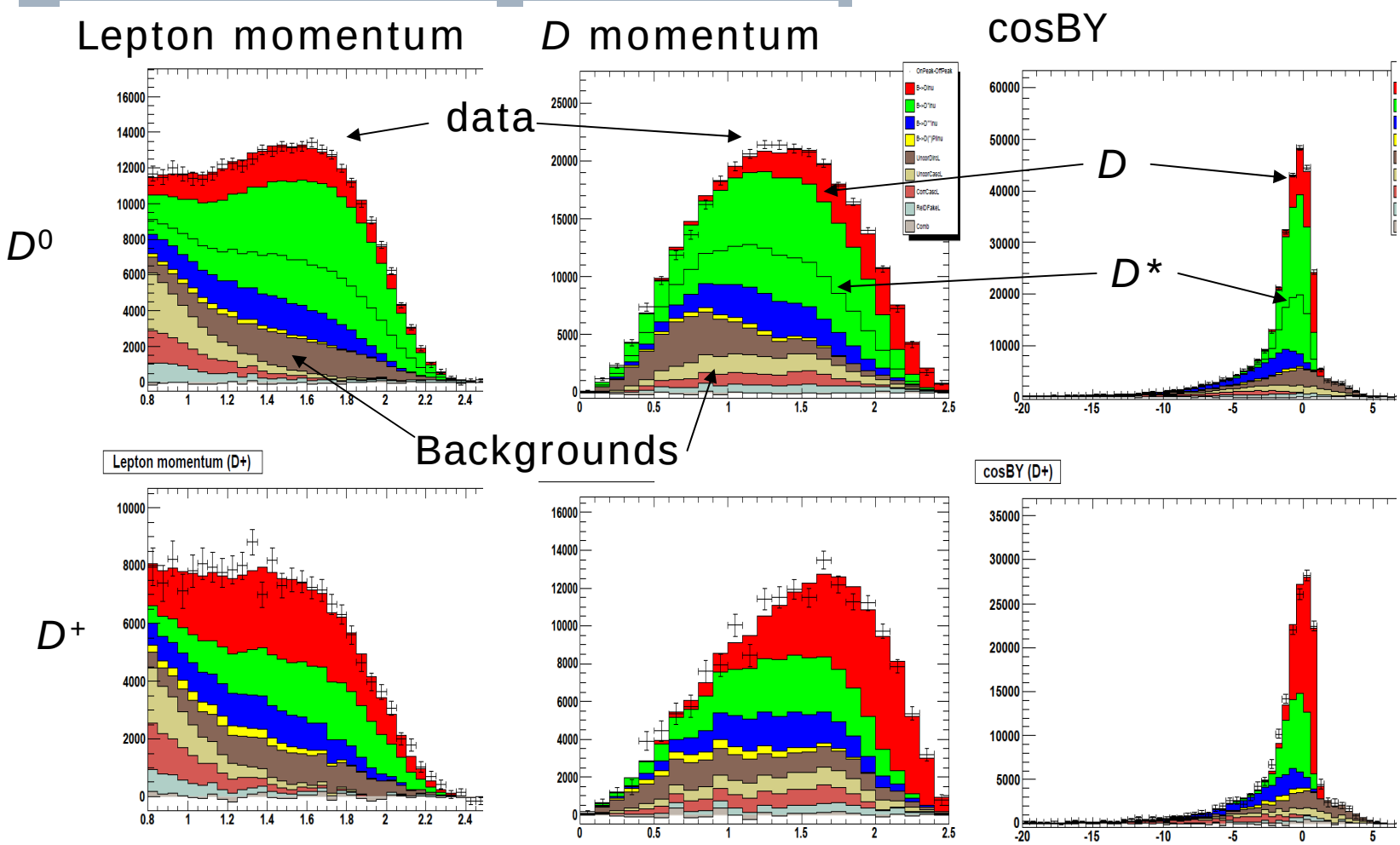
Global Fit for Branching Fractions and Form Factor Slope of $B->D^{(*)}l\nu$ Decays

- Toy MC study
- BF renormalization
- Systematic study
- Details are in BAD1586 V6

3 kinematic variables



The fit uses 3D binning ~120 bins each for D^0 and D^+

Current Fit Result (Run2 only)

- We use isospin constraint on $B \to D^{(*,**)}(\pi)\, l\nu$ decays

Parameters	Fit results
ρ_D^2	1.354 ± 0.066 (4.9 %)
ρ^2	1.338 ± 0.076 (5.7 %)
R_1	1.443 ± 0.123 (7.8 %)
R_2	0.680 ± 0.099 (14.5 %)
$\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu)$	0.02522 ± 0.00063 (2.4 %)
$\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu)$	0.05156 ± 0.00083 (1.6 %)
$\mathcal{BT}(B^+ \to \bar{D}^{**0}/(D\pi)^0 \ell^+ \nu)$	0.02197 ± 0.00096 (4.4 %)
f_{+0}	1.100 ± 0.031 (2.8 %)
χ^2/ndof (P-value)	237/215 (0.15)

- $f_{+0} = f_{+-}/f_{00}$ is not Gaussian constrained
- $D^{(*)}$ decay BF are fixed based on toy MC study.

Correlation

	ρ_D^2	ρ^2	R_1	R_2	$\mathcal{B}(D)$	$\mathcal{B}(D^*)$	Other	f_{+0}
ρ_D^2	1							
ρ^2	-0.304	1						
R_1	-0.190	0.821	1					
R_2	0.260	-0.900	-0.900	1				
$\mathcal{B}(D\ell\nu)$	0.447	0.094	0.094	0.043	1			
$\mathcal{B}(D^*\ell\nu)$	-0.402	0.216	0.018	-0.260	-0.593	1		
$\mathcal{B}(\mathrm{Oter})$	0.090	-0.146	-0.125	0.146	0.087	-0.487	1	
f_{+0}	0.152	0.111	0.081	-0.005	0.393	-0.518	0.160	1

Toy MC pulls

- Mean and r.m.s. of toy MC pull distributions.

Parameters	Mean	Standard Deviation
ρ_D^2	0.1031	1.022
ρ^2	-0.0254	1.028
R_1	-0.0903	1.045
R_2	0.0883	1.030
$\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu)$	0.0897	0.9314
$\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu)$	-0.0229	1.011
$\mathcal{BT}(B^+ \to \bar{D}^{**0}/(D\pi)^0 \ell^+ \nu)$	0.0873	0.9746
f_{+0}	0.0498	1.030
Uncertainty	0.0323	0.0228

- Based on 960 toy MC fits.
- Bias is small but need to be corrected.

Other results

- We renormalize BF to inclusive BF :
  - BF(B->$X_c l\nu$, E_l>1.5GeV) = 0.0454 ± 0.0003 ±0.0008
  - Renormalized BF are

$$\tilde{\mathcal{B}}(B^+ \to \bar{D}^0 \ell^+ \nu) = 0.0276 \pm 0.0007$$
$$\tilde{\mathcal{B}}(B^+ \to \bar{D}^{*0} \ell^+ \nu) = 0.0564 \pm 0.0009$$
$$\tilde{\mathcal{BT}}(B^+ \to \bar{D}^{**0}/(D\pi)^0 \ell^+ \nu) = 0.0240 \pm 0.0011$$

  - We assume $D/D^*/D^{**}/D^{(*)}\pi\, l\nu$ saturate the decay rate for E_l>1.5GeV
  - Contribution of $D^{(*)}\pi\,\pi\, l\nu$ and $DsKl\nu$ need to be evaluated.
- $G(1)V_{cb}$ and $F(1)V_{cb}$ with the fitted/renormalized BF
  - $G(1)V_{cb}$ = 0.04818 ± 0.00185 / 0.05038 ± 0.00193
  - $F(1)V_{cb}$ = 0.03505 ± 0.00103 / 0.03665 ± 0.00051
  - Correlation between these is -0.228

Systematics uncertainties 1 (%)

item	ρ_D^2	ρ^2	R_1	R_2	f_{+0}
$R_1(w)$ and $R_2(w)$	0.11	1.42	-1.38	3.18	0.12
D^{**} slope	-0.58	-2.77	1.67	-1.54	-0.56
D^{**} B_2	-0.62	1.21	1.15	-0.19	0.09
FF total	**0.85**	**3.34**	**2.45**	**3.54**	**0.58**
BF ratios total	**0.72**	**1.04**	**3.58**	**4.53**	**1.26**
$f_{D_2^*}$	-0.12	0.13	0.17	-0.34	0.31
D^{*+} BF	0.49	-0.37	-0.39	0.73	-0.83
D^0 BF	-0.32	-0.37	-0.39	0.73	-0.83
D^+ BF	0.24	-0.11	-0.16	0.30	-1.54
t_{+0}	-0.00	-0.03	-0.06	0.10	-0.82
Luminosity	0.05	0.07	0.06	-0.12	-0.01
Input parms total	**0.64**	**0.53**	**0.61**	**1.15**	**3.34**
Bkg BF total	**2.58**	**1.34**	**2.51**	**4.37**	**1.27**
Lepton PID	-0.45	-0.26	4.02	0.86	0.32
Kaon PID	0.01	0.91	0.41	-0.91	-0.31
Tracking eff.	-0.05	0.37	0.26	-0.52	1.14
PHOTOS	0.00	0.00	0.00	0.00	0.00
Corrections total	**0.46**	**1.01**	**4.05**	**1.35**	**1.23**
Grand total	**2.92**	**3.92**	**6.47**	**7.43**	**4.03**

"BF ratios" are ratios of $D^{**}/D(^*)\pi/\nu$ BF

Not yet done

Systematics uncertainties 2 (%)

	Fitted BF			Renormalized BF		
item	$\mathcal{B}(B \to D\ell\nu)$	$\mathcal{B}(B \to D^*\ell\nu)$	$\mathcal{B}(B \to D^{**}/D^{(*)}\pi\ell\nu)$	$\tilde{\mathcal{B}}(B \to D\ell\nu)$	$\tilde{\mathcal{B}}(B \to D^*\ell\nu)$	$\tilde{\mathcal{B}}(B \to D^{**}/D^{(*)}\pi\ell\nu)$
FF total	**0.17**	**1.58**	**3.84**	**1.04**	**1.18**	**3.44**
BF ratios total	**0.77**	**0.46**	**5.30**	**0.88**	**0.68**	**5.05**
$f_{D_2^*}$	-0.08	-0.01	0.41	-0.11	-0.04	0.38
D^{*+} BF	0.22	-0.17	0.05	0.27	-0.13	0.10
D^0 BF	-1.28	-0.17	0.05	-0.75	-0.13	0.10
D^+ BF	-0.54	-1.10	-0.97	0.40	-0.15	-0.02
t_{+0}	0.39	0.40	0.43	0.40	0.41	0.43
Luminosity	-1.12	-1.12	-1.08	-0.01	-0.01	0.03
Input parms total	**1.85**	**1.65**	**1.63**	**0.98**	**0.52**	**0.60**
Bkg BF total	**0.93**	**0.42**	**1.49**	**0.71**	**0.53**	**1.26**
Lepton PID	-3.17	-3.91	-1.99	-0.05	-0.81	1.17
Kaon PID	-0.08	0.18	-0.31	-0.16	0.10	-0.39
Tracking eff.	-1.85	-1.50	-1.62	-0.27	0.09	-0.04
PHOTOS	0.00	0.00	0.00	0.00	0.00	0.00
Corrections total	**3.67**	**4.19**	**2.59**	**0.31**	**0.82**	**1.23**
Inclusive BF				1.87	1.87	1.87
Higher X_c				0.00	0.00	0.00
BF renormalization total				**1.87**	**1.87**	**1.87**
Grand total	4.29	4.82	7.38	2.63	2.57	6.66

Not yet done

PID uncertainties need to be re-evaluated. Current : correction on and off.

Systematics uncertainties 3 (%)

item	$\mathcal{G}(1)V_{cb}$	$\mathcal{F}(1)V_{cb}$	$\tilde{\mathcal{G}}(1)V_{cb}$	$\tilde{\mathcal{F}}(1)V_{cb}$
FF total	**0.53**	**1.30**	**0.72**	**1.23**
BF ratios total	**0.45**	**0.72**	**0.57**	**0.79**
Input parms total	**1.11**	**0.82**	**0.84**	**0.26**
Bkg BF total	**2.00**	**0.46**	**1.89**	**0.51**
Lepton PID	-1.88	-2.22	-0.31	-0.65
Kaon PID	-0.03	0.27	-0.07	0.23
Tracking eff.	-0.96	-0.71	-0.16	0.09
PHOTOS	0.00	0.00	0.00	0.00
Corrections total	**2.11**	**2.34**	**0.36**	**0.70**
Inclusive BF			0.94	0.94
Higher X_c			0.00	0.00
BF renormalization total			**0.94**	**0.94**
Grand total	**3.19**	**2.93**	**2.48**	**1.96**

Not yet done

"BF ratios" are ratios of $D^{**}/D^{(*)}\pi l\nu$ BF

PID uncertainties needs to be re-evaluated.
Current : PID correction on and off

Remaining systematics (Plan)

- We use a 3D efficiency matrix.
  - Efficiency
    = # of selected events/# of generated events.
- Radiative Correction (PHOTOS)
  - We generate MC without PHOTOS and apply the efficiency matrix to get reconstructed, event selected and re-weighted MC without PHOTOS.
  - Then, fit with the MC to get systematic uncertainties.
- Bremsstrahlung
  - We apply a electron energy correction given in BAD 664 to estimate the systematic uncertainty.

$$\Delta E = \mp 0.0125 \frac{E}{\mathrm{GeV}} \pm 0.0425$$

- Higher X_c states ($B \to D^{(*)} \pi \pi l \nu$ and $B \to D_s^{(*)} K^{(*)} l \nu$)
  - We generate possible modes and apply the efficiency matrix to see the effect on fit results.

Current Results (Run2 only)

$$\rho_D^2 = 1.354 \pm 0.066(\text{stat.}, 4.9\%) \pm 0.040(\text{syst.}, 2.92\%)$$

$$\rho^2 = 1.338 \pm 0.076(\text{stat.}, 5.7\%) \pm 0.052(\text{syst.}, 3.92\%)$$

$$R_1 = 1.443 \pm 0.123(\text{stat.}, 7.8\%) \pm 0.093(\text{syst.}, 6.47\%)$$

$$R_2 = 0.680 \pm 0.099(\text{stat.}, 14.5\%) \pm 0.051(\text{syst.}, 7.43\%)$$

$$f_{+0} = 1.100 \pm 0.031(\text{stat.}, 2.8\%) \pm 0.044(\text{syst.}, 4.03\%)$$

$$\mathcal{B}(D^{*+} \to D^0\pi^+) = 0.02522 \pm 0.00063(\text{stat.}, 2.4\%) \pm 0.00108(\text{syst.}, 4.29\%)$$

$$\mathcal{B}(B^+ \to \bar{D}^{*0}\ell^+\nu) = 0.05156 \pm 0.00083(\text{stat.}, 1.6\%) \pm 0.00249(\text{syst.}, 4.82\%)$$

$$\mathcal{BT}(B^+ \to \bar{D}^{**0}/(D\pi)^0\ell^+\nu) = 0.02197 \pm 0.00096(\text{stat.}, 4.4\%) \pm 0.00162(\text{syst.}, 7.38\%)$$

$$\mathcal{G}(1)|V_{cb}| = 0.04818 \pm 0.00185(\text{stat.}, 3.8\%) \pm 0.00154(\text{syst.}, 3.19\%)$$

$$\mathcal{F}(1)|V_{cb}| = 0.03505 \pm 0.00049(\text{stat.}, 1.4\%) \pm 0.00103(\text{syst.}, 2.93\%)$$

Renormalized BF

$$\tilde{\mathcal{B}}(D^{*+} \to D^0\pi^+) = 0.02757 \pm 0.00068(\text{stat.}, 2.5\%) \pm 0.00073(\text{syst.}, 2.63\%)$$

$$\tilde{\mathcal{B}}(B^+ \to \bar{D}^{*0}\ell^+\nu) = 0.05637 \pm 0.00091(\text{stat.}, 1.7\%) \pm 0.00145(\text{syst.}, 2.57\%)$$

$$\tilde{\mathcal{BT}}(B^+ \to \bar{D}^{**0}/(D\pi)^0\ell^+\nu) = 0.02402 \pm 0.00105(\text{stat.}, 4.4\%) \pm 0.00160(\text{syst.}, 6.66\%)$$

$$\mathcal{G}(1)|V_{cb}| = 0.05038 \pm 0.00193(\text{stat.}, 3.8\%) \pm 0.00125(\text{syst.}, 2.48\%)$$

$$\mathcal{F}(1)|V_{cb}| = 0.03665 \pm 0.00051(\text{stat.}, 1.4\%) \pm 0.00072(\text{syst.}, 1.96\%)$$

Fit results without i-spin const.

- Fit results without isospin constraints.
- Gaussian constraints on f_{+0} to avoid high correlations.

Parameters	Fit results	Pull
ρ_D^2	1.385 ± 0.069 (5.1 %)	-0.073
ρ^2	1.338 ± 0.077 (5.7 %)	0.004
R_1	1.443 ± 0.114 (7.9 %)	-0.003
R_2	0.680 ± 0.099 (14.5 %)	0.004
$\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu)$	0.02592 ± 0.00096 (3.7 %)	0.733
$\mathcal{B}(B^0 \to D^- \ell^+ \nu)$	0.02275 ± 0.00079 (3.5 %)	-1.010
$\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu)$	0.05252 ± 0.00184 (3.5 %)	0.526
$\mathcal{B}(B^0 \to D^{*-} \ell^+ \nu)$	0.04746 ± 0.00242 (5.1 %)	-0.280
$\mathcal{BT}(B^+ \to \bar{D}^{**0}/(D\pi)^0 \ell^+ \nu)$	0.02197 ± 0.00097 (4.4 %)	-2.083
f_{+0}	1.040 ± 0.029 (2.8 %)	0.114

Pulls are calculated by the differences from nominal values

- Isospin is conserved for both $B \to D^* l \nu$ and $B \to D l \nu$.
- Thanks to new charm decay BF from CLEO-c (arXiv:0709.3783).

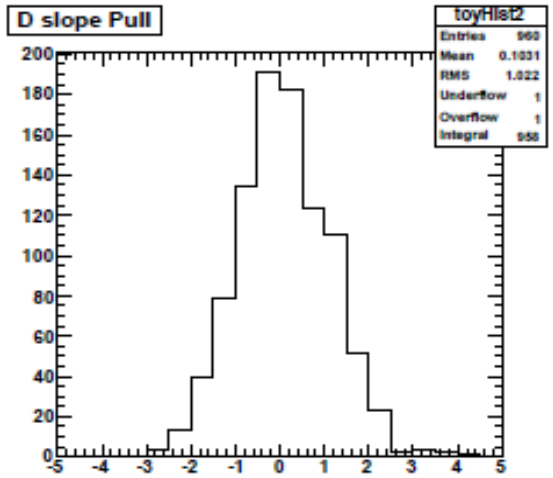
To do list

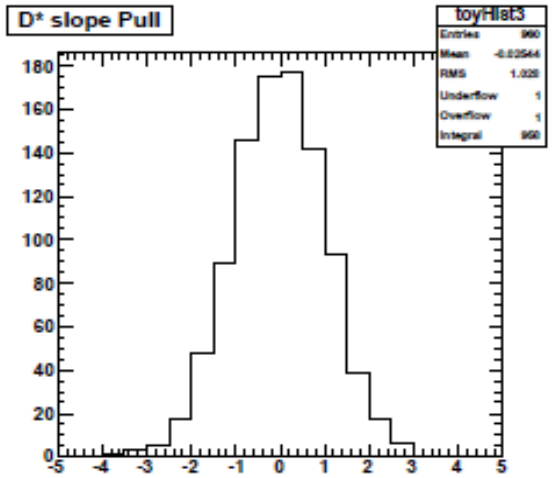
- Systematics to be done.
  - Effect of $D_1 \to D\pi\pi$
  - Radiative correction (PHOTOS)
  - Bremsstrahlung
  - Effect of $B \to D^{(*)}\pi\pi l\nu$ and $B \to D_s^{(*)}K^{(*)}l\nu$ contributions.
- Quote complete covariance matrix for statistic and systematic errors.
- Unblind to full Run1 – 4 data. (Before RC?)

Backup Slides

Toy MC pull plots 1

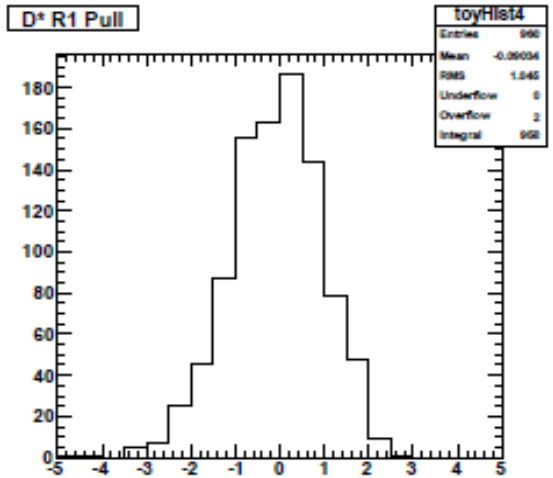
D slope

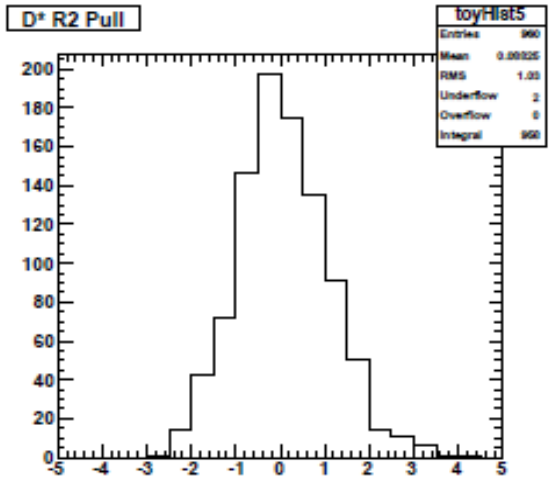




*D** slope

R_1

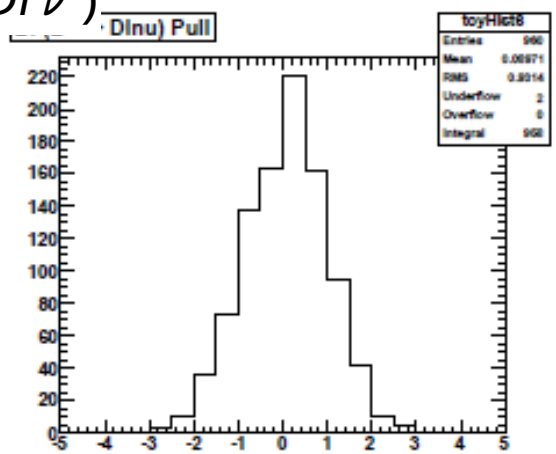




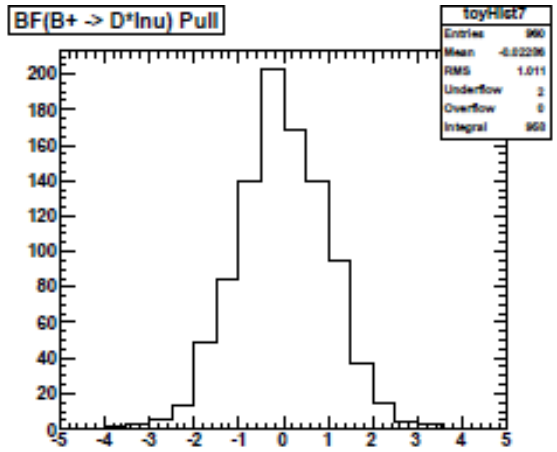
R_2

Toy MC pull plots 2

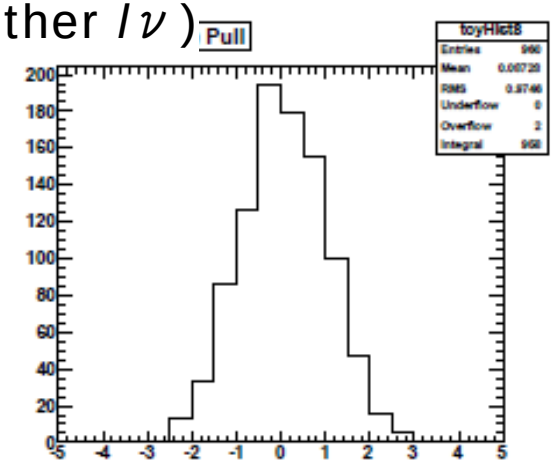
BF($B+->Dl\nu$)

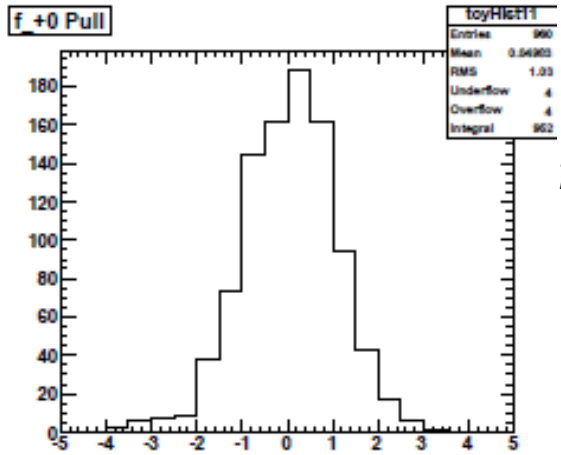


BF($B+->D^*l\nu$)



BF($B+->\text{Other } l\nu$)

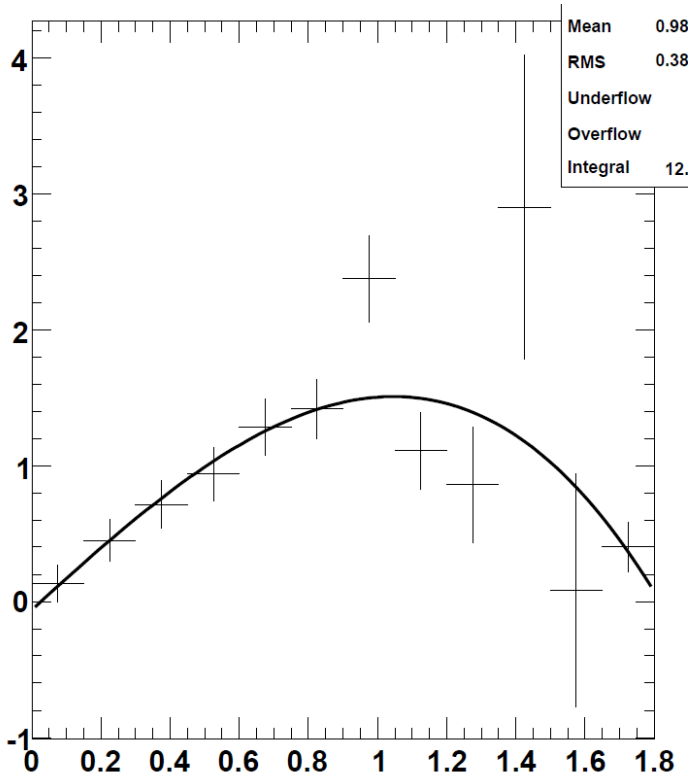




f_{+-}/f_{00}

p_D dependent B->D BF weight

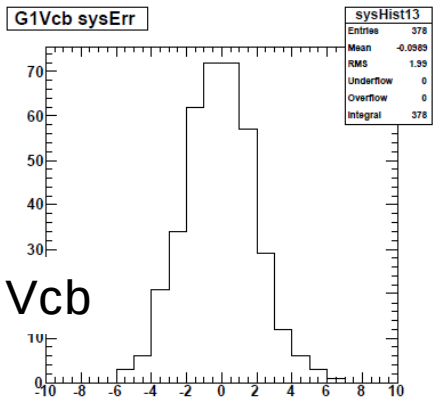
B^+->D^0 (uncorrelated) weight (an example).



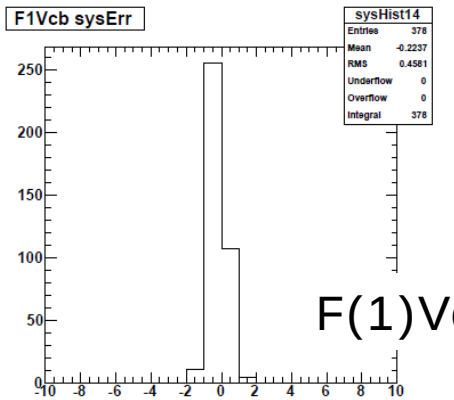
Fit with 3rd order polynomial.

Procedure to get systematic uncertainty.

1. Fluctuate weight by Gaussian random number and re-fit.
2. Make re-weighted histograms
3. Perform fitting and get systematic error.
4. Repeat above ~400 times to get uncertainty distributions -> rms.



G(1)Vcb



F(1)Vcb

Comparison of D^* FF parameters

- hep-ex/0607076v1
  - $B^0 \to D^{*-} l^+ \nu$, $D^{*-} \to D^0 \pi_s^-$
  - $\rho^2 = 1.179 \pm 0.048 \pm 0.028$
  - $R_1 = 1.417 \pm 0.061 \pm 0.044$
  - $R_2 = 0.836 \pm 0.037 \pm 0.022$
- arXiv:0707.2655v1 [hep-ex]
  - $B^- \to D^{*0} l^- \nu$, $D^{*0} \to D^0 \pi^0$
  - Use R_1 and R_2 from hep-ex/0607076v1
  - $\rho^2 = 1.15 \pm 0.06 \pm 0.08$
- Our current results
  - $\rho^2 = 1.338 \pm 0.076 \pm 0.052$
  - $R_1 = 1.443 \pm 0.076 \pm 0.093$
  - $R_2 = 0.680 \pm 0.099 \pm 0.051$

Fit with previous R_1 and R_2

Parameters	Fit results	Pull
ρ_D^2	1.399 ± 0.059	0.775
ρ^2	1.239 ± 0.036	-2.766
R_1	1.417 (Fixed)	n/a
R_2	0.836 (Fixed)	n/a
$\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu)$	0.02587 ± 0.00059	1.092
$\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu)$	0.04983 ± 0.00067	-2.568
$\mathcal{BT}(B^+ \to \bar{D}^{**0}/(D\pi)^0 \ell^+ \nu)$	0.02231 ± 0.00095	0.356
f_{+0}	1.119 ± 0.030	0.622
$C^{D^0}_{UncorDL}$	0.998 ± 0.048	0.039
$C^{D^0}_{UncorCL}$	0.833 ± 0.062	0.245
$C^{D^0}_{CascL}$	0.802 ± 0.091	0.046
$C^{D^+}_{UncorDL}$	1.089 ± 0.126	-0.079
$C^{D^+}_{UncorCL}$	0.818 ± 0.137	0.020
$C^{D^+}_{CascL}$	1.372 ± 0.225	0.093
χ^2/ndof (P-value)	248/215 (0.06)	

ISGW2 FF for $B->Dl\nu$

Parameters	Fit results	Pull
ρ^2	1.471 ± 0.075	1.775
R_1	1.574 ± 0.128	1.024
R_2	0.505 ± 0.112	-1.553
$\mathcal{B}(B^+ \to \bar{D}^0 \ell^+ \nu)$	0.02300 ± 0.00052	-4.302
$\mathcal{B}(B^+ \to \bar{D}^{*0} \ell^+ \nu)$	0.05398 ± 0.00073	3.293
$\mathcal{BT}(B^+ \to \bar{D}^{**0}/(D\pi)^0 \ell^+ \nu)$	0.02137 ± 0.00096	-0.628
f_{+0}	1.063 ± 0.030	-1.248
$C^{D^0}_{UncorDL}$	1.009 ± 0.052	0.235
$C^{D^0}_{UncorCL}$	0.893 ± 0.062	1.222
$C^{D^0}_{CascL}$	0.750 ± 0.091	-0.529
$C^{D^+}_{UncorDL}$	1.239 ± 0.126	1.140
$C^{D^+}_{UncorCL}$	0.873 ± 0.134	0.435
$C^{D^+}_{CascL}$	1.292 ± 0.221	-0.266
χ^2/ndof (P-value)	277/216 (0.003)	

Differential decay rate