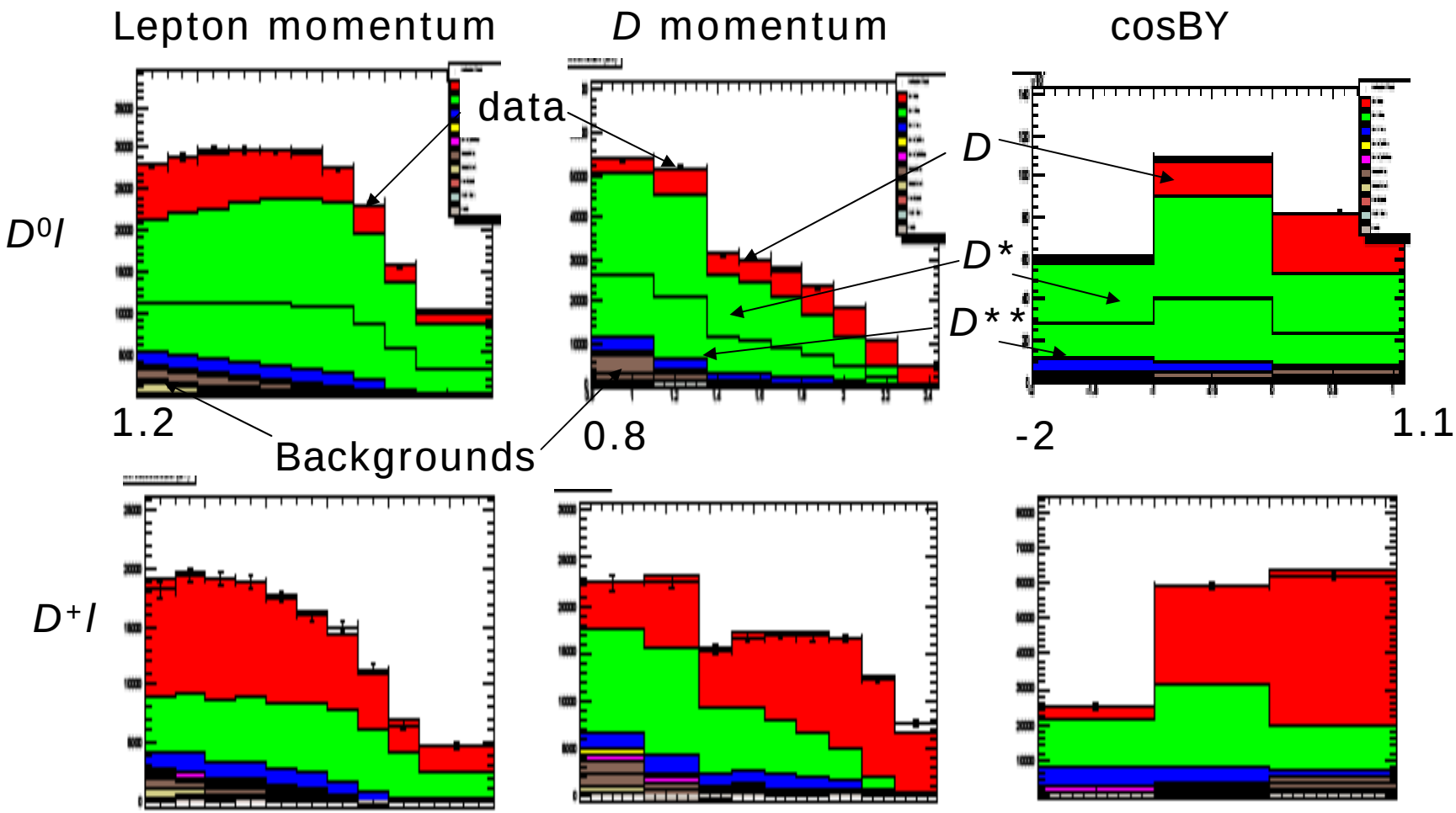
# Global Fit for Branching Fractions and Form Factor Slope of $B \to D^{(*)} l \nu$ Decays

- Muon mass effect
- Electron and muon combined results
- Radiative correction systematics
- Details are in BAD1586 V10

# Method

- Reconstruct only *Dl* pairs.
- 3-D fit by Lepton momentum, *D* momentum and cosThetaBY.
- Simultaneously fit to both $D^0 l$ and $D^+ l$ distributions.
- Fit for
  - $B \to D l \nu$ BF and FF slope
  - $B \to D^* l \nu$ BF and FF parameters (slope, ($R_1$ and $R_2$))
- Isospin constraint on $B \to D^{(*)} (\pi) l \nu$ decays.

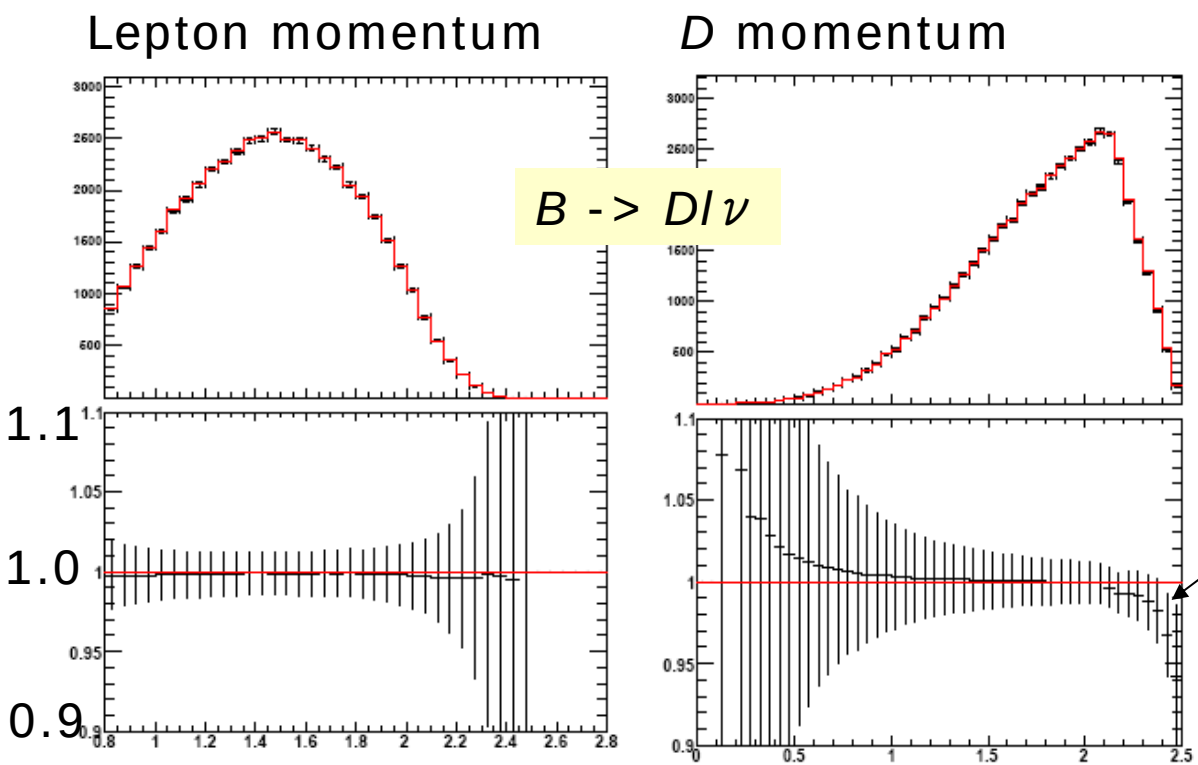
# 3D fit (projection plots)




The fit uses 3D binning ~240 bins each for $D^0 l$ and $D^+ l$

# Muon mass effect (1)

- Muon mass was neglected in decay rate formula (details in BAD1586 V10).
- Need additional terms in phase space and FF.




Without muon mass

With muon mass

Ratio = with/without

Effect is small

# Muon mass effect (2)

- We included muon mass effect only in $B \to Dl\nu$ and $B \to D^* l\nu$

| | Result | Difference from Nominal fit |
|---|---|---|
| $\rho_D^2$ | $1.132 \pm 0.066$ (5.9 %) | -3.25 % |
| $\rho^2$ | $1.326 \pm 0.064$ (4.8 %) | -3.35 % |
| $R_1$ | $1.527 \pm 0.104$ (6.8 %) | -4.17 % |
| $R_2$ | $0.684 \pm 0.084$ (12.3 %) | +7.94 % |
| $\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu)$ | $0.02282 \pm 0.00042$ (1.9 %) | -0.24 % |
| $\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu)$ | $0.05272 \pm 0.00056$ (1.1 %) | +0.54 % |
| $\chi^2$/ndof (P-value) | 492/464 (0.17) | |

Effect on FF parameters is not small

# Results (1)

- Electron results

$$\rho_D^2 = 1.27 \pm 0.05(\text{stat.}, 3.6\%) \pm 0.08(\text{syst.}, 6.2\%)$$
$$\rho^2 = 1.22 \pm 0.02(\text{stat.}, 2.0\%) \pm 0.07(\text{syst.}, 5.5\%)$$
$$\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu) = 0.0243 \pm 0.0003(\text{stat.}, 1.4\%) \pm 0.0015(\text{syst.}, 6.4\%)$$
$$\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu) = 0.0538 \pm 0.0003(\text{stat.}, 0.6\%) \pm 0.0026(\text{syst.}, 4.9\%)$$

- Muon results

$$\rho_D^2 = 1.16 \pm 0.06(\text{stat.}, 5.3\%) \pm 0.09(\text{syst.}, 7.7\%)$$
$$\rho^2 = 1.23 \pm 0.03(\text{stat.}, 2.4\%) \pm 0.06(\text{syst.}, 5.3\%)$$
$$\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu) = 0.0230 \pm 0.0004(\text{stat.}, 1.7\%) \pm 0.0017(\text{syst.}, 7.4\%)$$
$$\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu) = 0.0519 \pm 0.0004(\text{stat.}, 0.7\%) \pm 0.0038(\text{syst.}, 7.4\%)$$

- Electron and muon results are consistent.
- Slopes and *D* BF agree with previous Babar measurements.
- *D** BF has a fair agreement with previous Babar measurements.

# Results (2)

- Electron and muon combined results

$$\rho_D^2 = 1.23 \pm 0.04(stat.) \pm 0.07(syst.)$$

$$\rho^2 = 1.21 \pm 0.02(stat.) \pm 0.07(syst.)$$

$$\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu) = 0.0238 \pm 0.0003(stat.) \pm 0.0014(syst.)$$

$$\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu) = 0.0529 \pm 0.0002(stat.) \pm 0.0025(syst.)$$

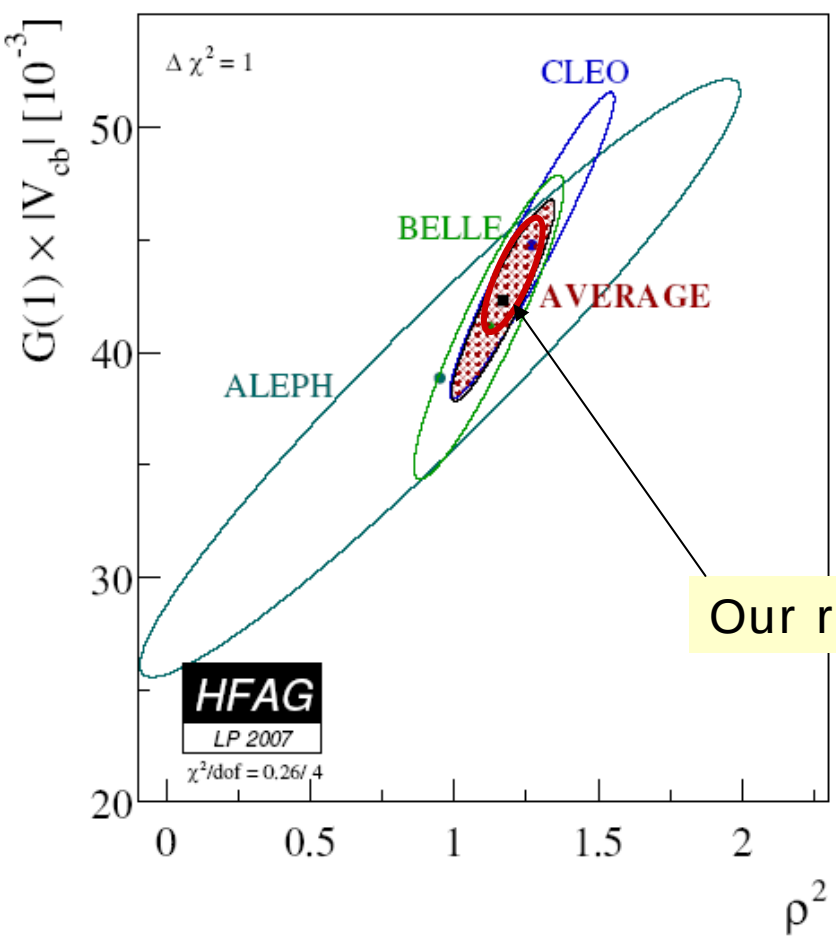
(We fit for common values, $\chi^2$/ndf = 2.0/4)

$$\mathcal{G}(1)|V_{cb}| = 0.0442 \pm 0.0008(stat.) \pm 0.0025(syst.)$$

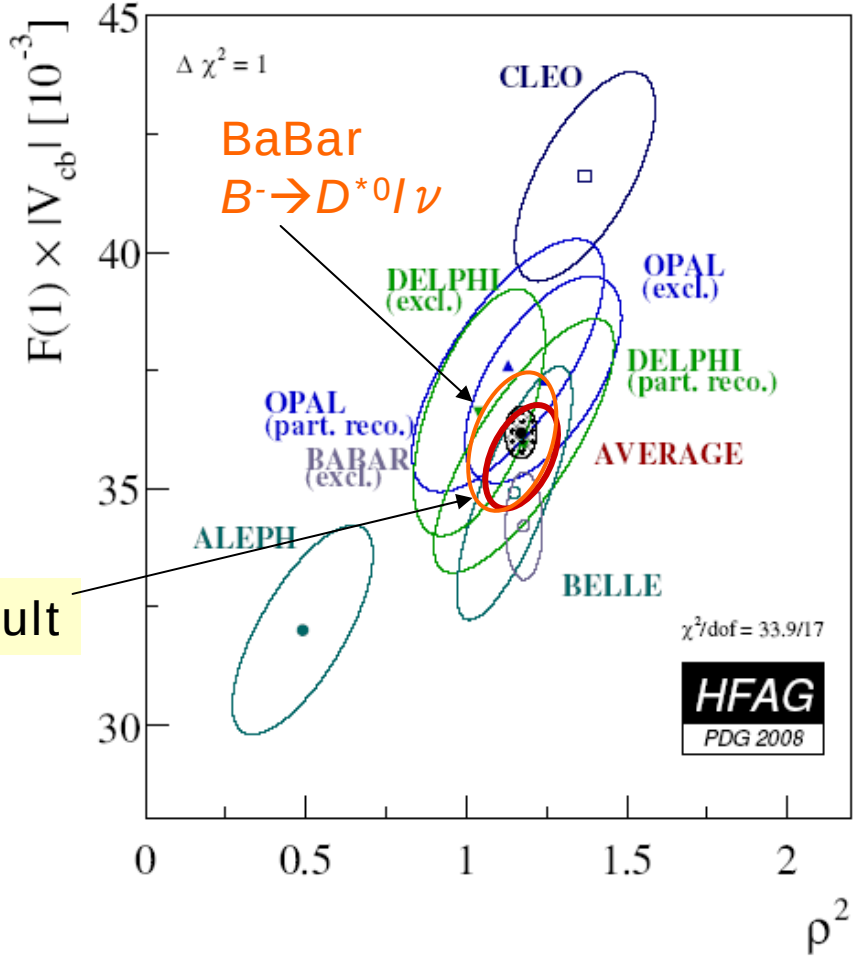
$$\mathcal{F}(1)|V_{cb}| = 0.0355 \pm 0.0002(stat.) \pm 0.0013(syst.)$$

- G(1)|Vcb| is twice as precise as world average.
- F(1)|Vcb| is as good as existing best measurement.

# Comparison with others




Our result



# Systematic uncertainties

Electron

| item | $\rho^2_D$ | $\rho^2$ | $\mathcal{B}(D^0\ell\nu)$ | $\mathcal{B}(D^{*0}\ell\nu)$ |
|---|---|---|---|---|
| FF total | 1.45 | 2.70 | 0.13 | 0.24 |
| $D^{(*)}\pi\ell\nu$ total | 3.12 | 2.18 | 2.23 | 1.62 |
| $D^{(*)}\pi\pi\ell\nu$ total | 2.56 | 2.96 | 0.82 | 1.84 |
| Input parms total | 2.85 | 2.44 | 3.05 | 2.76 |
| Corrections total | 3.35 | 1.71 | 5.04 | 3.13 |
| Background total | 0.42 | 0.62 | 0.44 | 0.21 |
| **Total** | **6.16** | **5.48** | **6.37** | **4.85** |

Muon

| item | $\rho^2_D$ | $\rho^2$ | $\mathcal{B}(D^0\ell\nu)$ | $\mathcal{B}(D^{*0}\ell\nu)$ |
|---|---|---|---|---|
| FF total | 1.50 | 2.81 | 0.17 | 0.26 |
| $D^{(*)}\pi\ell\nu$ total | 4.15 | 2.27 | 2.26 | 1.75 |
| $D^{(*)}\pi\pi\ell\nu$ total | 3.41 | 2.68 | 0.89 | 1.77 |
| Input parms total | 3.08 | 2.32 | 3.01 | 2.80 |
| Corrections total | 4.29 | 1.36 | 6.33 | 6.31 |
| Background total | 0.67 | 0.59 | 0.51 | 0.28 |
| **Total** | **7.71** | **5.27** | **7.44** | **7.35** |

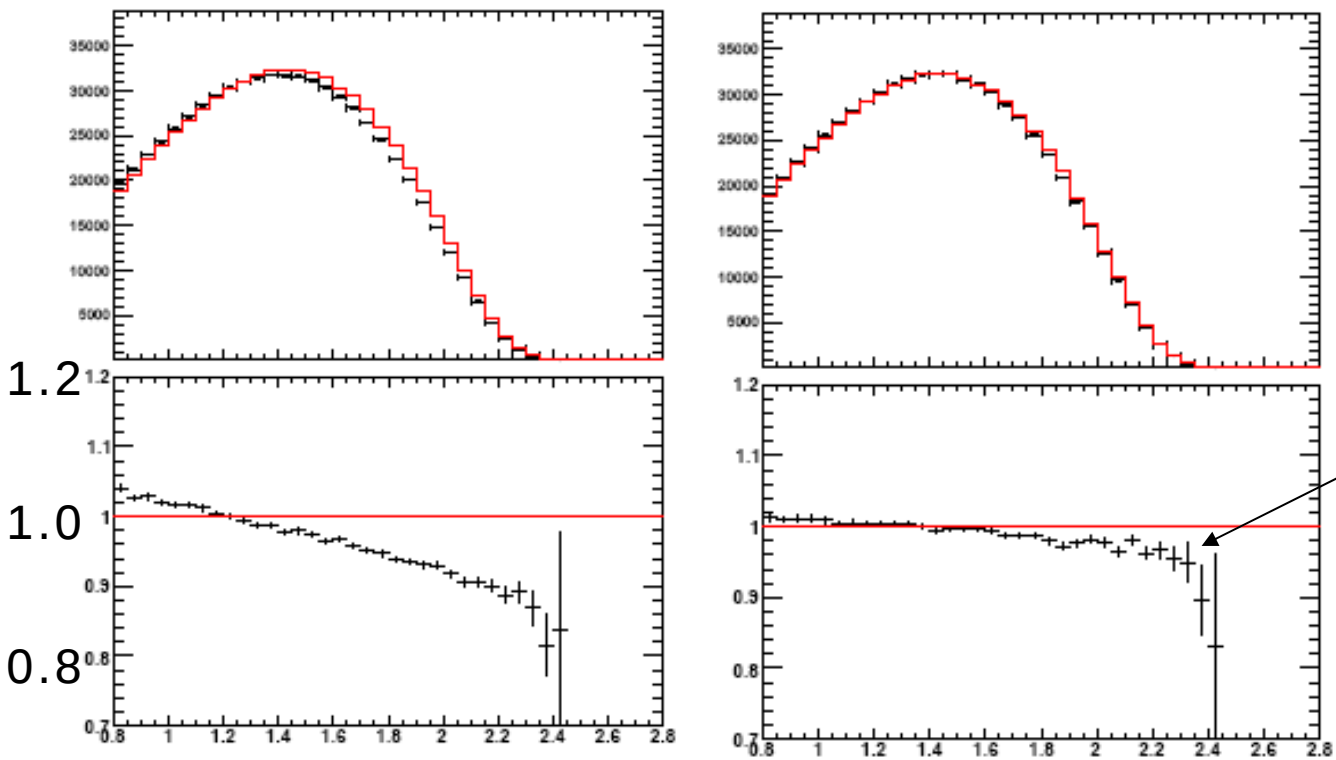
- Main source of systematic errors :
  - Not well measured $B \to D^{**} l \nu$ BF and FF parameters
  - Unknown $B \to D^{(*)} \pi \pi l \nu$ component
  - Input parameters : $D^{*+}$ BF, $R_1$ and $R_2$
  - Corrections : Electron PHOTOS and Muon PID

# Radiative Corrections (1)

- Comparison with and without PHOTOS

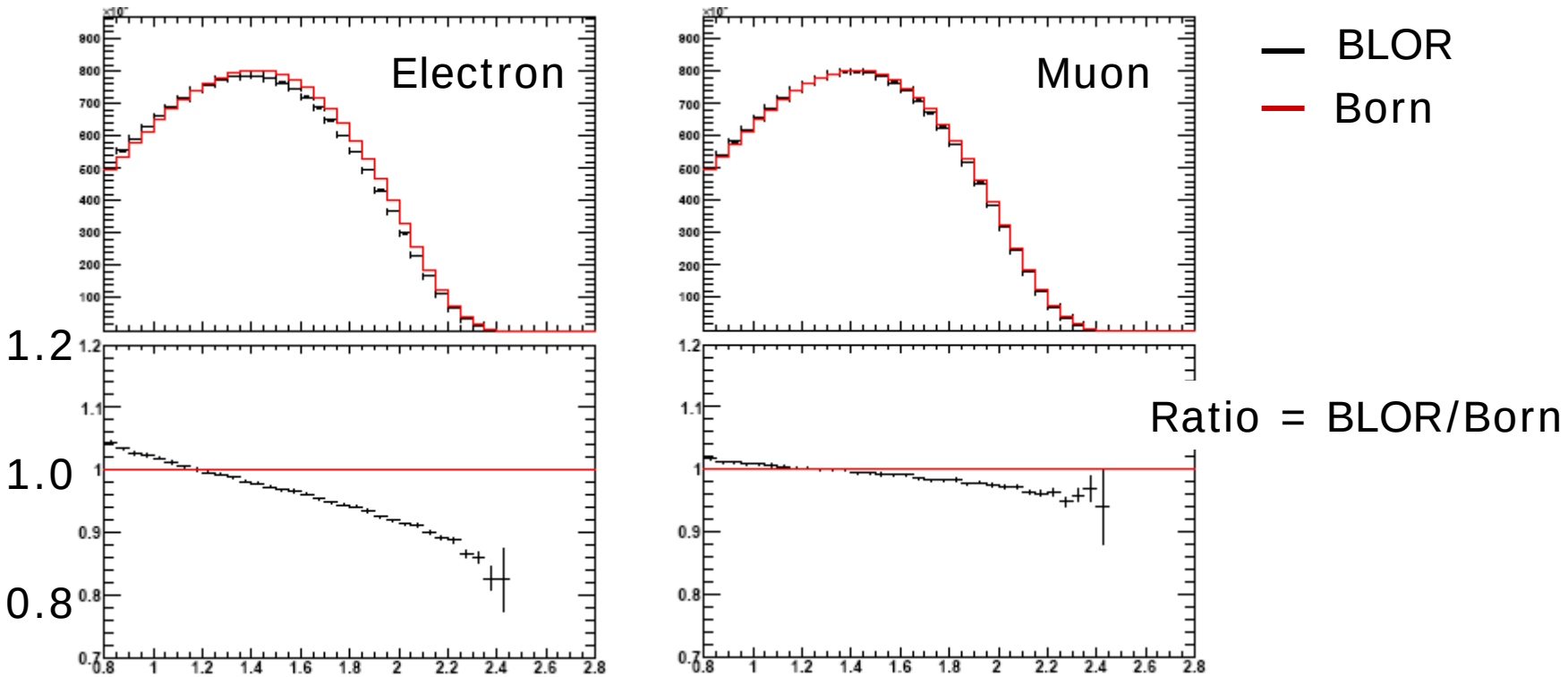
Electron momentum

Muon momentum



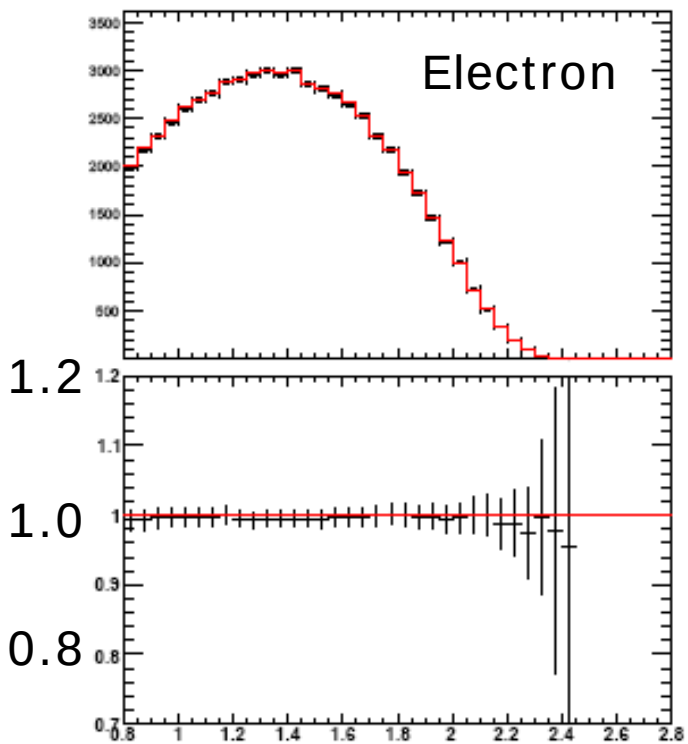
# Radiative Corrections (2)

- KLOR = radiative correction for *K* decays.
- BLOR = B decay version of KLOR
  - Florian Bernlochner is working on this.



# Radiative Corrections (3)

- Plan for systematic error estimate :
  - Replace MC histograms by BLOR and perform fit.
  - Difference from nominal fit can be systematic uncertainty.




PHOTOS vs BLOR

Ratio = BLOR/PHOTOS

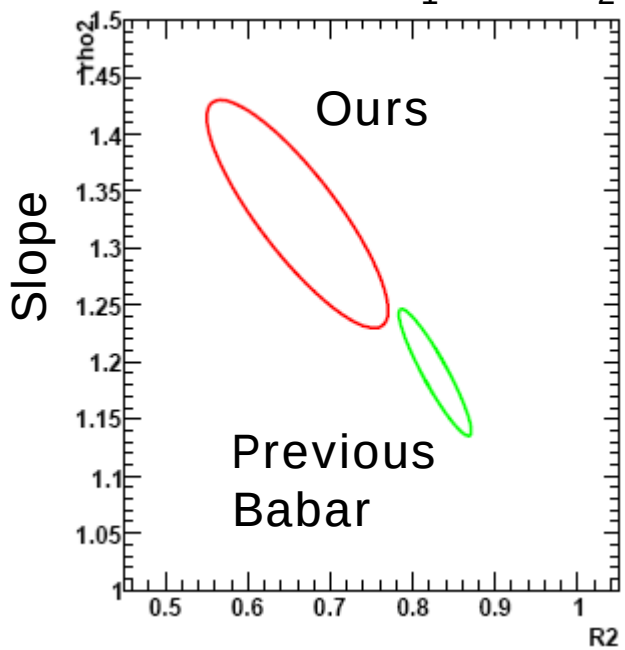
# To do list

- Further systematic study on
  - Radiative correction
  - Lepton PID
- Write PRD draft.

# Comparison with previous measurements

- Previous Babar measurements
  - $B^0$ -> $D^{*-} l \nu$ mode (arXiv:0705.4008[hep-ex])
    - Slope = 1.191 ± 0.048 ±0.028
  - $B^0$ -> $D^{*-} l \nu$ mode (arXiv:0712.3493[hep-ex])
    - Slope = 1.15 ± 0.06 ± 0.08
- Our result
  - Slope = 1.227 ± 0.083

If we float $R_1$ and $R_2$



# $R_1$ and $R_2$ floated results

- $R_1$ and $R_2$ floated results

$$\rho_D^2 = 1.19 \pm 0.04(stat.) \pm 0.07(syst.)$$
$$\rho^2 = 1.33 \pm 0.04(stat.) \pm 0.09(syst.)$$
$$R_1 = 1.55 \pm 0.07(stat.) \pm 0.14(syst.)$$
$$R_2 = 0.66 \pm 0.05(stat.) \pm 0.09(syst.)$$
$$\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu) = 0.0236 \pm 0.0003(stat.) \pm 0.0013(syst.)$$
$$\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu) = 0.0538 \pm 0.0004(stat.) \pm 0.0024(syst.)$$
$$\mathcal{G}(1)|V_{cb}| = 0.0432 \pm 0.0009(stat.) \pm 0.0024(syst.)$$
$$\mathcal{F}(1)|V_{cb}| = 0.0353 \pm 0.0003(stat.) \pm 0.0010(syst.)$$

# Results without isospin constraints.

- Results without isospin constraints on $B \to Dl\nu$ and $B \to D^* l\nu$ decays.

$$\rho_D^2 = 1.16 \pm 0.10(8.7\%)$$
$$\rho^2 = 1.32 \pm 0.10(7.3\%)$$
$$R_1 = 1.53 \pm 0.15(10.0\%)$$
$$R_2 = 0.67 \pm 0.10(15.1\%)$$
$$\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu) = 0.0232 \pm 0.0013(5.8\%)$$
$$\mathcal{B}(B^0 \to D^- \ell^+ \nu) = 0.0217 \pm 0.0013(6.0\%)$$
$$\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu) = 0.0525 \pm 0.0032(6.0\%)$$
$$\mathcal{B}(B^0 \to D^{*-} \ell^+ \nu) = 0.0525 \pm 0.0056(10.7\%)$$

# $|V_{cb}|$

| | | $V_{cb}$ |
|---|---|---|
| $\mathcal{G}(1)$ | $R_1$ and $R_2$ fixed | $0.0411 \pm 0.0008 \pm 0.0023 \pm 0.0009$ |
| | $R_1$ and $R_2$ floated | $0.0402 \pm 0.0008 \pm 0.0022 \pm 0.0009$ |
| $\mathcal{F}(1)$ | $R_1$ and $R_2$ fixed | $0.0384 \pm 0.0002 \pm 0.0014 \pm 0.0009$ |
| | $R_1$ and $R_2$ floated | $0.0382 \pm 0.0005 \pm 0.0015 \pm 0.0009$ |

- We used (Okamoto *et.al.*, hep-lat/0409116)

$$\mathcal{G}(1) = 1.074 \pm 0.018 \pm 0.016$$

and (Raiho, arXiv:0710.1111[hep-lat])

$$\mathcal{F}(1) = 0.924 \pm 0.012 \pm 0.019$$