Semileptonic D decays & $B \to \tau\nu$ at BaBar

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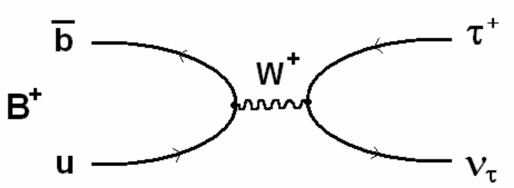
Nagoya, CKM 2006

Outline

- Leptonic B decays: $B^+ \to \tau^+ \nu$



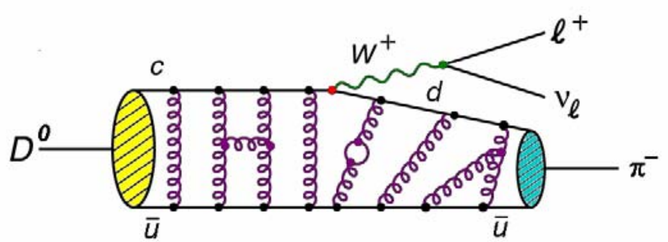
--- H+--- ?

★ Check New Physics

★ Determination of the decay constant f_B

$$\mathcal{B}(B^+ \to \ell^+ \nu) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

- Charm semileptonic decays: $D^0 \to K\ell\nu$ $D^0 \to \pi\ell\nu$ $D_s \to \eta/\eta'\ell\nu$ $D_s \to \phi\ell\nu$ $D \to K\pi\ell\nu$ ...



★ Determination of form factors $f_+(q^2)$

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{24\pi^3}|V_{cd}|^2 p_\pi^3(q^2)\left|f_+(q^2)\right|^2$$

$B \to \tau \nu$

★ 288 fb^{-1}

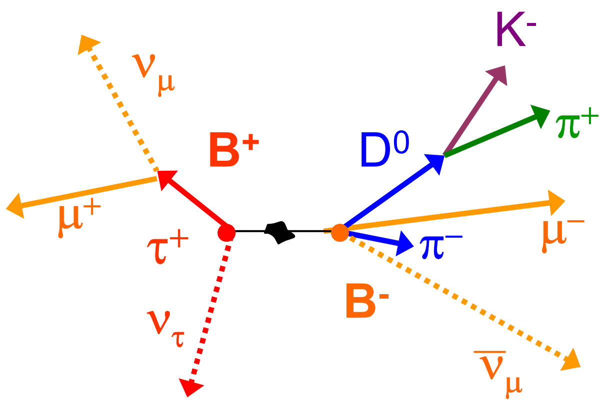
- **Analysis technique:**

★ One B reconstructed (B_{tag}) in the semileptonic mode $B^- \to D^0 X \ell^- \nu$

($D^0 \to K^-\pi^+$, $K^-\pi^+\pi^-\pi^+$, $K^-\pi^+\pi^0$, $K^0_s\pi^+\pi^-$)

★ Search for signal $B^+ \to \tau^+ \nu$ from the other B

($\tau^+ \to e^+\nu\nu$ (eff: 4.1%), $\mu^+\nu\nu$ (2.4%), $\pi^+\nu$ (4.9%), $\pi^+\pi^0\nu$ (1.2%))



★ Determine the extra energy in the event (E_{extra})

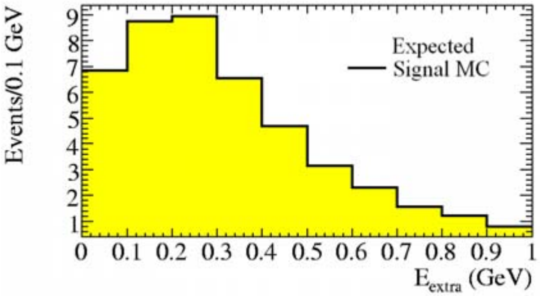
★ Subtract bkg estimate

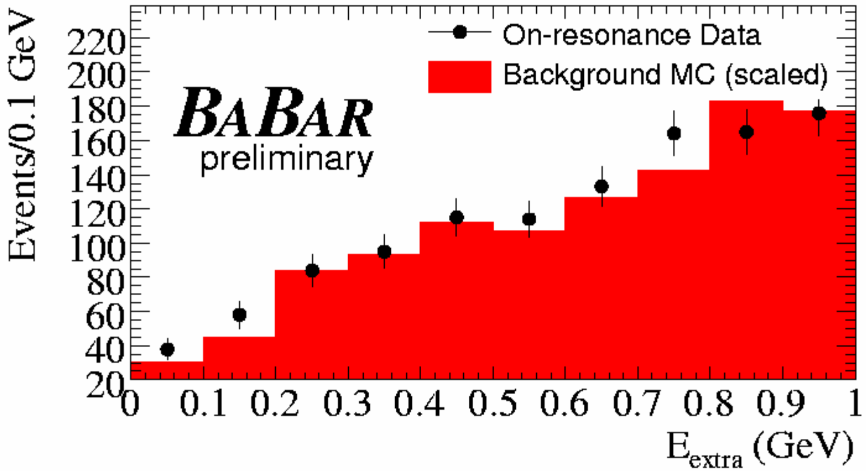
★ Blind analysis

★ Control samples from data (double-tag, wrong sign events)

B → τ ν

- Results:





Selection	Expected Background Events	Observed Events in On-resonance Data
$e^+\nu_e\bar{\nu}_\tau$	41.9 ± 5.2	51
$\mu^+\nu_\mu\bar{\nu}_\tau$	35.4 ± 4.2	36
$\pi^+\bar{\nu}_\tau$	99.1 ± 9.1	109
$\pi^+\pi^0\bar{\nu}_\tau$	15.3 ± 3.5	17
All modes	191.7 ± 11.8	213

Found no significant signal

$$\mathcal{B}(B^+ \to \tau^+\nu_\tau) =$$
$$(0.88^{+0.68}_{-0.67}(\text{stat.}) \pm 0.11(\text{syst.})) \times 10^{-4}$$

↓

$$\mathcal{B}(B^+ \to \tau^+\nu_\tau) < 1.8 \times 10^{-4}$$ @ 90% CL

$B \to \tau \nu$

	$\mathcal{B}(B\to\tau\nu)$	f_B*	Statistics
BaBar	$(0.88\,^{+0.68}_{-0.67}\,(stat)\ \pm 0.11\,(syst))10^{-4}$	$0.159\,^{+0.052}_{-0.082}\,(stat)\ ^{+0.015}_{-0.016}\,(syst)$	288 fb^{-1}
Belle	$(1.79\,^{+0.56}_{-0.49}\,(stat)\ ^{+0.46}_{-0.51}\,(syst))10^{-4}$	$0.229\,^{+0.036}_{-0.031}\,(stat)\ ^{+0.034}_{-0.037}\,(syst)$	414 fb^{-1}
SM	$(1.59 \pm 0.40)10^{-4}$	0.216 ± 0.022 GeV (HPQCD)	

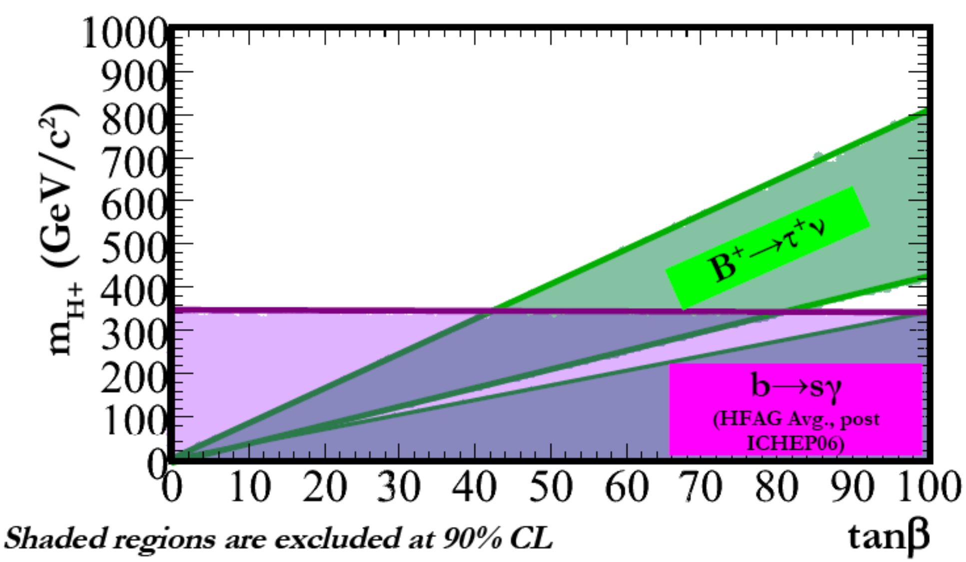
* $|V_{ub}|=(4.39\pm0.33)10^{-4}$ from B sl decays

- **B-factories average:**

$\mathcal{B}(B\to\tau\nu)=(1.42 \pm 0.43)10^{-4}$

(~0.25 with 2ab^{-1})

- **Constraints on 2HDM:**



Semileptonic D decays

- Charm sl decays provide a powerful test of Lattice calculations $\rightarrow$

  confidence in theoretical errors in the B sector

- B-factories have a very large charm sample:
  very large $\mathcal{L}$; large σ_{cc} (1.3nb) @ the Υ(4s).

- Extensive program in BaBar, study of many channels ongoing:

  $D^0 \rightarrow K \ell \nu$ $D^0 \rightarrow \pi \ell \nu$ $D_s \rightarrow \eta/\eta' \ell \nu$
  $D_s \rightarrow \phi \ell \nu$ $D \rightarrow K\pi \ell \nu$ ...

- Measurements of form factors and (relative)$\mathcal{B}$ranching fractions

Semileptonic D decays

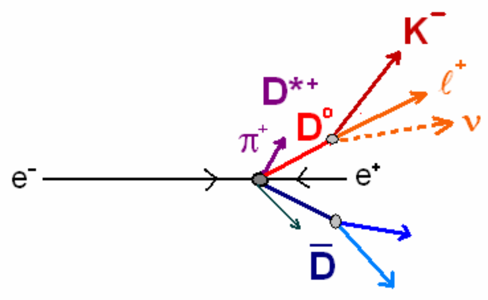
- **Analysis basis:**

  - ★ Untagged analyses:
    - → large statistics
    - → some background
  - ★ From continuum events
    - → use event shape variables to remove BB's
    - → use event topology and kinematical variables to reduce the charm background
  - ★ Kinematical fit to extract the $q^2=(p_\ell+p_\nu)^2=(p_{Xc}-p_{Xq})^2$
    - → input missing energy in the event and D direction estimates
  - ★ Different fit methods to extract the form factor(s)
  - ★ Data control samples: test the efficiency reconstruction, resolution, control on systematics ...

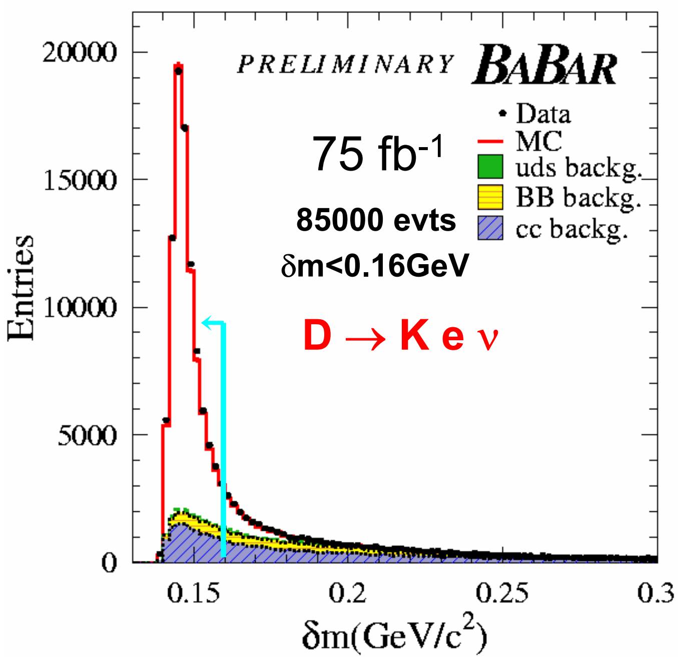
Semileptonic D decays

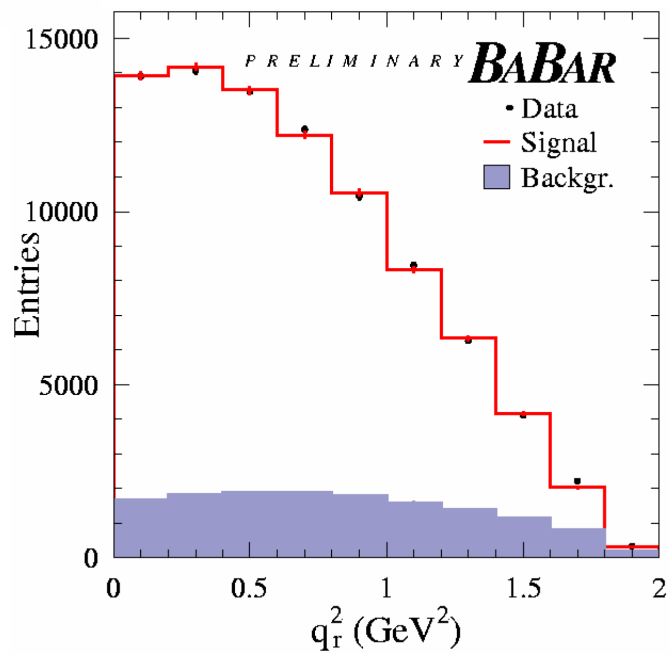
- **D→Keν:**

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



- ★ 75 fb^{-1} (1/5 of the total data)
- ★ 16% of background
- ★ q^2 resolution (0.08-0.25) GeV^2





Semileptonic D decays

- $D \to K e \nu$:

★ Form factor extraction

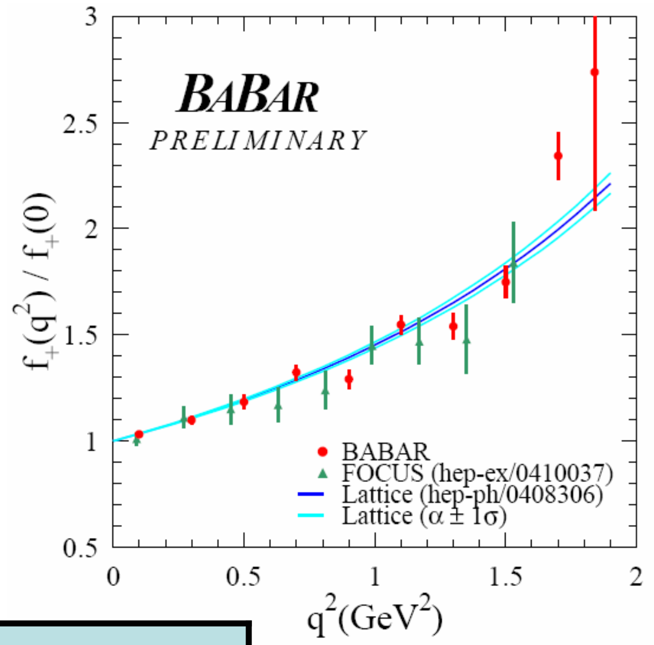
$$\frac{d\Gamma}{dq^2} = \frac{G_f^2 |V_{cs}|^2 \; p_K^3}{24\pi^3} |f_+(q^2)|^2$$

Pole form factor KS, Z.Phys.C38 (88) 511

$$\left|f_+(q^2)\right| = \frac{f_+(0)}{1 - \frac{q^2}{m_{pole}^2}}$$

Modified pole B&K, PLB478 (00) 417

$$\left|f_+(q^2)\right| = \frac{f_+(0)}{\left(1 - \frac{q^2}{m_{D_s^*}^2}\right)\left(1 - \frac{\alpha_{pole} q^2}{m_{D_s^*}^2}\right)}$$



	stat	m_{pole}(GeV/c^2)	α_{pole}	
CLEO-III	7 fb^{-1}	$1.89 \pm 0.05 ^{+0.04}_{-0.03}$	$0.36 \pm 0.10 ^{+0.03}_{-0.07}$	PRL94 (05) 011802
FOCUS	13k evts	$1.93 \pm 0.05 \pm 0.03$	$0.28 \pm 0.08 \pm 0.07$	PLB207 (05) 233
CLEO-c	281 pb^{-1}	$1.98 \pm 0.03 \pm 0.02$	$0.19 \pm 0.05 \pm 0.03$	*preliminary*
Belle	282 fb^{-1}	$1.82 \pm 0.04 \pm 0.03$	$0.52 \pm 0.08 \pm 0.06$	PRL97(06) 061804
BaBar	75 fb^{-1}	$1.854 \pm 0.016 \pm 0.020$	$0.43 \pm 0.03 \pm 0.04$	*preliminary* (hep-ex/0607077)

★ Clear discrepancy (3σ) with CLEO-c

★ Agreement with Lattice $\alpha = 0.50 \pm 0.04$

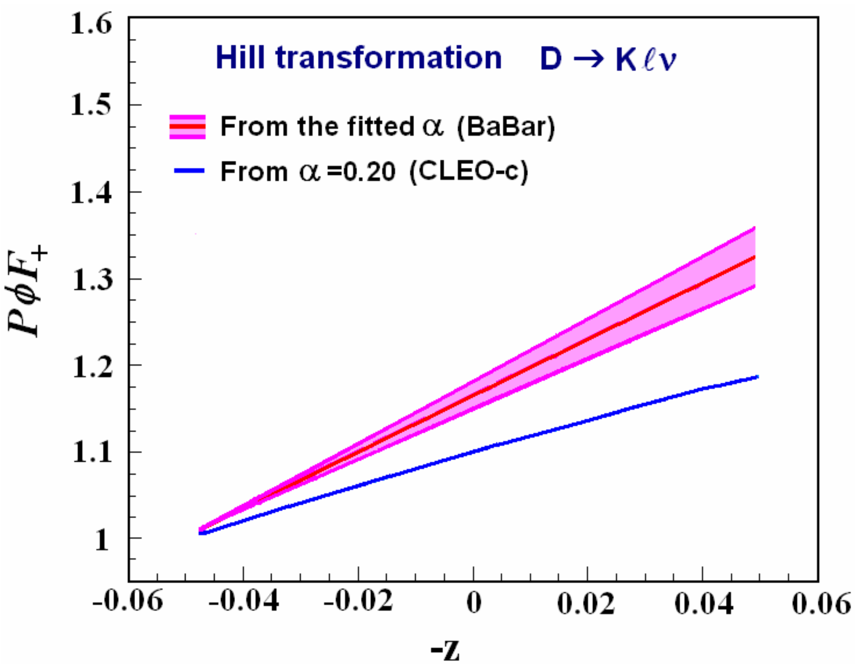
PRL94 (05) 011601

Semileptonic D decays

- $D \to K e \nu$:

★ New approach for the form factor parameterization:

Richard J. Hill (hep-ph/0606023) $F(q^2) \to F(z(q^2))$



$$z(t, t_0) \equiv \frac{\sqrt{t_+ - t} - \sqrt{t_+ - t_0}}{\sqrt{t_+ - t} + \sqrt{t_+ - t_0}}$$

$$t \equiv q^2$$

$$t_\pm \equiv (m_{X_c} \pm m_{X_s})^2$$

$$t_0 = t_+(1 - \sqrt{1 - t_-/t_+})$$

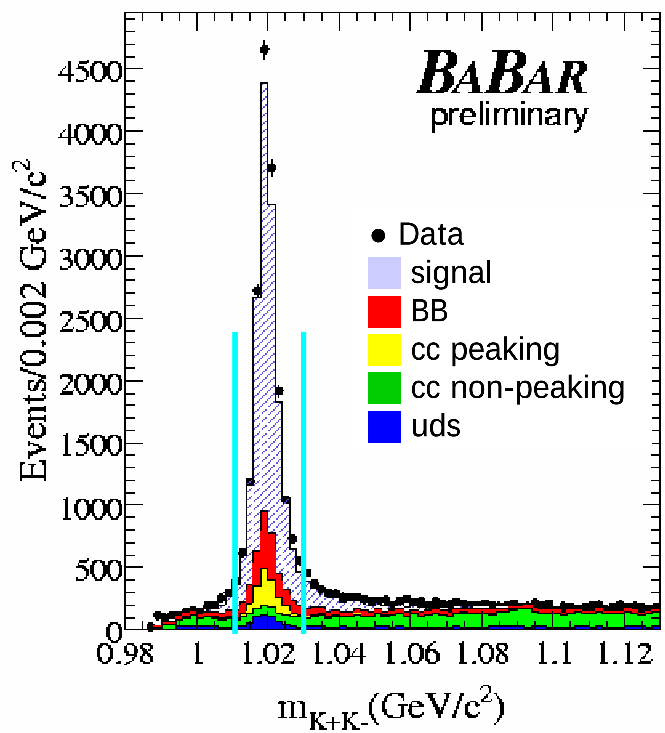
$$F(t) = \frac{1}{P(t)\phi(t, t_0)} \sum_{k=0}^{\infty} a_k(t_0) z(t, t_0)^k$$

★ $P\phi F_+$ nearly linear as function of z

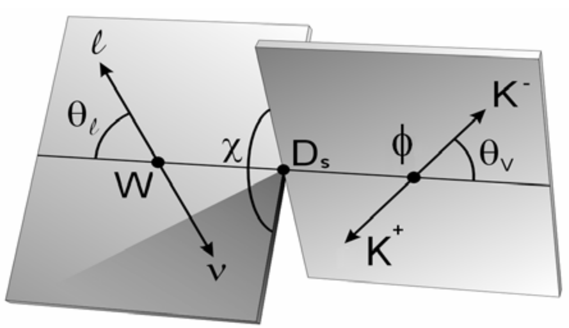
Semileptonic D_s decays

- $D_s \to \phi e \nu$:

  - ★ 75 fb^{-1} (1/5 of the total data)
  - ★ $\phi \to K^+K^-$ reconstruction
    (no γ reconstruction from $D_s^* \to D_s\gamma$)
  - ★ 26% of background (13000 signal evts)
  - ★ The $D_s \to \phi e \nu$ decay rate depends on 4 variables: q^2, θ_V, θ_ℓ, χ and 2 form factor ratios r_V and r_2



$$r_2 \equiv A_2(0)/A_1(0)$$
$$r_v \equiv V(0)/A_1(0)$$



$A_1(q^2)$, $A_2(q^2)$, and $V(q^2)$ shapes:

- ▸ Pole form factors
- ▸ More sophisticated (B&K based) → Fajfer and Kamenic, PRD72(05) 034029

Semileptonic D_s decays

★ Fit in 4D, using pole form factor shapes:

$$V(q^2) = \frac{V(0)}{1 - q^2/M_V^2}$$

$$A_{1,2}(q^2) = \frac{A_{1,2}(0)}{1 - q^2/M_A^2}$$

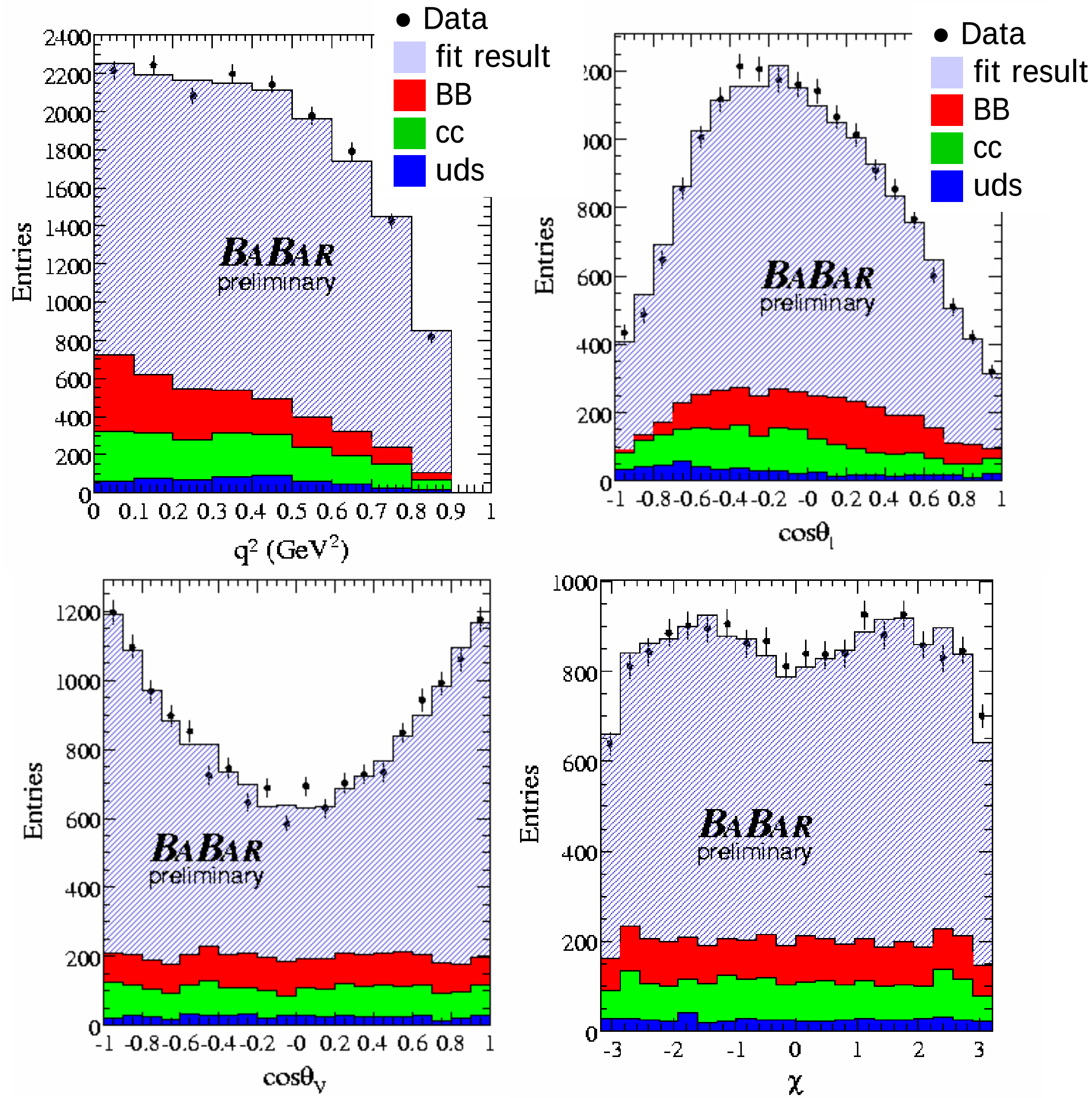
with M_A=2.5GeV and M_V =2.1 GeV

↓

$r_2 = 0.705 \pm 0.056 \pm 0.029$

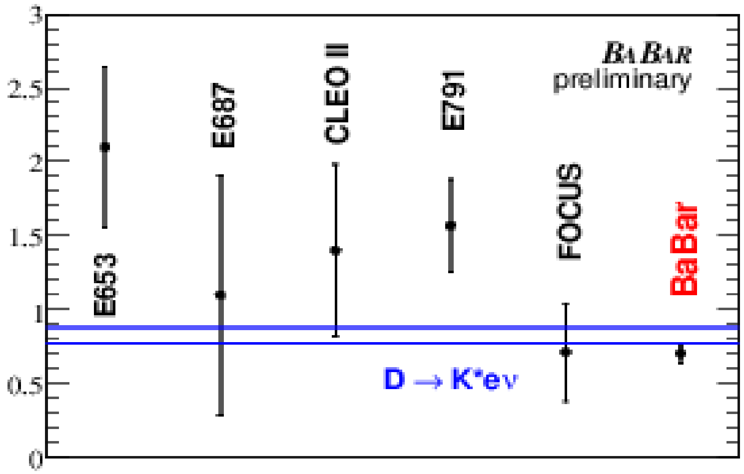
$r_V = 1.636 \pm 0.067 \pm 0.038$

hep-ex/0607085

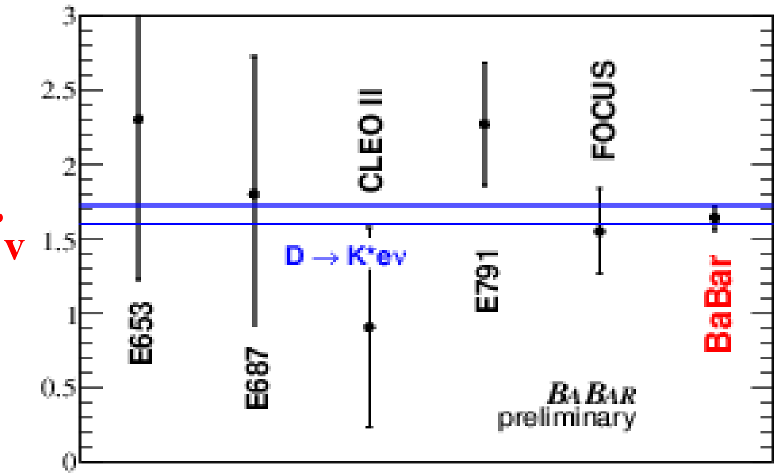


Semileptonic D_s decays

r_2



r_V



- ★ Similar accuracy as $D \to K^* \ell \nu$
- ★ Letting free the axial pole mass in the fit →

$$r_2 = 0.711 \pm 0.111 \pm 0.096$$
$$r_V = 1.633 \pm 0.081 \pm 0.068$$
$$M_A = 2.53\ ^{+0.54}_{-0.34} \pm 0.054\ \mathrm{GeV}/c^2$$

Semileptonic D decays

- Coming soon:

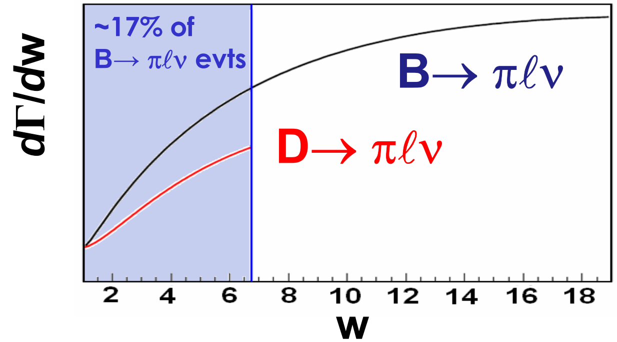
★ Final results for D→Keν with improved errors, including the form factor normalization and branching ratio measurents

★ Normalization and form factor shapes for $D_s \to \phi e\nu$

★ Form factor and branching ratio measurements for D→πeν

→ Exploit the relation:

$$\frac{d\Gamma(B\to\pi e\overline{\nu}_e)/dE_\pi}{d\Gamma(D\to\pi e\overline{\nu}_e)/dE_\pi} = \left|\frac{V_{ub}}{V_{cd}}\right|^2 \left(\frac{M_B}{M_D}\right) \left|\frac{f_+^{B\to\pi}}{f_+^{D\to\pi}}\right|^2$$



→ w overlap to relate D→π and B→π form factors

★ Form factor and branching ratio measurements for D→Kπeν

Summary

★ Not found (yet) a significant $B \to \tau\nu$ signal

$\to$ BaBar results with updated statistics coming soon

★ Extensive program on charm semileptonic decays

$\to$ High accuracy results on form factors:

- Better understanding of the decay dynamics

  (ex: from $D \to Ke\nu$ ISW2 and simple pole (with $m_{pole}=m_{D^*s}$) excluded)

- 3σ discrepancy between BaBar and Cleo-c for $D \to Ke\nu$
- Impressive accuracy for the D_s (similar to $D \to K^* \ell\nu$)

$\to$ With the present accuracy we need a better understanding from theory and experiments of radiative effects