$ @ 4.0 GeV/c

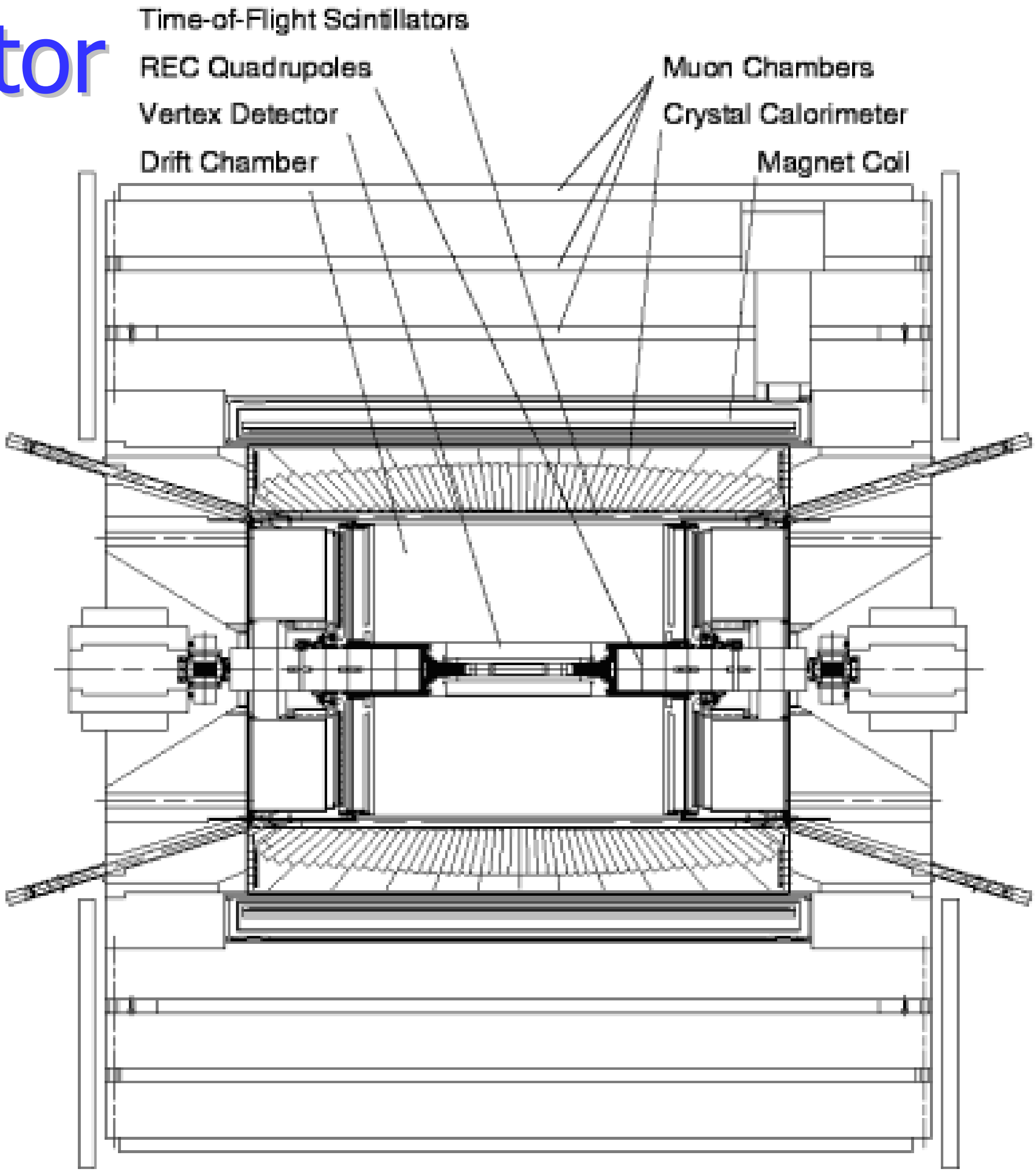
EMC: $\sigma_E/E = 2.3\ \% \times E^{-1/4} \oplus 1.9\ \%$

The BELLE detector

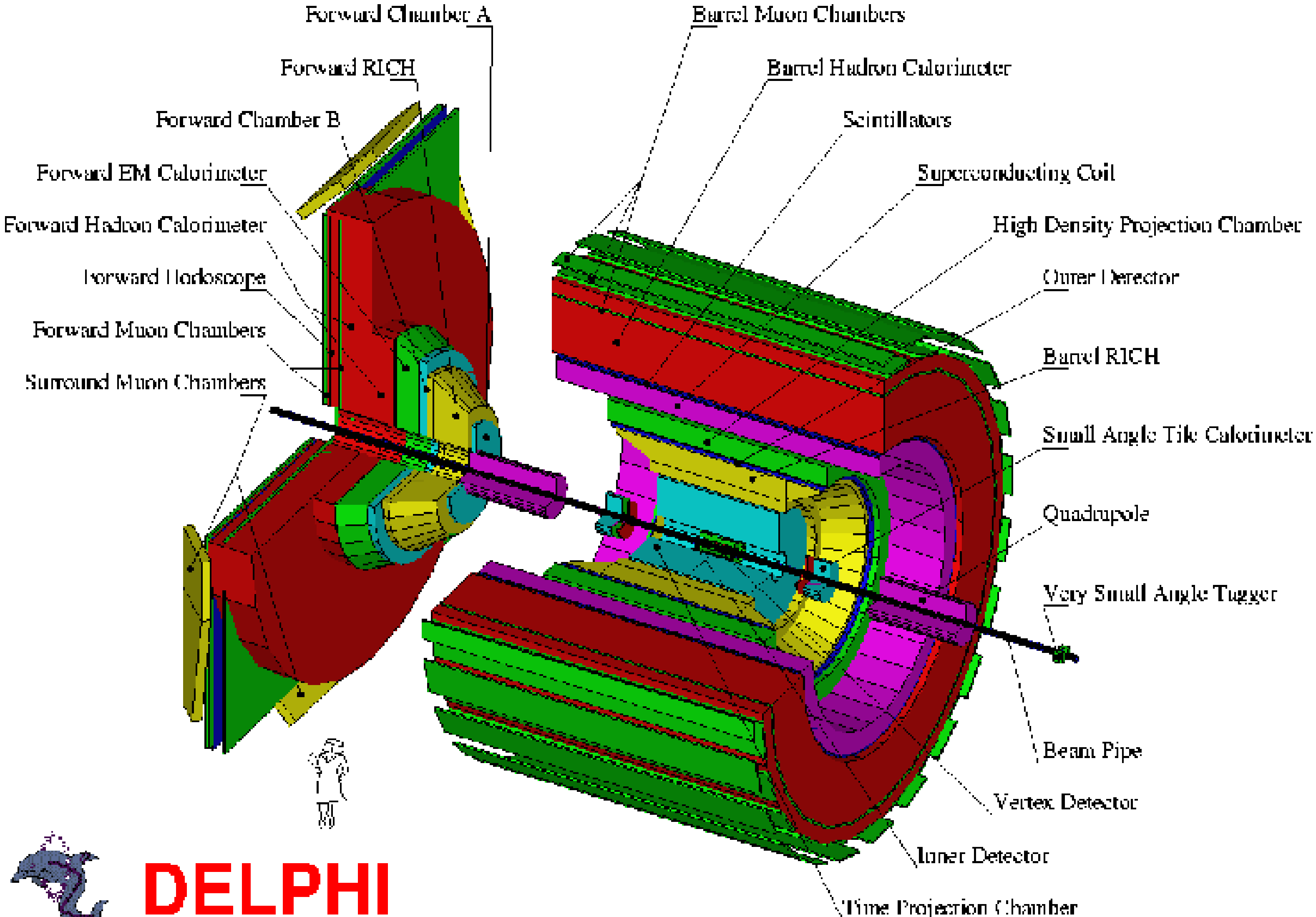


vtx $\sigma_{xy,z}$ ~55μm @1GeV
mom σ_{pt}/p_t=0.19p_t (+) 0.34 %
E σ_E/E~1.8% @E=1GeV
PID: ACC+TOF+dE/dx(CDC)
ε~90%, η~6% up to 3GeV
e-id: ε>90%, η~0.3% (>1GeV)
μ-id: ε>90%, η <2% (>1GeV)
[ε=efficiency, η=fake rate]

The CLEO detector

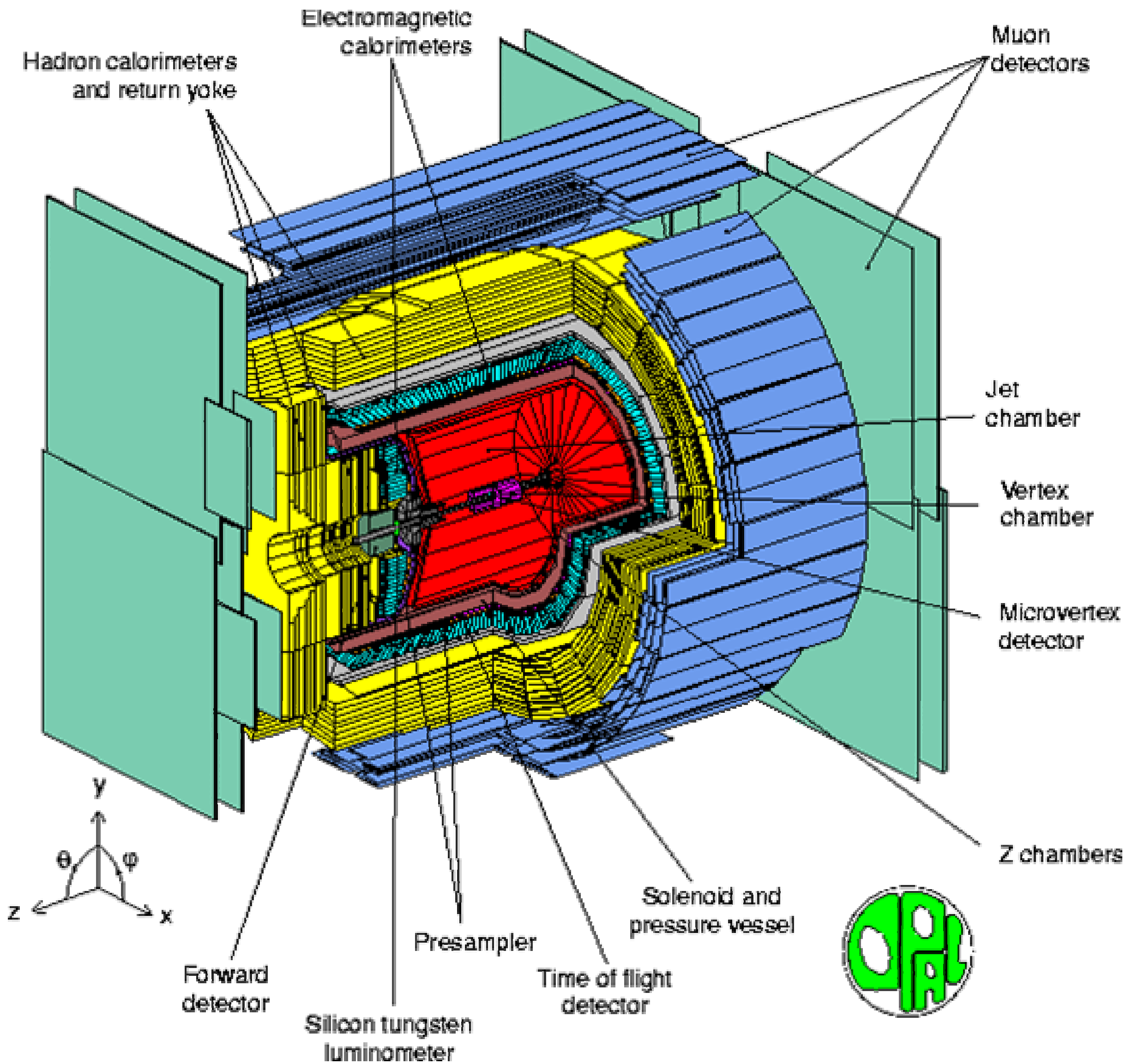


The DELPHI detector



DELPHI

The OPAL detector



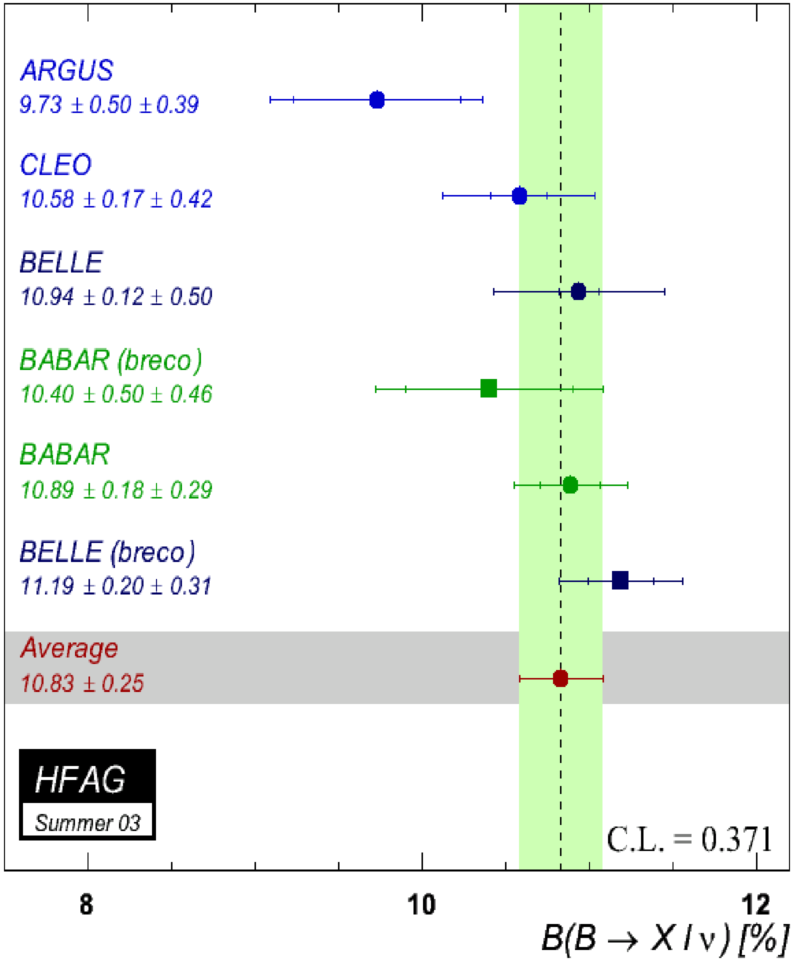
Inclusive $b \to c l \nu$

- rather than focusing on one hadronic final state, sum over all states and compare to quark level calculation

$$\sum_i \Gamma(\overline{B} \to X_c^{(i)} l \overline{\nu}) = \Gamma(b \to c l \overline{\nu})$$

- relies on assumption of quark-hadron duality
- constrain theory parameters and test consistency

Inclusive $BR(B \to X_c l^- \nu)$ and τ_B



Y(4S) $BR(B \to X_c l^- \nu) = (10.83 \pm 0.25) \times 10^{-2}$

$\tau_B = (1.598 \pm 0.01)$ ps

$\Gamma_{B \to Xc\, l-\nu} = 0.446\ (1 \pm 0.023 \pm 0.007) \times 10^{-10}$ MeV

LEP $BR(B \to X l^- \nu) = (10.59 \pm 0.22) \times 10^{-2}$

$BR(B \to X_u l^- \nu) = (\ 0.17 \pm 0.05) \times 10^{-2}$

$BR(B \to X_c l^- \nu) = (10.42 \pm 0.26) \times 10^{-2}$

$\tau_b = (1.573 \pm 0.01)$ ps

$\Gamma_{B \to Xc\, l-\nu} = 0.436\ (1 \pm 0.022 \pm 0.014) \times 10^{-10}$ MeV

word average $\Gamma_{B \to X_C l^- \nu} = 0.441\ (1 \pm 0.018) \times 10^{-10}$ MeV

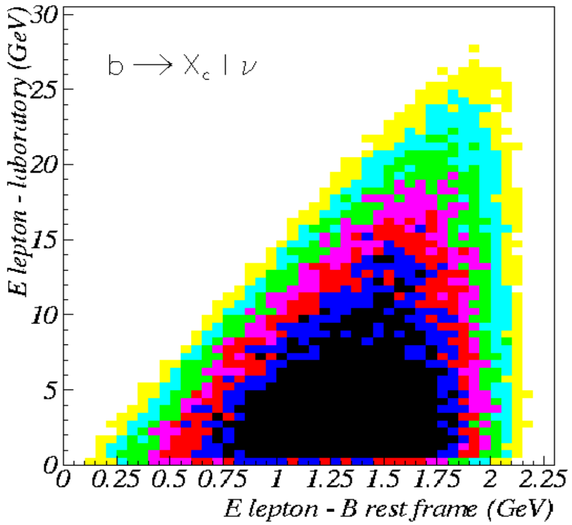
Reconstruction and cuts

TM and © Laurent de Brunhoff

D^*/D^0 are reconstructed in the following modes:

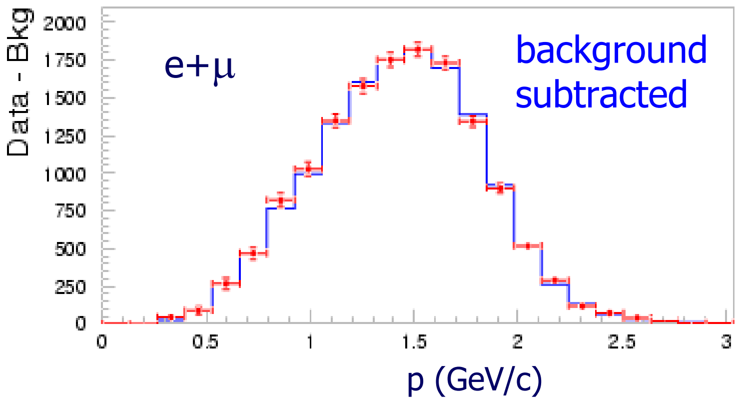
decay mode	BR (%)
$D^{*\pm} \to D^0\pi^\pm$	67.7 ± 0.5
$D^0 \to K\pi$	3.80 ± 0.09
$D^0 \to K_s\pi\pi$	2.96 ± 0.18
$D^0 \to K\pi\pi^0$	13.1 ± 0.9
$D^0 \to K\pi\pi\pi$	7.46 ± 0.31

Moments of lepton energy spectrum and hadronic mass spectrum in $Z \to b\bar{b}$ events



large momentum of b-hadrons (E_B ~30 GeV) gives sensitivity to full lepton energy spectrum in B rest frame: measure first, second and third moment

lepton spectrum in $B \to X_c l^- \nu$



B system reconstructed from lepton+neutrino+charm vertex

lepton boosted in B rest frame

DELPHI'03-28

Results for M_n

$$<m^n_H> = p_D\, m^n_D + p_{D*}\, m^n_{D*} + (1-p_D-p_{D*})<m^n_{D**}>$$

measured

moments of the hadronic mass

$M_1 = <m^2_H - \bar{m}^2_D>$ $= 0.647 \pm 0.046 \pm 0.093\ (GeV/c^2)^2$

$M_2 = <(m^2_H - \bar{m}^2_D)^2>$ $= 1.98 \pm 0.23 \pm 0.29\ (GeV/c^2)^4$

$M_2' = <(m^2_H - <m^2_H>)^2> = 1.56 \pm 0.18 \pm 0.17\ (GeV/c^2)^4$

$M_3' = <(m^2_H - <m^2_H>)^3> = 4.05 \pm 0.74 \pm 0.31\ (GeV/c^2)^6$

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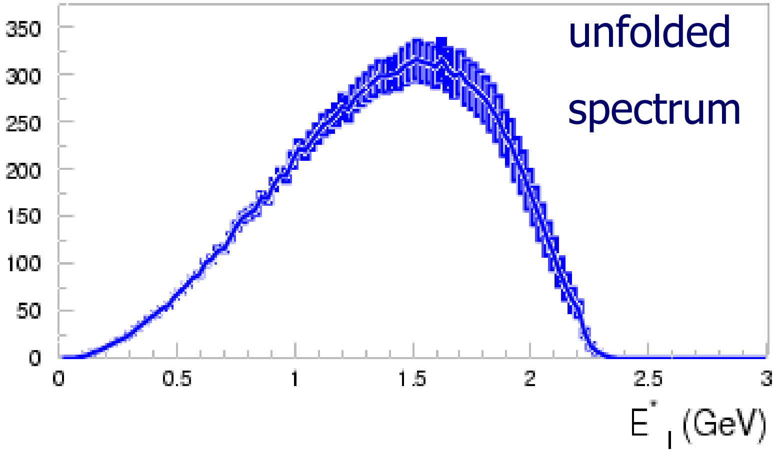
moments of the lepton energy spectrum

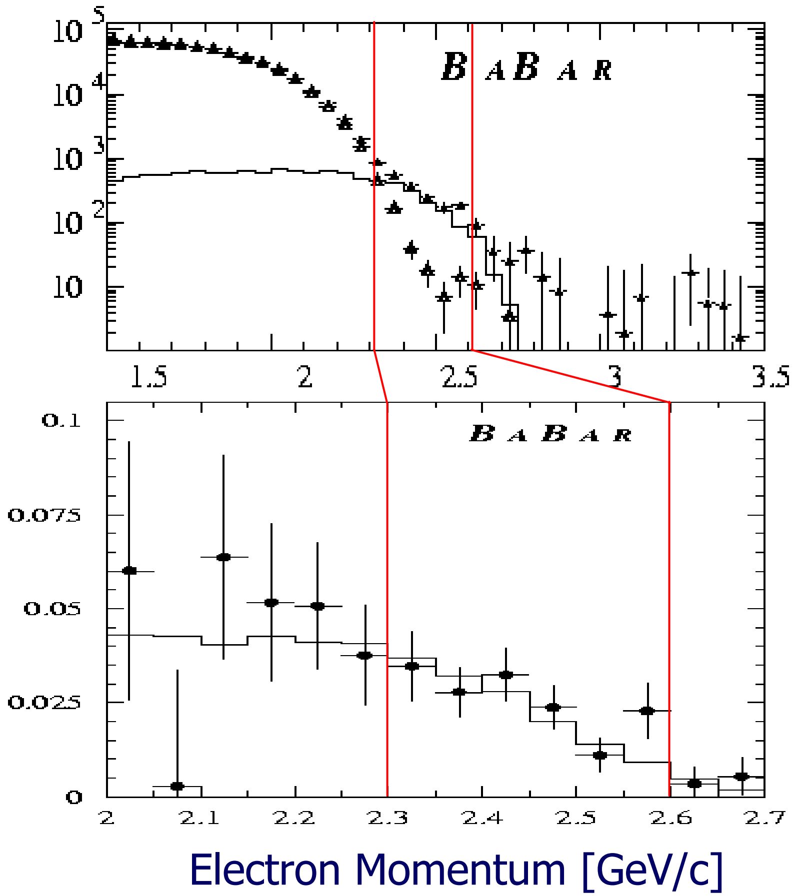
$<E_l^*>$ $= 1.383 \pm 0.012 \pm 0.009$ GeV

$<(E_l^* - <E_l^*>)^2> = 0.192 \pm 0.005 \pm 0.008\ GeV^2$

$<(E_l^* - <E_l^*>)^3> = -0.029 \pm 0.005 \pm 0.006\ GeV^3$



Lepton endpoint



from the partial branching ratio

$$\Delta B(B \to X_u e \nu) = (0.152 \pm 0.014 \pm 0.014) \cdot 10^{-3}$$

with f_u from CLEO ($b \to s\gamma$ measurement)

$$f_u(\Delta p) = \frac{\Delta B}{B} = 0.074 \pm 0.014 \pm 0.009$$

$$B(B \to X_u e \nu) = (2.05 \pm 0.27_{exp} \pm 0.46_{f_u}) \cdot 10^{-3}$$

hep-ex/0207081

Hadronic moments - info

DELPHI '03

							sys
M1	0,647	±	0,046	±	0,093	GeV^2	0,14
M2	1,98	±	0,23	±	0,29	GeV^4	0,15
M2'	1,56	±	0,18	±	0,17	GeV^4	0,11
M3'	4,05	±	0,74	±	0,31	GeV^6	0,08

E1	1,383	±	0,012	±	0,009	GeV	0,01
E2	0,192	±	0,005	±	0,008	GeV^2	0,04
E3	-0,029	±	0,005	±	0,006	GeV^3	0,21

									sys mom	sys theo
$\bar{\Lambda}$	0,542	±	0,065	±	0,087	±	0,040	GeV	0,16	0,07
λ_1	-0,238	±	0,055	±	0,028	±	0,060	GeV^2	0,12	0,25
λ_2	0,116	±	0,004	±	0,000	±	0,010	GeV^2	0,00	0,09
ρ_1	0,030	±	0,028	±	0,007	±	0,030	GeV^3	0,23	1,00
ρ_2	0,066	±	0,025	±	0,019	±	0,190	GeV^3	0,29	2,88
τ_i	0,000	±	0,125	GeV^3						

m_b	4,570	±	0,082	±	0,010	±	0,005	GeV	0,002	0,001
m_c	1,133	±	0,134	±	0,019	±	0,020	GeV	0,02	0,02
μ_π^2	0,382	±	0,070	±	0,031	±	0,020	GeV^2	0,08	0,05
μ_G^2	0,35	±	0,05	GeV^2						
ρ_D^3	0,089	±	0,039	±	0,004	±	0,010	GeV^3	0,04	0,11
ρ_{LS}^3	-0,15	±	0,15	GeV^3						

DELPHI '02

							sys
M1	0,534	±	0,041	±	0,074	GeV^2	0,14
M2	1,508	±	0,200	±	0,230	GeV^4	0,15
M2'	1,226	±	0,158	±	0,152	GeV^4	0,12
M3'	2,970	±	0,673	±	0,478	GeV^6	0,16

E1	1,383	±	0,012	±	0,009	GeV	0,01
E2	0,192	±	0,005	±	0,008	GeV^2	0,04
E3	-0,029	±	0,005	±	0,006	GeV^3	0,21

							sys tot
$\bar{\Lambda}$	0,40	±	0,10	±	0,02	GeV	0,05
λ_1	-0,15	±	0,07	±	0,03	GeV^2	0,20
λ_2	0,12	±	0,01	±	0,01	GeV^2	0,08
ρ_1	-0,01	±	0,03	±	0,03	GeV^3	3,00
ρ_2	0,03	±	0,03	±	0,01	GeV^3	0,33
τ_i	0,000	±	0,125	GeV^3			

m_b	4,59	±	0,08	±	0,01	GeV	0,002
m_c	1,13	±	0,13	±	0,03	GeV	0,027
μ_π^2	0,31	±	0,07	±	0,02	GeV^2	0,065
μ_G^2	0,35	±	0,05	GeV^2			
ρ_D^3	0,05	±	0,04	±	0,01	GeV^3	0,200
ρ_{LS}^3	-0,15	±	0,15	GeV^3			

End of Backup Slides