Exclusive Semileptonic Decays in BABAR

IV CKM WORKSHOP - Nagoya

OUTLINE :

- Motivations
- Untagged measurements:
  - Br($B^0 \to D^{*-} l^+ \nu$), F.F. and $|V_{cb}|$
  - Br($B \to D_1/D^*_2 l^+ \nu$)
- Measurements on tagged events
  - Br($B^- \to D/D^*/D^{**} l \nu$)

franco simonetto INFN & Universita' di Padova

INFN

Motivations for Xclusive analysis

- LQCD calculations of FF (will) push theoretical error on $|V_{cb}|$ close to inclusive result
- Need detailed understanding of $B \to D^{(*)(*)} l\nu$ spectra to fix background for $|V_{ub}|$ measurements
- Sum of Xclusive states misses inclusive BR

Decay Mode	Branching Fraction
$B^+ \to l^+ \nu_l$ + anything	10.9 ± 0.4 %
$B^+ \to \bar{D}^*(2007)^0 \ell^+ \nu_\ell$	(6.5 ± 0.5) %
$B^+ \to \bar{D}^0 \ell^+ \nu_\ell$	(2.15 ± 0.22) %
$B^+ \to \bar{D}_1(2420)^0 \ell^+ \nu_\ell$	(0.56 ± 0.16) %
$B^+ \to \bar{D}_2(2460)^0 \ell^+ \nu_\ell$	< 0.8% @90CL
$B^+ \to D^- \pi^+ \ell^+ \nu_\ell$	(0.53 ± 0.10) %
$B^+ \to D^{*+} \pi^+ \ell^+ \nu_\ell$	(0.64 ± 0.15) %
$B^+ \to \bar{D}^{(*)} n\pi \ell^+ \nu_\ell$	??

PDG 2006:

5 (10)% mismatch for B^+ (B^0)

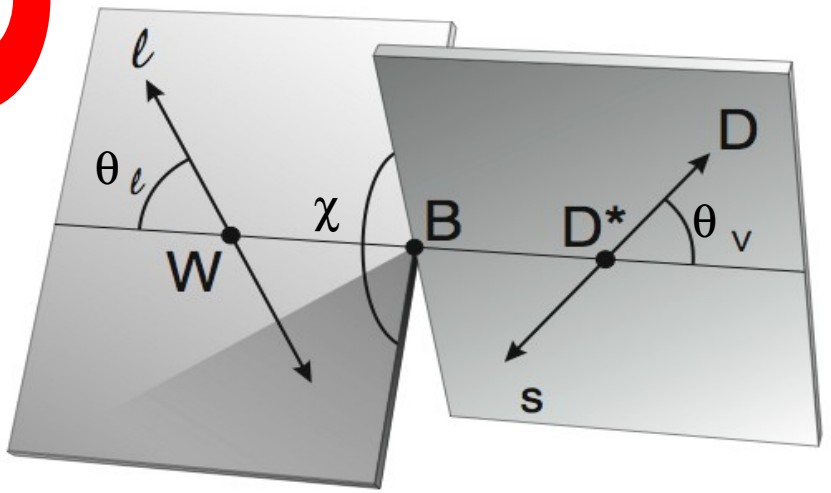
INFN

$B^0 \to D^{*-} l^+ \nu$: F.F. , Br & $|V_{cb}|$

Phase Space

$$\frac{d\Gamma(B^0 \to D^{*-}\ell^+\nu_\ell)}{dw\, d\cos\theta_\ell\, d\cos\theta_V\, d\chi} = \frac{G_F^2 |V_{cb}|^2}{48\pi^3} F(w,\theta_\ell,\theta_V,\chi) G(w)$$

Form factors parameterized in terms of R_1, R_2 (ratios of *FF* at *w=1*), and ρ^2 (slope at *w=1*), using analicity and QCD bounds
(from *NPB530 (1998) 153*)



$$w = v_B \cdot v_{D^*} = \frac{M_B^2 + M_{D^*}^2 - q^2}{2 M_B M_{D^*}}$$

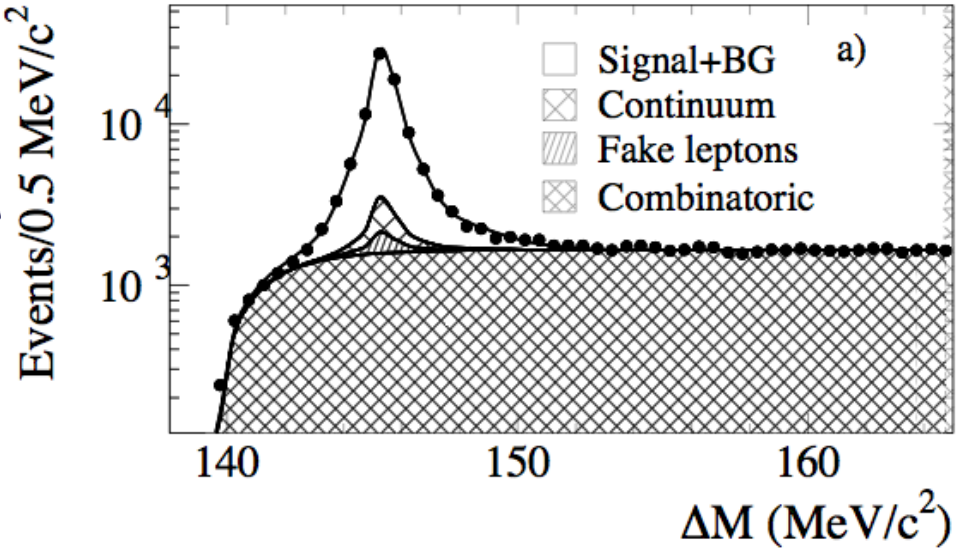
franco simonetto INFN & Universita' di Padova

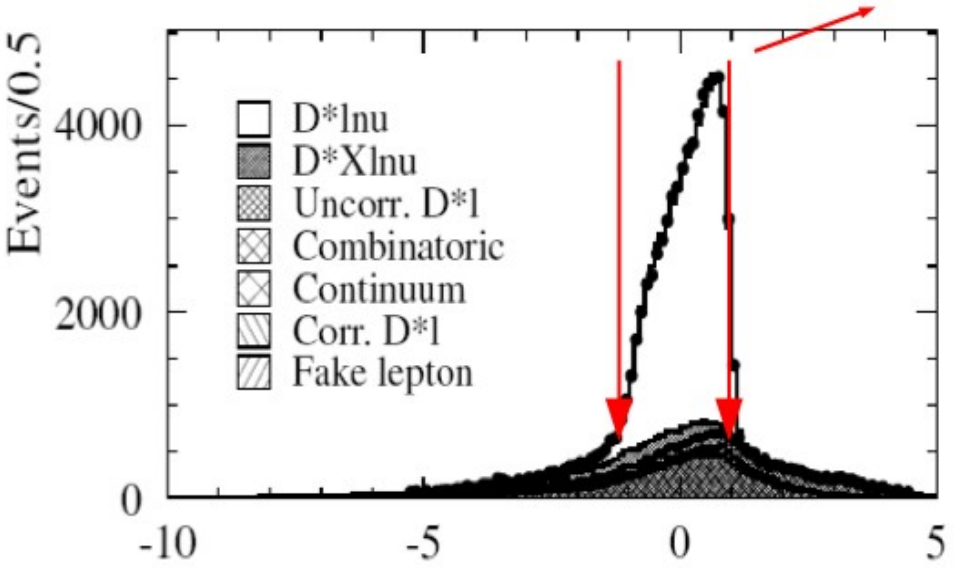
The Measurement

- Determine R_1, R_2, ρ^2 and $|V_{cb}|$, by χ^2 fit to w, $\cos\theta_l$ and $\cos\theta_V$ projections (account for correlations)
- 50K signal evts (72 fb^{-1}) from

  $D^{*+} \to \pi^+ D^0$, $D^0 \to K\pi, K3\pi, K\pi\pi^0$

- Background (combinatoric, uncorrelated,D**) in each bin from Δm, $\cos\theta_{BY}$ side bands
- Signal : reweight Monte Carlo





$$\cos\theta_{BY} = -\frac{M_B^2 + M_Y^2 - 2E_B E_Y}{2p_B p_Y}$$

Results

χ^2/ndof = 24/24

- Combined with loosely correlated BABAR result, hep-ex 0602023 :

$R_1 = 1.417 \pm 0.061 \pm 0.044$

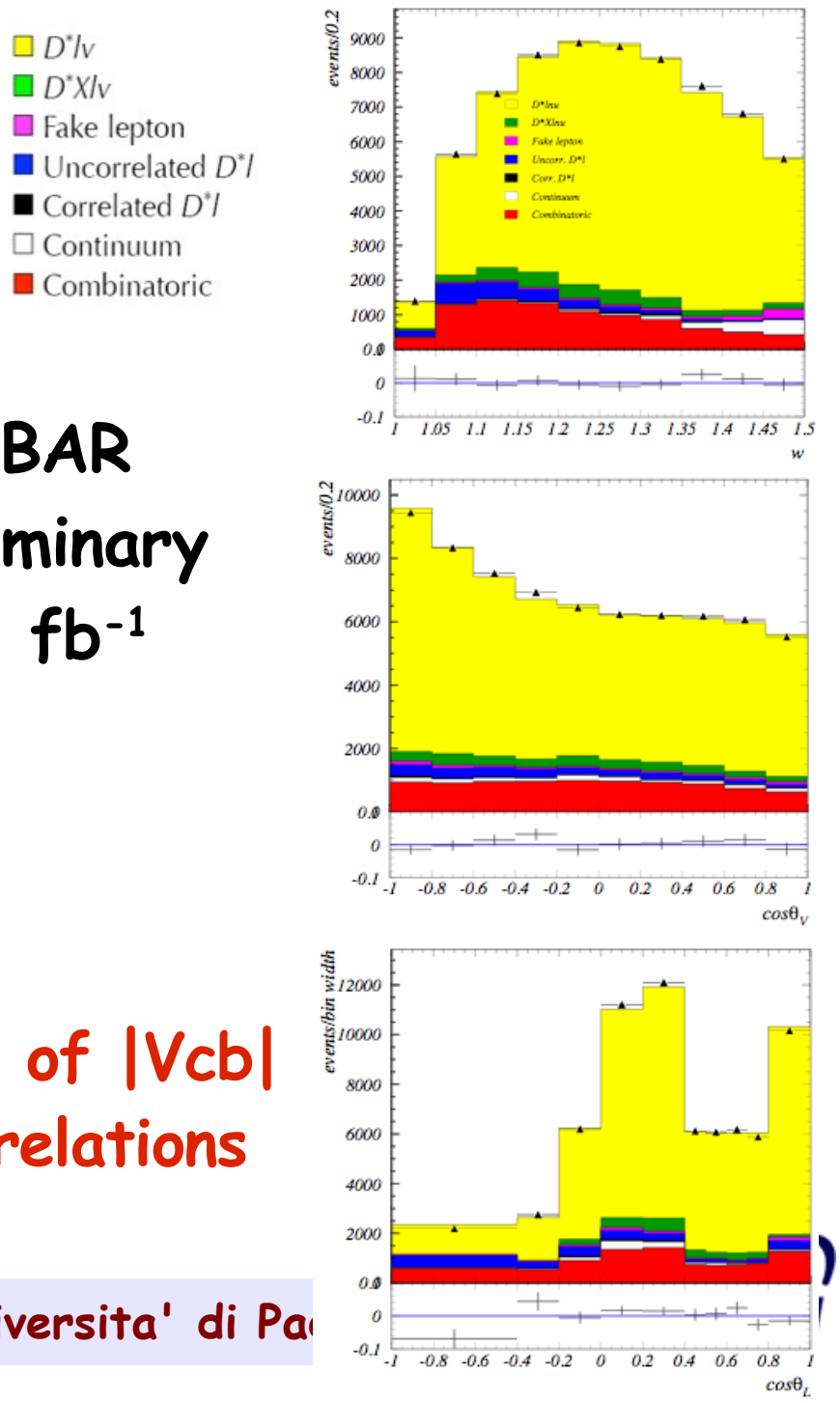
$R_2 = 0.836 \pm 0.037 \pm 0.022$

$\rho^2 = 1.179 \pm 0.048 \pm 0.028$

$\mathcal{F}(1)|V_{cb}| = (34.68 \pm 0.32 \pm 1.15) \times 10^{-3}$

$\mathcal{B}(B^0 \to D^{*-} l^+ \nu_l) = (4.77 \pm 0.04 \pm 0.39)\%$

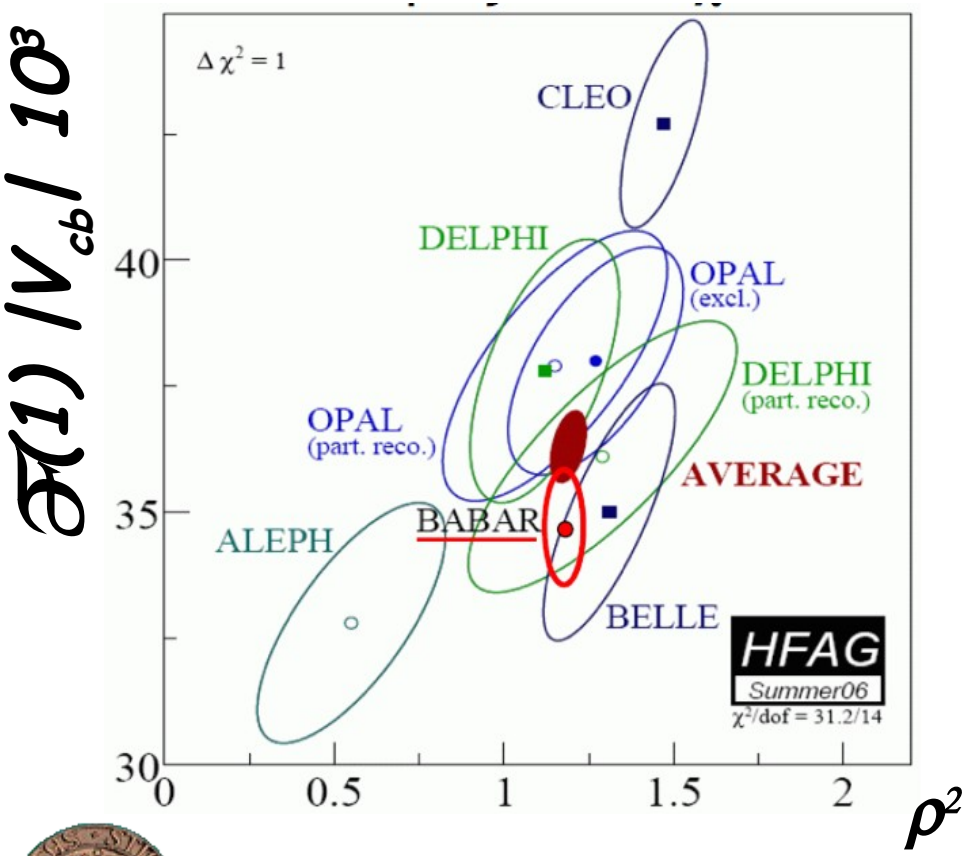
BABAR Preliminary 72 fb^{-1}

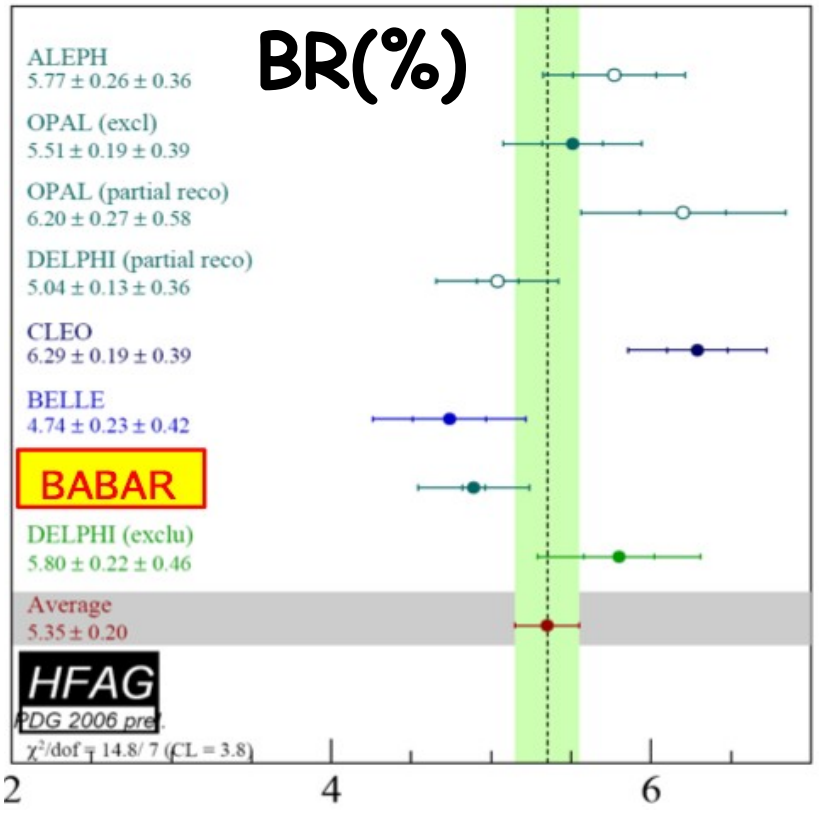


First Simultaneous Measurement of |Vcb| and FF, fully accounting for correlations

Results vs World Average

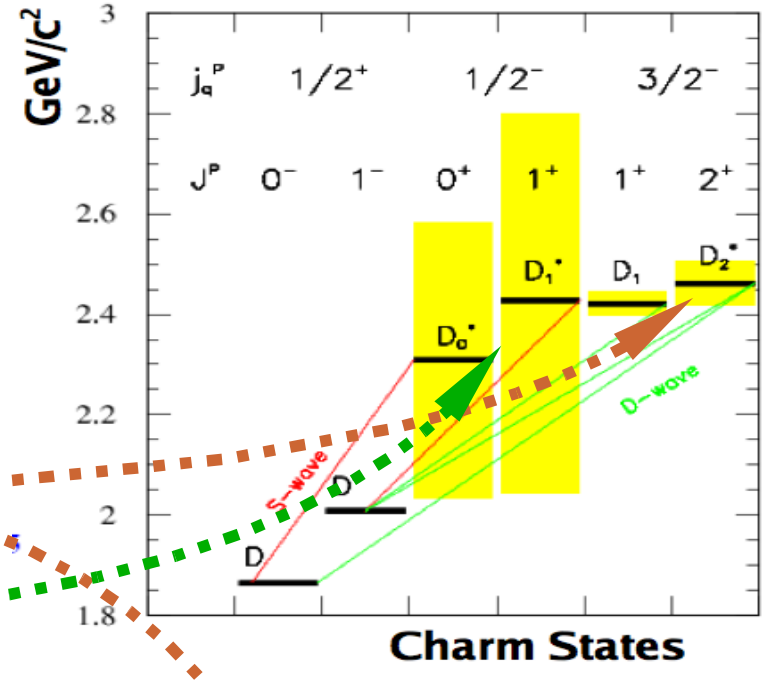
- BABAR FF measurement improves WA $|V_{cb}|$ determination
- Overall consistency rather loose

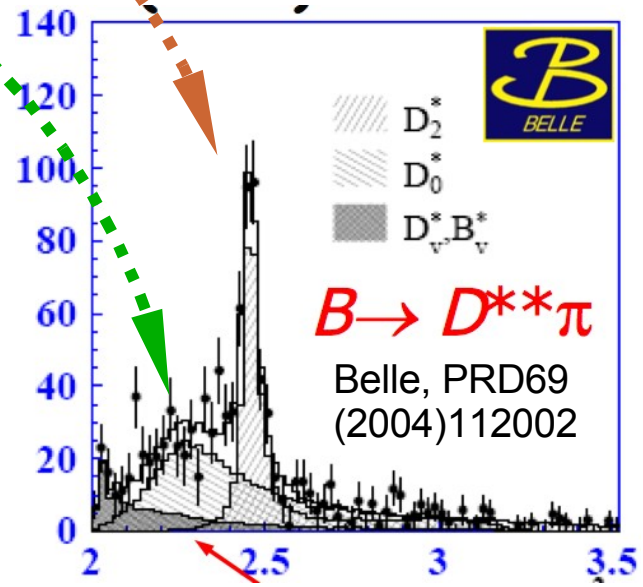




B->D** l ν

- D** : nickname for $D^{(*)}n\pi$, (n>0) final states, including:
  - Narrow States (D_1,D_2^*)
  - Broad States (D_0,D_1^*)
  - Non-resonant ?
- BABAR:
  - Narrow states with untagged *B-> ($D^{(*)}\pi$) lν* decays
  - Inclusive *B->D**lν* using tagged samples





INFN

$B \to D_1 / D^*_2 l\nu$: selection

- Untagged analysis, reconstruct only $D^{**} \to D^{(*)}\pi^{\pm}$:

$D^*_2{}^0 \to D^{(*)+}\pi^-$ $\quad$ $D^*_2{}^+ \to D^{(*)0}\pi^+$

$D_1{}^0 \to D^{+*}\pi^-$ $\quad$ $D_1{}^+ \to D^{0*}\pi^+$

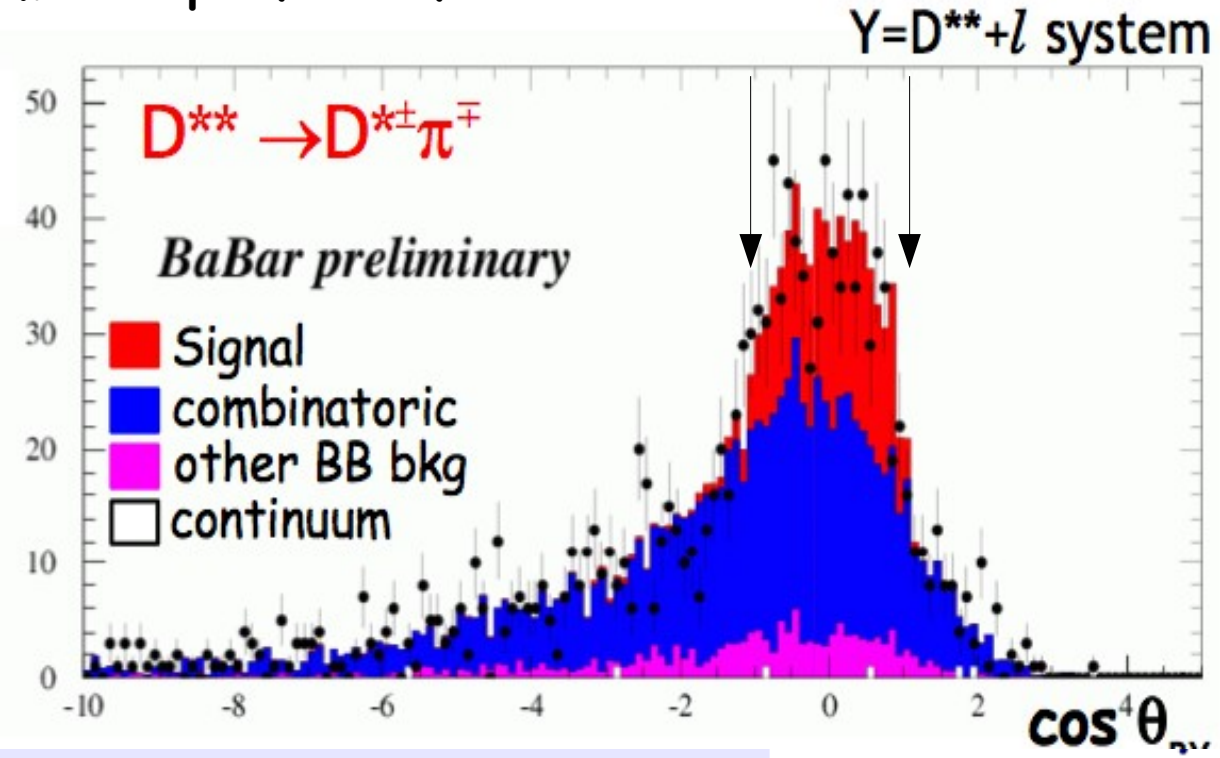
$$D^{*0} \to D^+ \pi^0$$
$$D^{*+} \to D^0 \pi^+$$
$$D^0 \to K^- \pi^+$$
$$D^+ \to K^- \pi^+ \pi^+$$

Assume single pion saturates Ddecays**

Assume Isospin for π^0 final states

- $p_{e/\mu} > 0.8$ GeV
- $|\cos\theta_{BY}| < 1$

$\varepsilon(D^{*\pm}\pi^{\mp}) = (6.54 \pm 0.28)\%$
$\varepsilon(D^{*0}\pi^{\pm}) = (5.26 \pm 0.41)\%$
$\varepsilon(D^{\pm}\pi^{\mp}) = (7.59 \pm 0.67)\%$
$\varepsilon(D^0\pi^{\pm}) = (14.77 \pm 1.46)\%$



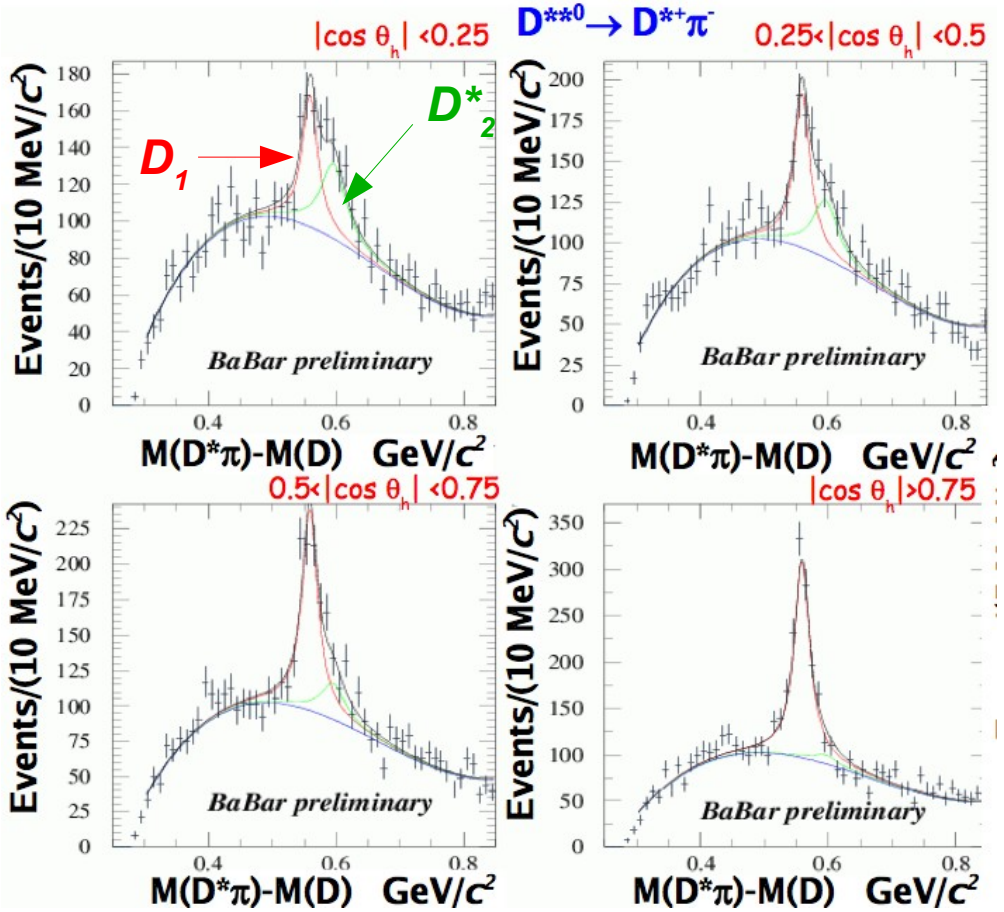
B->D_1/D^*_2 lν :analysis

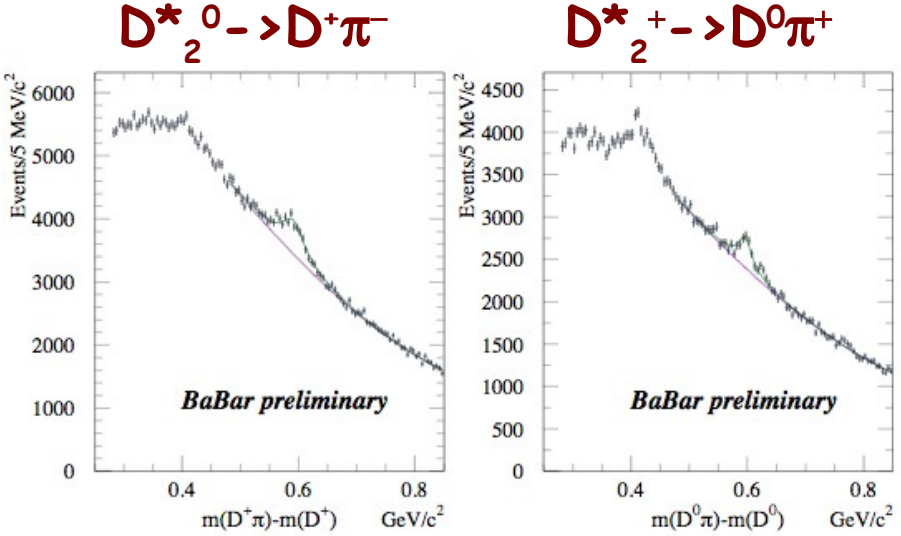
D_1 polarization
Unpolarized : A=2

- Fit simultaneously $M(D^{**})$ - $M(D^{(*)})$ in the four modes
- Four D^* Helicity (λ) bins to split D_1 from D^*_2

$$\begin{cases} \lambda(D_1) \sim 1 + A\cos^2\theta_\lambda \\ \lambda(D^*_2) \sim \sin^2\theta_\lambda \end{cases}$$

Θ_λ : angle between π from D^{**} and π from D^* in the D^* rest frame





franco simonetto INFN & Universita' di Padova

Results

- Fit 12 parameters (2 peak, 4 widths, 5 Br and A)

$$\mathcal{B}(B^- \to D_1^0 l^- \nu) = (4.48 \pm 0.26(stat.) \pm 0.35(syst.)) \cdot 10^{-3}$$

$$\mathcal{B}(B^- \to D_2^{*0} l^- \nu) = (3.54 \pm 0.32(stat.) \pm 0.54(syst.)) \cdot 10^{-3}$$

$$\mathcal{B}(B^0 \to D_1^- l^+ \nu) = (3.64 \pm 0.32(stat.) \pm 0.49(syst.)) \cdot 10^{-3}$$

$$\mathcal{B}(B^0 \to D_2^{*-} l^+ \nu) = (2.70 \pm 0.35(stat.) \pm 0.43(syst.)) \cdot 10^{-3}$$

$$\mathcal{B}(D_2^* \to D\pi) = 0.69 \pm 0.03$$

Mixing Parameter $A = 2.75 \pm 0.44$

$$\frac{\chi^2}{ndf} = \frac{698.4}{600}$$

BABAR PRELIMINARY, 208 fb^{-1}

franco simonetto INFN & Universita' di Padova

INFN

Tagged Analysis

- Untagged analyses won't improve with increasing statistics
- Use of tagged samples pioneered in inclusive ($B \to X_{c,u}\, l\, \nu$) studies
- Due to large $\int L dt$ and good efficiency ($\epsilon \sim 3\text{-}5\ 10^{-3}$), tagged analyses start to be competitive also in the Xclusive field:
  - (Much) reduced backgrounds (↑S/N)
  - Fully exploit kinematic constraints (↑ resolution)
- Wide future potential. Present (hep-ex 0607067) :

$$Br(B^- \to D/D^*/D^{**}\, l\, \nu)$$

INFN

Tagged Analysis: selection

$p_{e/\mu} > 0.6 \ GeV$

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

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

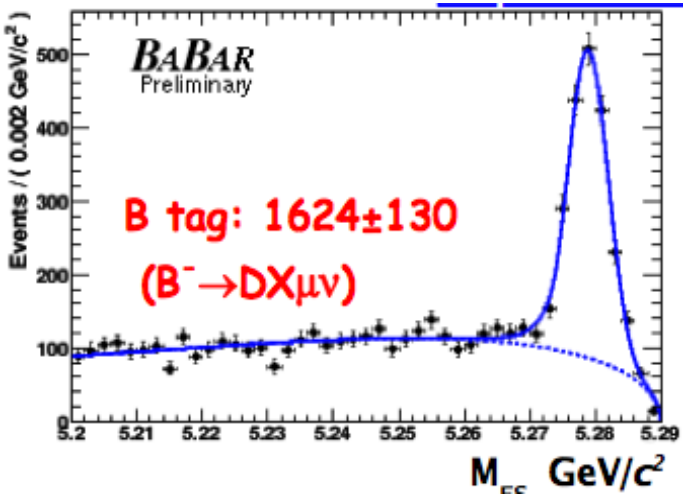
1) First select B^- ->lDX decay (↑ ε)

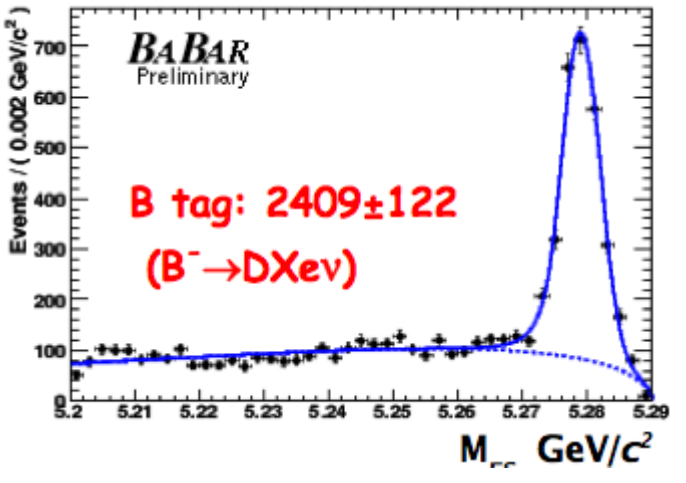
2) Then fully reconstruct B^+ from the remaining particles in the event

3) Sort $lD/lD^*/lD^{**}$ using kinematics/topology

☺ Weak sensitivity to D** decay mode, or D** composition (narrow/wide/non-res)

☹ Can only measure relative fractions of D/D*/D**, does not determine absolute Branching Fractions





Tagged Analysis: Measurement

- Global binned-χ^2 fit to:

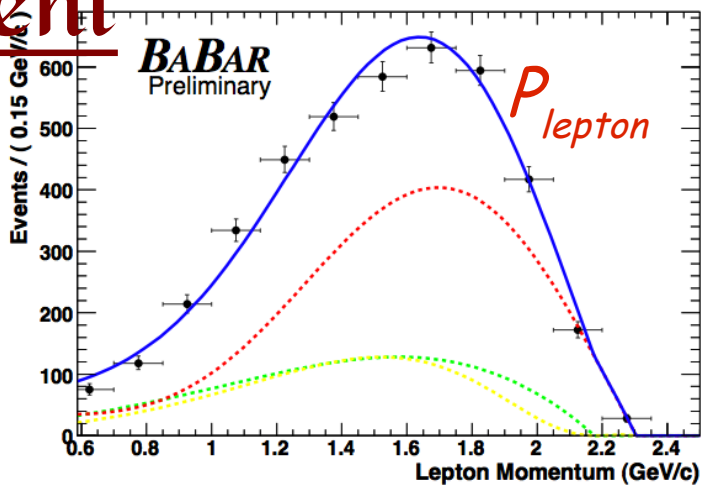
  P_{lepton} $= 0\ (Mass^2(\nu))$ *for* $B \to D l \nu$

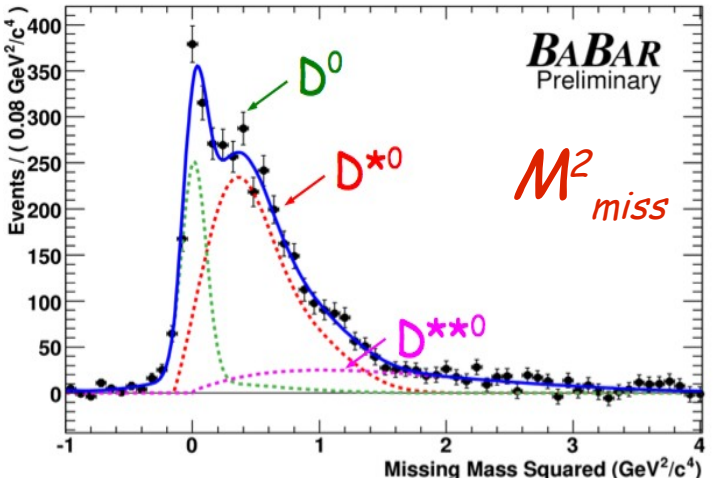
  $M^2_{miss} = (p(\Upsilon) - p(B_{tag}) - p(D) - p_l)^2$

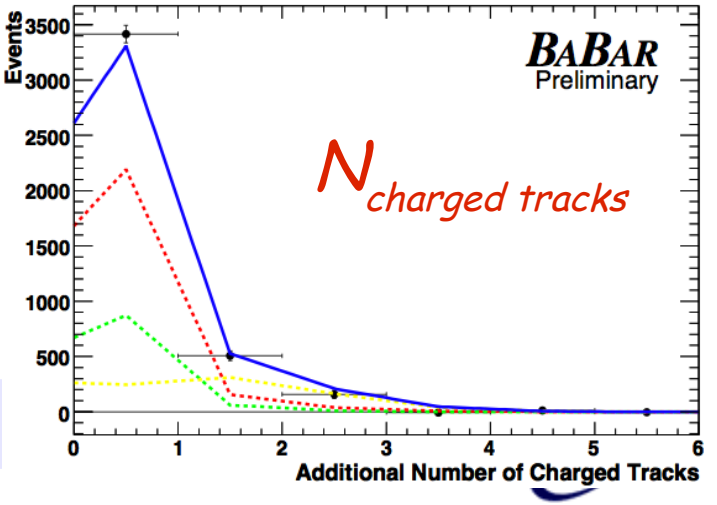
  N (residual charged tracks) , remove B_{tag}, D and l

- Distributions obtained from data control samples

- 33 parameters fit:
  - Rates
  - Feedown, shape parameters ...







franco simonetto INFN & Universita

Tagged Analysis: results

$$\Gamma(B^- \to D^0 l\nu)/\Gamma(B^- \to DX l\nu) = 0.210 \pm 0.017(stat.) \pm 0.021(syst.)$$

$$\Gamma(B^- \to D^{*0} l\nu)/\Gamma(B^- \to DX l\nu) = 0.611 \pm 0.021(stat.) \pm 0.027(syst.)$$

$$\Gamma(B^- \to D^{**0} l\nu)/\Gamma(B^- \to DX l\nu) = 0.173 \pm 0.017(stat.) \pm 0.021(syst.)$$

- Largest contribution to σ(syst) : MC statistics !
- Assuming these states saturate $B^- \to X_c l\nu$ decays:

$$BR(B^- \to X_c l\nu) = (10.9 \pm 0.04)\ \%$$

$$BR(B^- \to D^0 l\nu) = 2.23 \pm 0.19(stat.) \pm 0.23(syst.)\ \%$$

$$BR(B^- \to D^{*0} l\nu) = 6.81 \pm 0.23(stat.) \pm 0.30(syst.)\ \%$$

$$BR(B^- \to D^{**0} l\nu) = 1.93 \pm 0.19(stat.) \pm 0.23(syst.)\ \%$$

BABAR PRELIMINARY, 208 fb^{-1}

INFN

Tagged Analysis: remarks

- BABAR results are consistent with Belle computation of absolute BR

BABAR hep-ex 0607067

$BR(B^- \to D^0 l\nu) = 2.23 \pm 0.19(stat.) \pm 0.23(syst.)\ \%$

$BR(B^- \to D^{*0} l\nu) = 6.81 \pm 0.23(stat.) \pm 0.30(syst.)\ \%$

$BR(B^- \to D^{**0} l\nu) = 1.93 \pm 0.19(stat.) \pm 0.23(syst.)\ \%$

Belle PRD72 051109

$BR(B^- \to D^0 l\nu) = 2.37 \pm 0.10(stat.)\ \%$

$BR(B^- \to D^{*0} l\nu) = 6.06 \pm 0.25(stat.)\%$

$BR(B^- \to D^{**0} l\nu) = 1.81 \pm 0.20(stat.) \pm 0.20(syst.)\ \%$

INFN

B->D*lν puzzle ?

- B factories measure

LEP values somewhat larger
CLEO value much larger

$BR(B^0 \to D^{*-} l\nu)$	$= 4.77 \pm 0.39^{\text{total}}$ %	(Babar Untagged)
$BR(B^0 \to D^{*-} l\nu)$	$= 4.74 \pm 0.48^{\text{total}}$ %	(Belle Untagged)
$BR(B^0 \to D^{*-} l\nu)$	$= 4.70 \pm 0.24^{\text{stat}}$ %	(Belle Tagged)

$BR(B^- \to D^{*0} l\nu)$	$= 6.81 \pm 0.39^{\text{total}}$ %	(Babar Tagged)
$BR(B^- \to D^{*0} l\nu)$	$= 6.06 \pm 0.25^{\text{stat}}$ %	(Belle Tagged)

- Ratio of Br does not match lifetime ratio (& Isospin):

$$R = \frac{Br(B^+)}{Br(B^0)} = 1.32 \pm 0.07 \neq \frac{\tau(B^+)}{\tau(B^0)} = 1.07 \pm 0.02$$

B-factories Br average from Lopez-Pegna talk@ DPF

INFN

Conclusions

- Bla bla bla

INFN