B Semileptonic Decay Problem
– CLEO's View

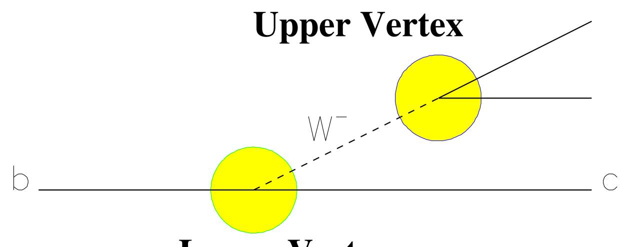
Youngjoon Kwon
University of Rochester

The CLEO Collaboration:

Cal Tech UC-San Diego UC-Santa Barbara
Colorado Cornell Florida Harvard
Hawaii Illinois Carleton McGill Ithaca
Kansas Minnesota SUNY-Albany Ohio State
Oklahoma Purdue Rochester SLAC
Sothern Methodist Syracuse Vanderbilt Virginia Tech

The B semileptonic Decay Problem

b decay modes		Branching Ratio (%) $b_{\mathrm{SL}} = 10.5 \pm 0.5$
$b \to c(u) e\nu$	b_{SL}	10.5 ± 0.5
$b \to c(u) \mu\nu$	b_{SL}	10.5 ± 0.5
$b \to c(u) \tau\nu$	$\frac{1}{4} b_{\mathrm{SL}}$	2.6 ± 0.1
$b \to c(u) \bar{u} d$	$r_{ud}\ b_{\mathrm{SL}}$	$42.0 \pm 2.0 \pm 4.2$[a]
$b \to c(u) \bar{c} s$		
D_s		10.0 ± 2.7
$(c\bar{c})$		3.0 ± 0.5
baryons		1.1 ± 0.8
upper vertex $\bar{D}^0, D^-$		0??
$b \to s(d) g, s(d) q\bar{q}$		1??
Total		$80.7 \pm 4.2 \pm 4.2$



< 100 % !!!

[a] We take $r_{ud} = 4.0 \pm 0.4$ from QCD calculation by E. Bagan, P. Ball, V.M. Braun, & P. Gosdzinsky, Nucl. Phys. **B432**, 3 (1994)

How to measure $\Gamma(B \to DX)$

- Tag one B with high-P (> 1.5GeV/c) lepton
- Angle ($\theta_{D\ell}$) between lepton and D
  - ⋆ ℓ and D from same B ("same B")
    $\Longrightarrow$ peaking towards $\cos\theta_{D\ell} \sim -1$
  - ⋆ ℓ and D from different B's ("other B")
    $\Longrightarrow$ isotropic in $\cos\theta_{D\ell}$
- Take the ratio

$$\frac{N(\ell^-/D, \text{other } B)}{N(\ell^-/\bar{D}, \text{other } B)}$$

- Correct for $B\bar{B}$ mixing etc., and obtain

$$\frac{\Gamma(B \to DX)}{\Gamma(B \to \bar{D}X)}$$

How to measure $\mathcal{B}(b \to sg)$

$$
\begin{aligned}
P_g &\equiv Prob\ (D \text{ production in generic } B \text{ decay}) \\
&= 1 - 2\,|V_{ub}/V_{cb}|^2 - (D_s;\ \text{low. vtx.}) - (c\bar{c}) - baryons\ \ - (b \to sg) \\
P_s &\equiv Prob\ (D \text{ production in semileptonic } B \text{ decay}) \\
&= 1 - 3\,|V_{ub}/V_{cb}|^2
\end{aligned}
$$

- Take the ratio

$$\frac{N(\ell^-/\bar{D}, \text{other } B)}{N(\ell^-/D, \text{same } B)}$$

- Correct for $B\bar{B}$ mixing etc., and obtain

$$\frac{P_g}{P_s} \approx 1 + |V_{ub}/V_{cb}|^2 - (D_s;\ \text{low. vtx.}) - (c\bar{c}) - baryons\ \ - (b \to sg)$$

$\Longrightarrow$ Extract $\mathcal{B}(b \to sg)$ from the ratio!

Experimental Procedure

- Dataset

  ⋆ $\mathcal{L} = 2.41\ \mathrm{fb}^{-1}$ on $\Upsilon(4S)$ (ON)

  ⋆ $= 1.14\ \mathrm{fb}^{-1} \sim 55$ MeV below $\Upsilon(4S)$ (OFF)

- Leptons

  $e^{\pm}$, $\mu^{\pm}$ with $1.5 < p_{\ell} < 2.8$ GeV/c

- D's

  ⋆ $D^0 \to K^-\pi^+$; particle ID[a] – consistent with D^0 but not consistent with $\bar{D}^0$

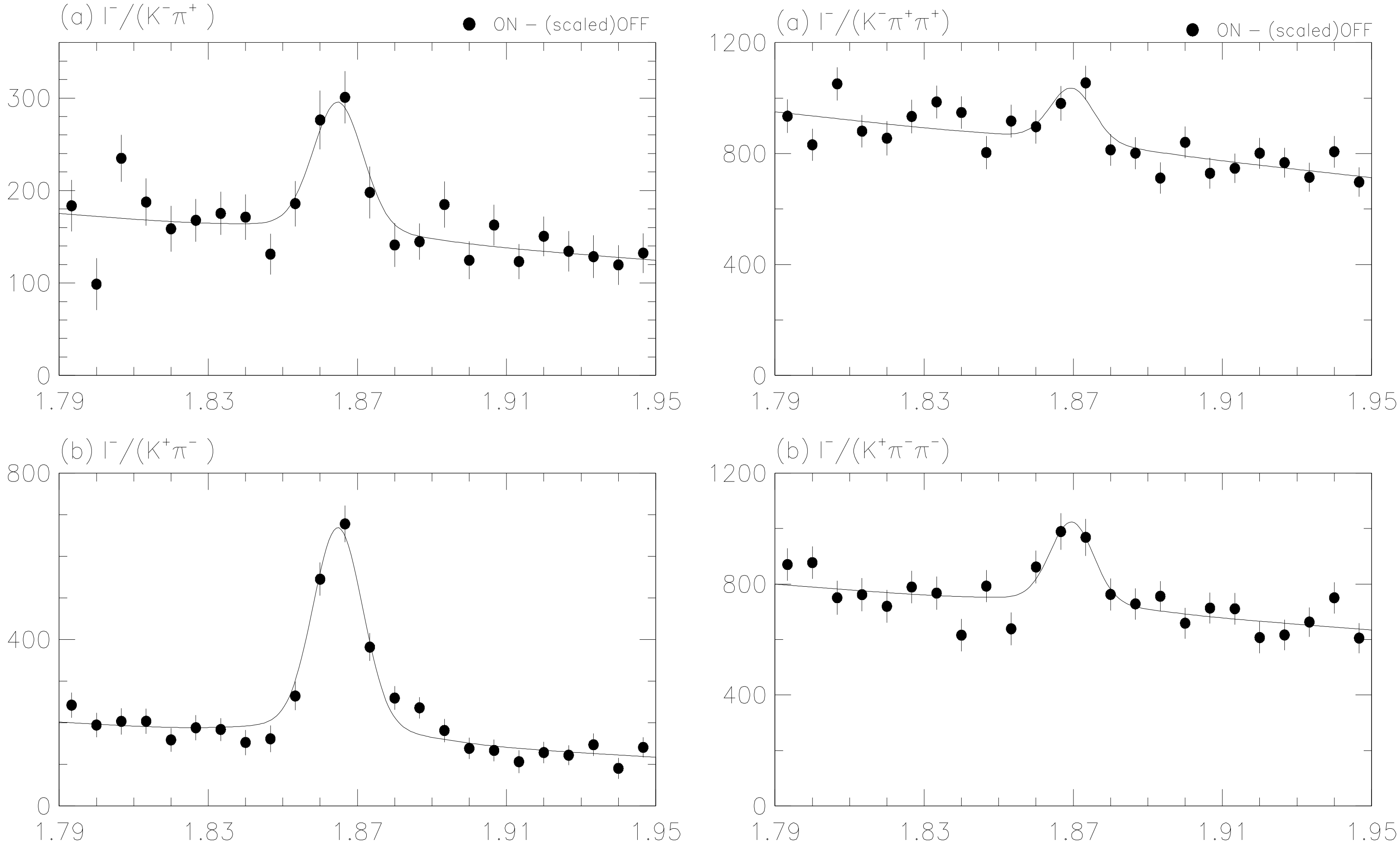
  ⋆ $D^+ \to K^-\pi^+\pi^+$; particle ID[a] – consistent with D^+

- Correct for D^0 and D^+ detection efficiency (a function of D momentum and polar angle), event by event

---

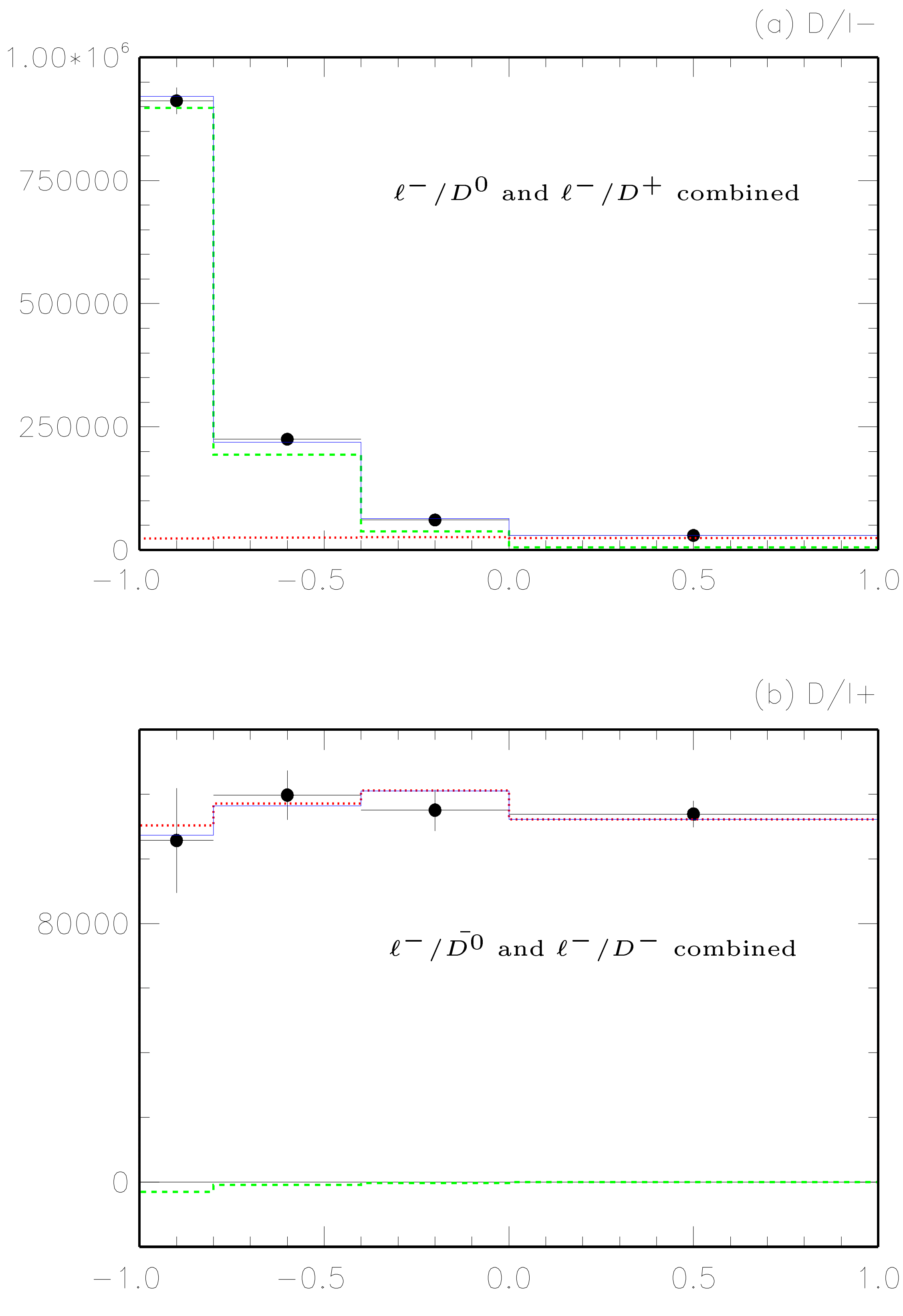
[a] use dE/dx and/or Time-of-Flight

D^0 and D^+ yields



$$0.7 < p_D < 1.4 \text{ GeV/c}; \quad \cos\theta_{D\ell} > 0.0$$

Decomposition into “same B” and “other B”



Results

D-lepton yields from "same B" and "other B"		
$(D,\ \ell^-)$		
	"same B"	$(276.0 \pm 7.5)\times 10^3$
	"other B"	$(48.6 \pm 6.1)\times 10^3$
$(D,\ \ell^+)$		
	"same B"	$(2.9 \pm 5.5)\times 10^3$
	"other B"	$(225.4 \pm 7.3)\times 10^3$

Evidence for D^0 & D^+ from upper vertex

Let

$$x \equiv \frac{N(\ell^-/D, \text{other } B)}{N(\ell^-/\bar{D}, \text{other } B)}$$

Then

$$\frac{\Gamma(B \to DX)}{\Gamma(B \to \bar{D}X)} = \frac{(x - F_m)}{(1 - xF_m)}$$

where F_m is a correction factor for $B\bar{B}$ mixing and lepton-mistag ($F_m \sim 0.11$)

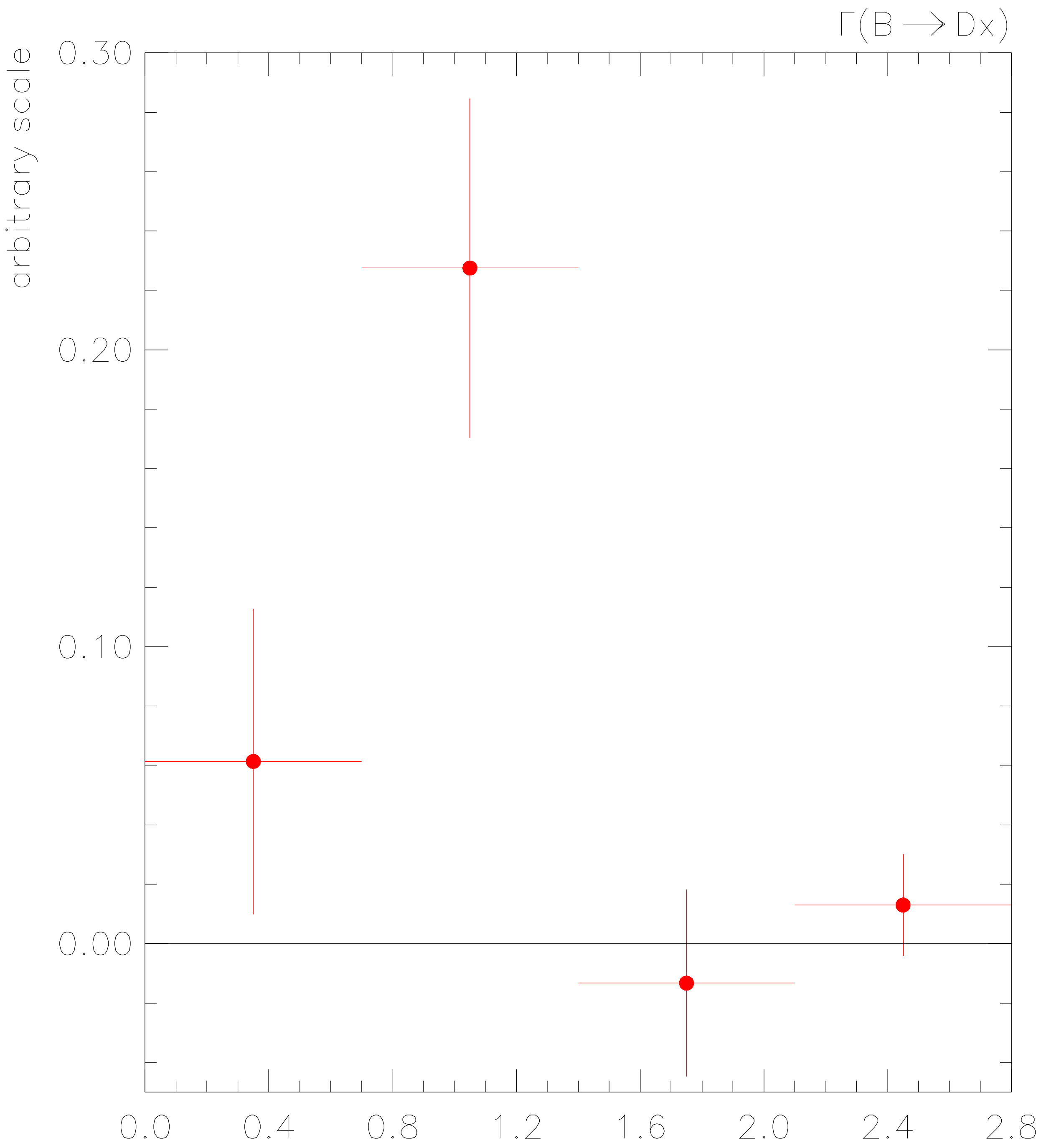
We have measured

$$x = 0.216 \pm 0.028$$

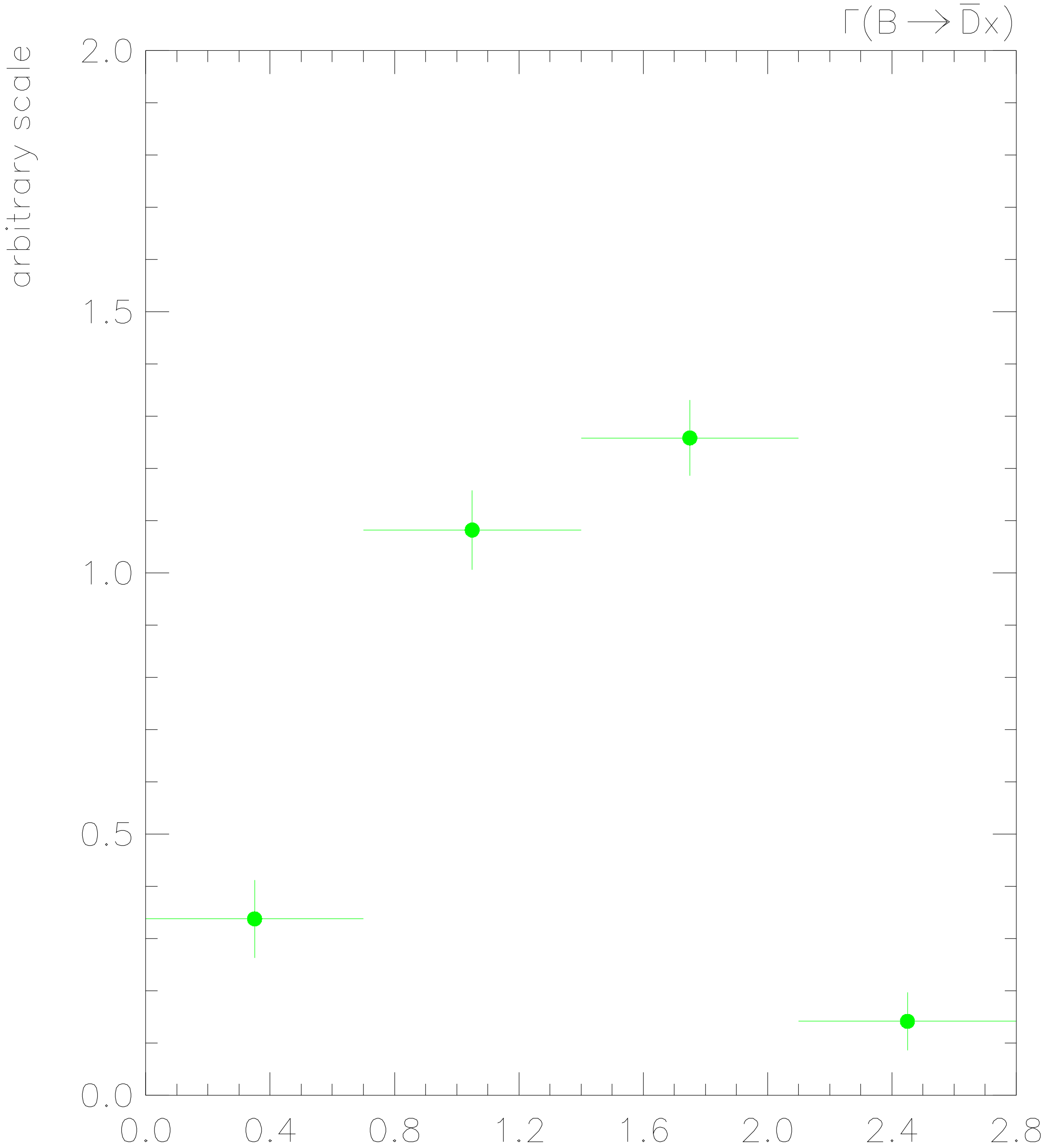
and

$$\frac{\Gamma(B \to DX)}{\Gamma(B \to \bar{D}X)} = 0.107 \pm 0.029 \pm 0.018$$

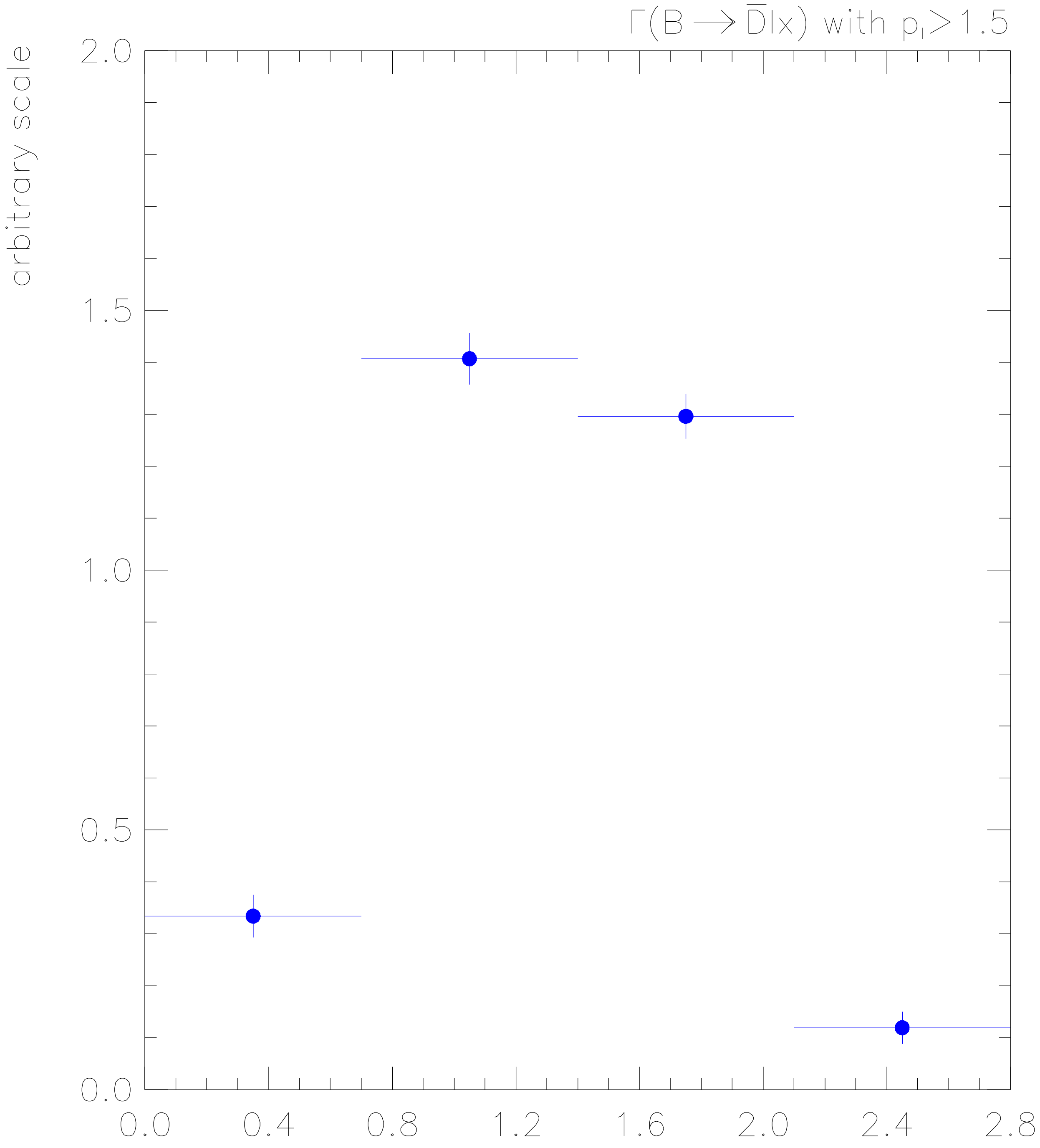
Momentum distribution of upper vertex D



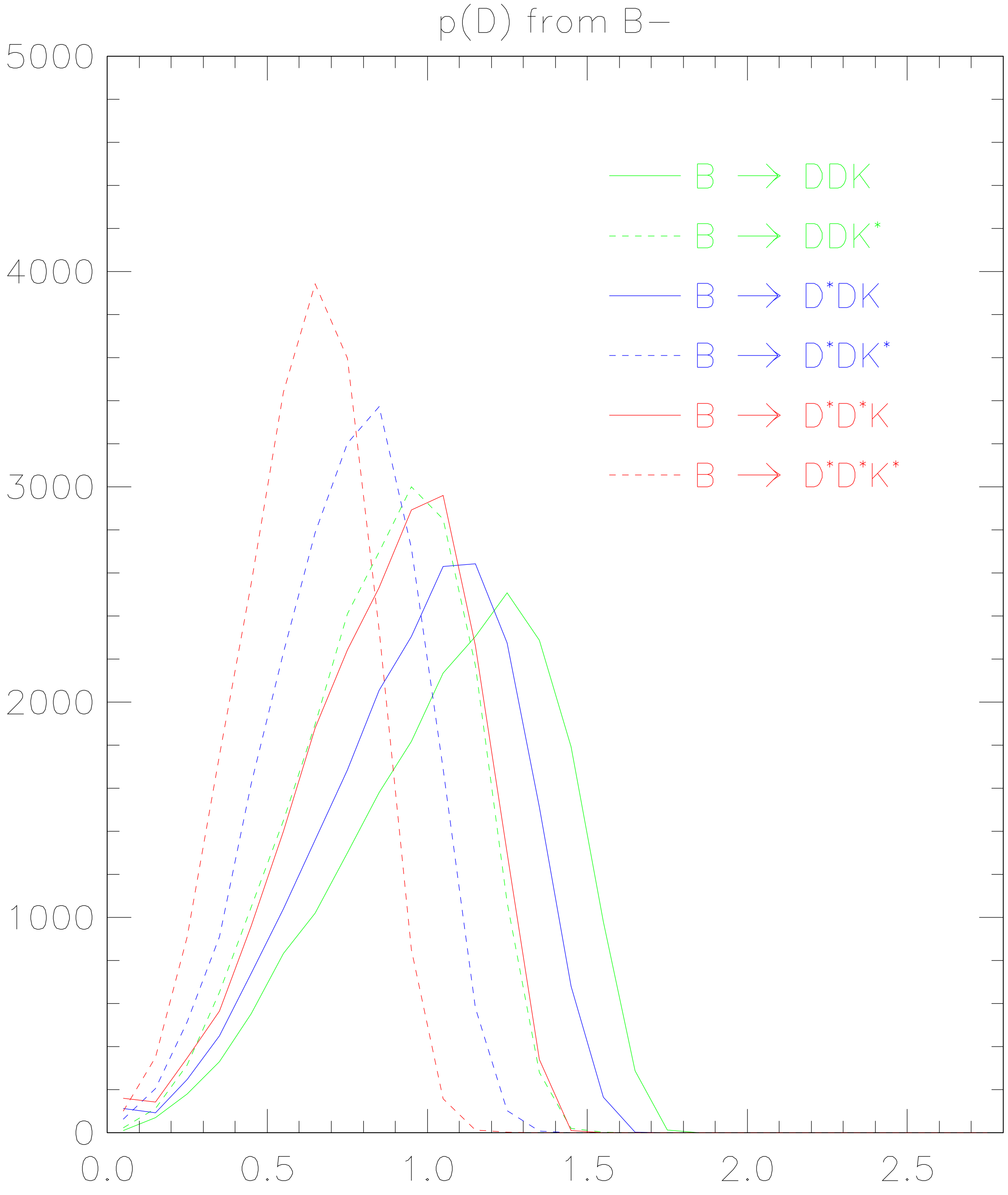
Momentum distribution of lower vertex D



Momentum distrib. of D from $\bar{B} \to D\ell^- X$ decay



$p(D)$ in MC 3-body phase-space decay of $B \to D\bar{D}KX$



What about $b \to sg$?

We have measured

$$\frac{N(\ell^-/\bar{D}, \text{other } B)}{N(\ell^-/D, \text{same } B)} = 0.834 \pm 0.034$$

After correcting for $B\bar{B}$ mixing and lepton-mistag,

$$\begin{aligned} \frac{P_g}{P_s} &\equiv \frac{\Gamma(B \to \bar{D}X)}{\Gamma(B \to \text{all})} \Big/ \frac{\Gamma(B \to \ell^+ \bar{D}X)}{\Gamma(B \to \ell^+ X)} \\ &= 0.886 \pm 0.037 \pm 0.019 \end{aligned}$$

$b \to sg$ *(continued)*

Since

$$\frac{P_g}{P_s} \approx 1 + |V_{ub}/V_{cb}|^2 - (D_s;\ \text{low. vtx.}) - (c\bar{c}) - \textit{baryons} \ - (b \to sg)$$

$$= 1.000 + |V_{ub}/V_{cb}|^2 - (0.010 \pm 0.005) - (0.030 \pm 0.005) - (0.065 \pm 0.015)$$

$$-(b \to sg)$$

$$= 0.895 \pm 0.017 + |V_{ub}/V_{cb}|^2 - (b \to sg)$$

Using $|V_{ub}/V_{cb}|^2 = 0.008 \pm 0.003$, we obtain

$$\mathcal{B}(b \to sg) = (1.7 \pm 3.7 \pm 1.7 \pm 1.9)\% < 8.5\% \quad @90\%\ \text{CL}$$

Note: For lower-vertex D_s we used a guesstimate from CLEO's preliminary results presented in CLEO-CONF95-11.

The B s-l. Decay Problem Revisited

To find the contribution of upper vertex D to the B decay table in p.3, use

$$\mathcal{B}(B \to DX) = (0.107 \pm 0.034) \times \mathcal{B}(B \to \bar{D}X)$$

and

$$\begin{aligned} \mathcal{B}(B \to \bar{D}X) \quad &= \quad b_{\mathrm{SL}}(2.25 + r_{ud}) + (B \to D_s^+ X) - (B \to D_s^- X) \\ &\quad -(B \to \text{ baryons}) + (B \to DX) \end{aligned}$$

Taking $r_{ud} = 4.0 \pm 0.4$[a] we have

$$\mathcal{B}(B \to DX) = (8.1 \pm 2.6)\ \%$$

---

[a] E. Bagan, *et al.* (1994)

The B s-l. Decay Problem Revisited (*cont.*)

b decay modes	Branching Ratio (%)	$b_{\mathrm{SL}} = 10.5 \pm 0.5$
$b \to c(u)e\nu$	b_{SL}	10.5 ± 0.5
$b \to c(u)\mu\nu$	b_{SL}	10.5 ± 0.5
$b \to c(u)\tau\nu$	$\frac{1}{4}b_{\mathrm{SL}}$	2.6 ± 0.1
$b \to c(u)\bar{u}d$	$(4.0 \pm 0.4)\ b_{\mathrm{SL}}$	$42.0 \pm 2.0 \pm 4.2$
$b \to c(u)\bar{c}s$		
D_s		10.0 ± 2.7
$(c\bar{c})$		3.0 ± 0.5
baryons		1.1 ± 0.8
upper vertex $\bar{D}^0, D^-$		8.1 ± 2.6
$b \to s(d)g, s(d)q\bar{q}$		1.7 ± 4.5
Total		$89.5 \pm 6.8 \pm 4.2$

Note: If we take r_{ud} as a parameter to be determined, and use the "measured" value for $b \to sg$, we find $r_{ud} = 4.89 \pm 0.58$.

Summary and Conclusions

- First evidence for upper vertex D production!

$$\frac{\Gamma(B \to DX)}{\Gamma(B \to \bar{D}X)} = 0.107 \pm 0.029 \pm 0.018$$

- First shot at inclusive $b \to sg$ decay:

$$\mathcal{B}(b \to sg) < 8.5\% \qquad @90\%\ \mathrm{CL}$$

- New assessment of B semileptonic decay problem:
  - ⋆ $(89.5 \pm 6.8 \pm 4.2)$ % is accounted for.
  - ⋆ Upper vertex D helps but may not be enough!