

Global Fit for Branching Fractions and Form Factor Slope of $B \rightarrow D^{(*)} \ell \bar{\nu}$ Decays

D momentum dependent BF correction
(background components)
cosBY beam energy correction
Systematic study

Fitting Method (Review)

- Binned chi-square fitting

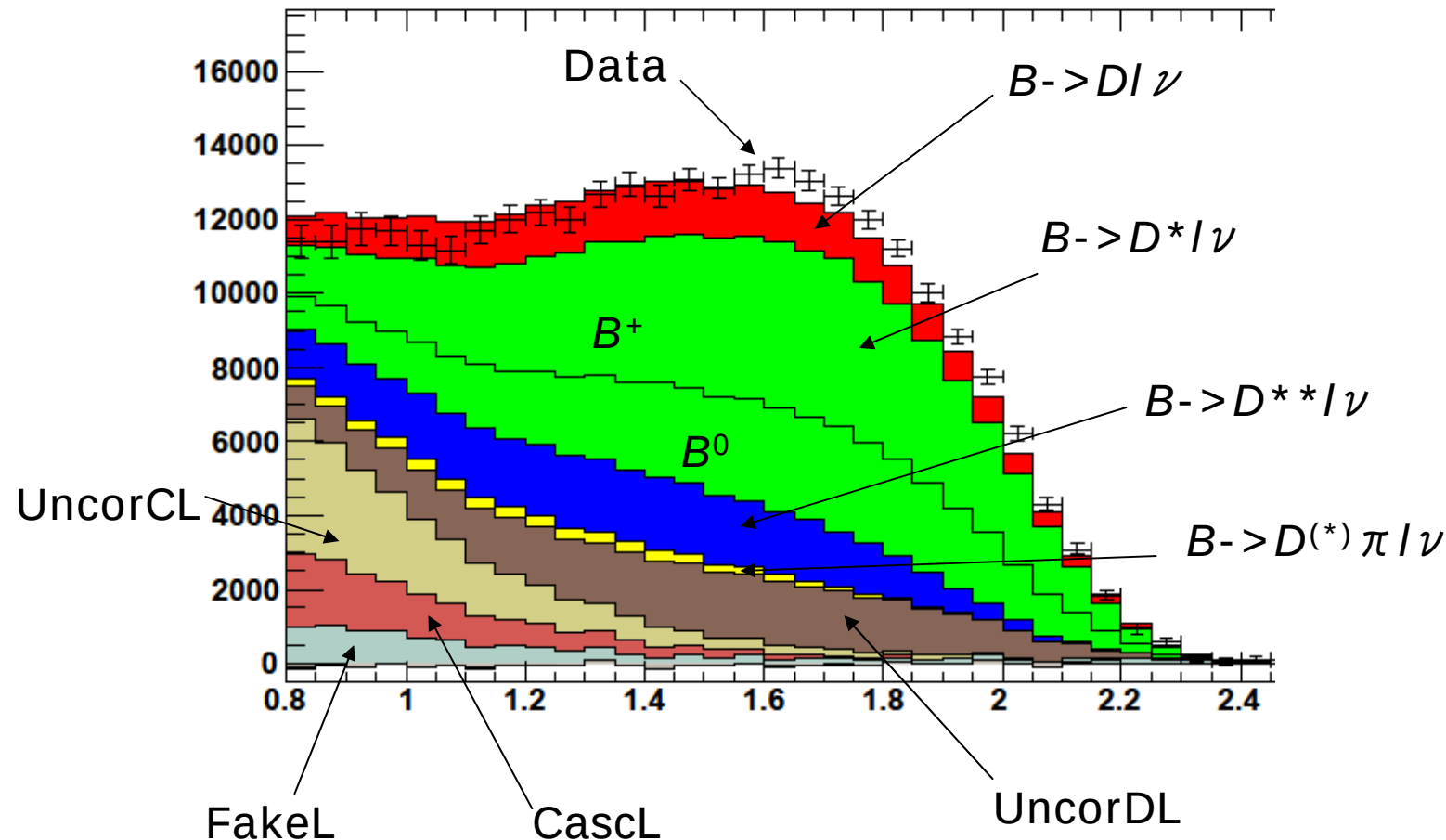
$$\chi^2 = \sum_{i=bin}^{D^0} \frac{\left(N_i^{\text{OnPeak data}} - N_i^{\text{OffPeak data}} - \sum C N_i^{B\bar{B}MC} \right)^2}{\left(\sigma_i^{\text{OnPeak data}} \right)^2 + \left(\sigma_i^{\text{OffPeak data}} \right)^2 + \sum \left(C \sigma_i^{B\bar{B}MC} \right)^2} + \sum_{i=bin}^{D^+} \frac{\left(N_i^{\text{OnPeak data}} - N_i^{\text{OffPeak data}} - \sum C N_i^{B\bar{B}MC} \right)^2}{\left(\sigma_i^{\text{OnPeak data}} \right)^2 + \left(\sigma_i^{\text{OffPeak data}} \right)^2 + \sum \left(C \sigma_i^{B\bar{B}MC} \right)^2}$$

- $N_i^{B\bar{B}MC}$: expected number of candidates from $B\bar{B}$ MC.
- C : consists of **branching fractions** to be determined by the fit.
- BF or FF **re-weighting** is done to produce $N_i^{B\bar{B}MC}$.
- 4 major backgrounds after D mass sideband subtraction.

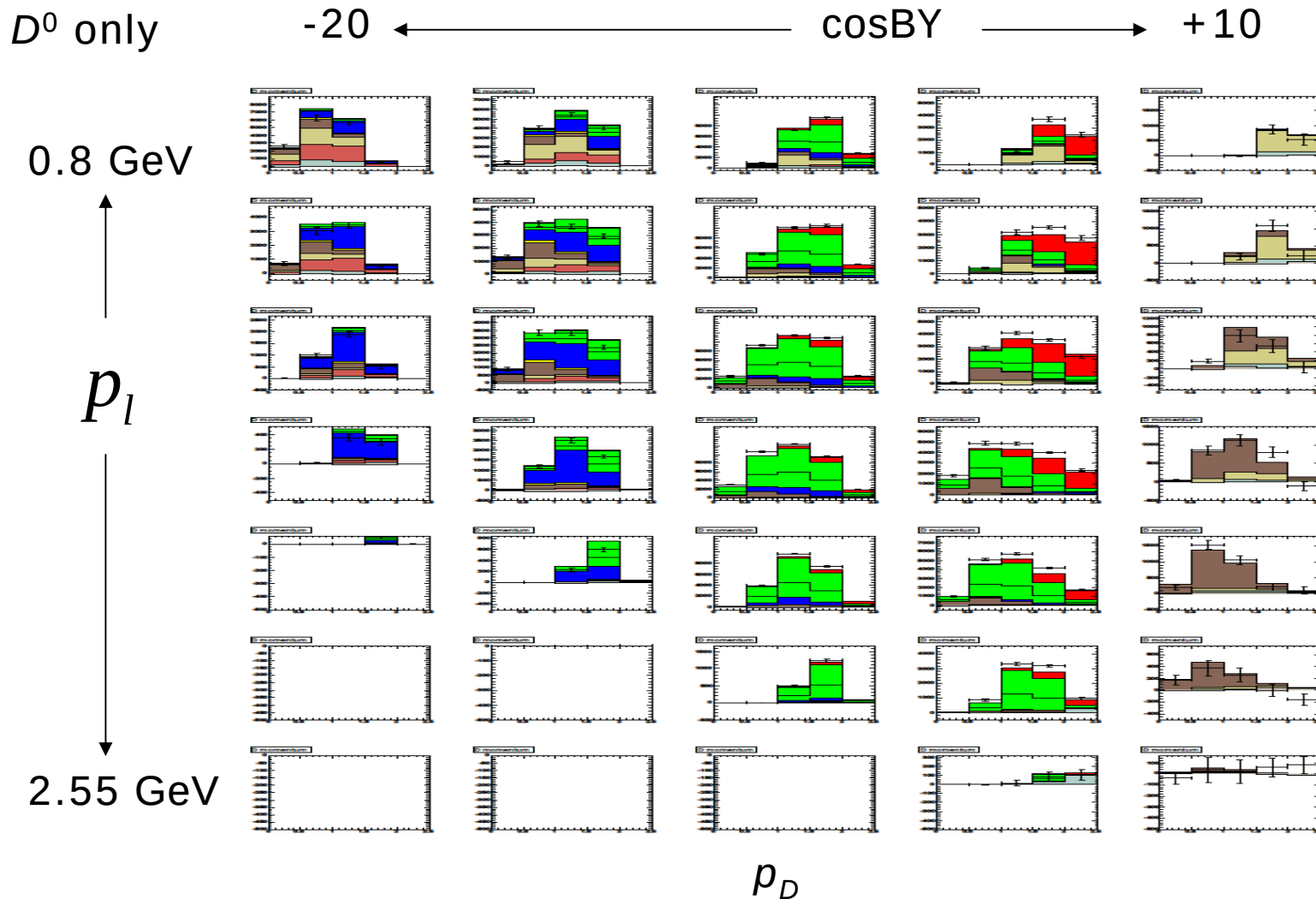
Lepton Momentum : P_l (Review)

(OnPeak – OffPeak) data vs BB MC

D mass sideband subtracted.
 D^0 only



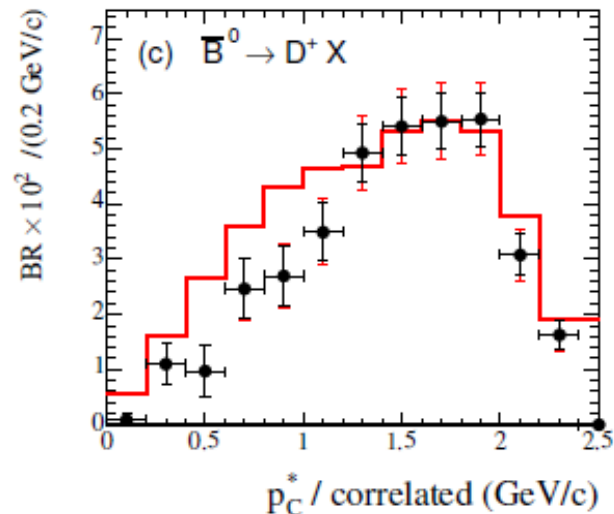
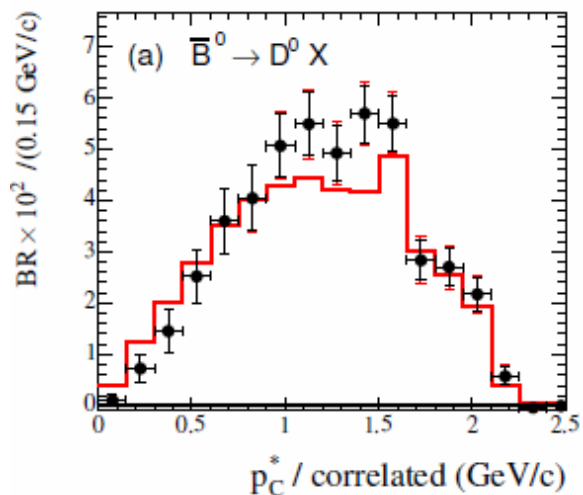
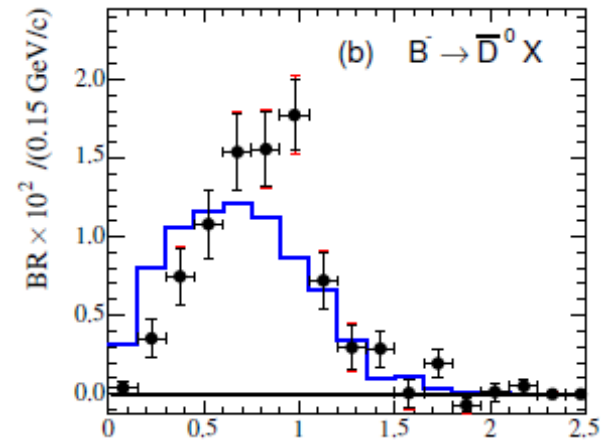
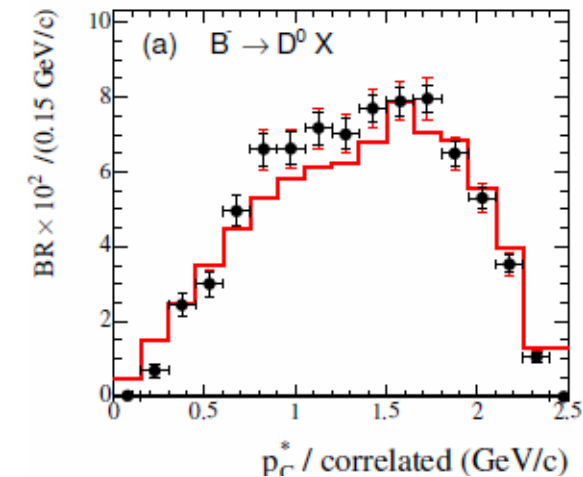
3D Binning : p_l , p_D , cosBY (Review)



Background BF re-weighting (1)

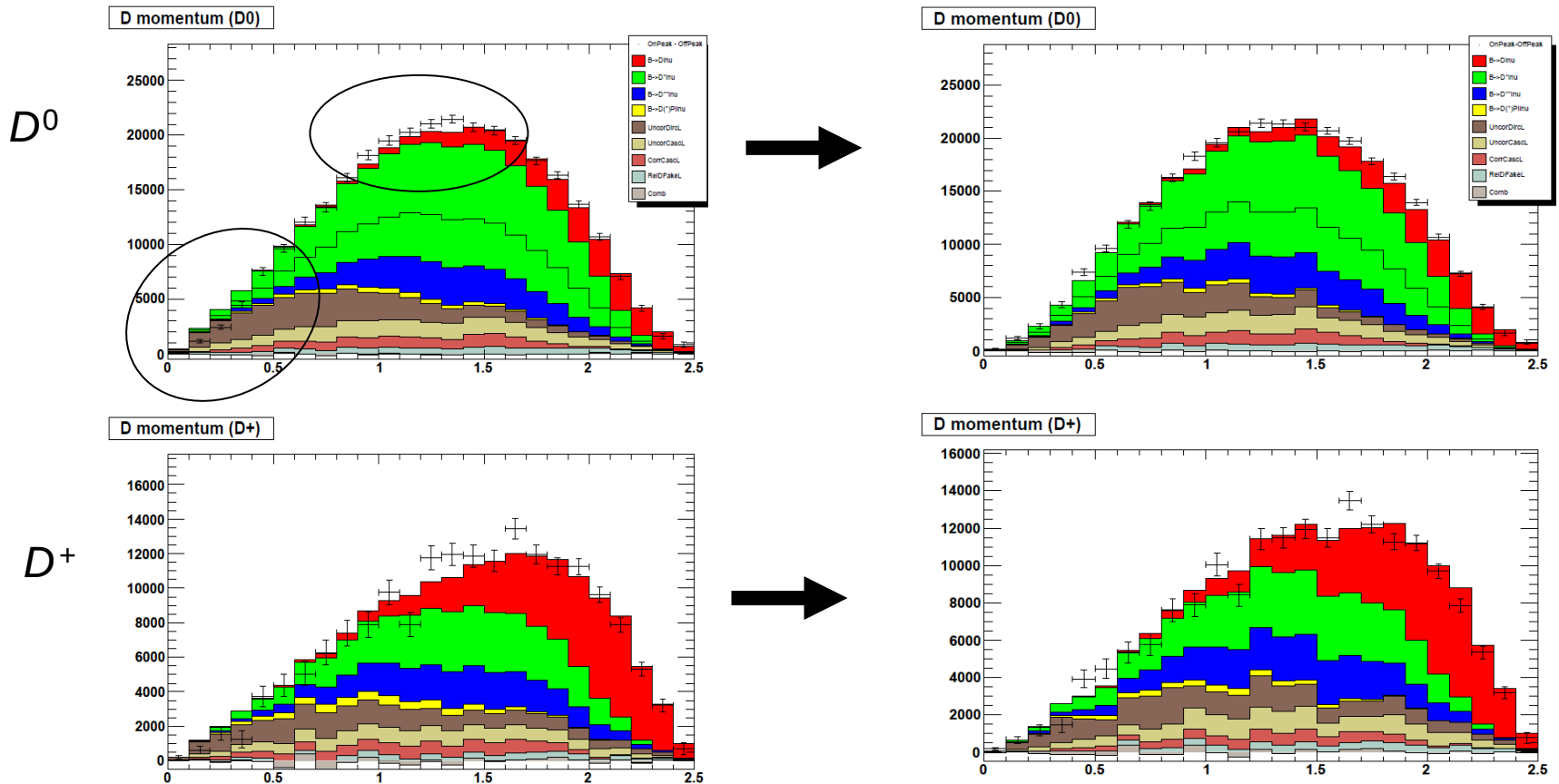
$B \rightarrow D$ inclusive BF. **D momentum dependence.**

BABAR-PUB-06/020 (BAD 1234)



Background BF re-weighting (2)

$B \rightarrow D$ inclusive BF re-weighting (based on BABAR-PUB-06/020)
D momentum dependence is included.



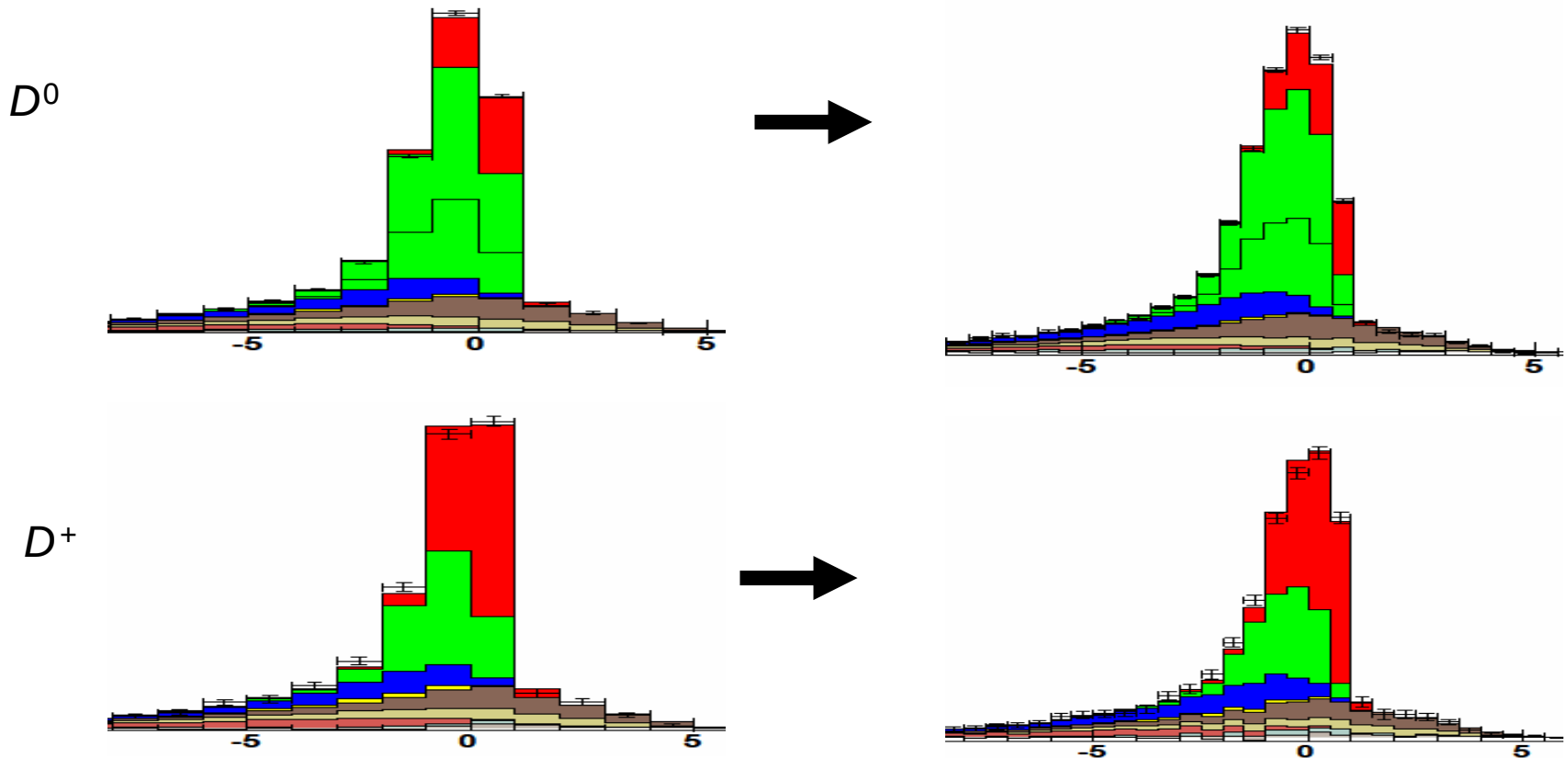
Effect is visible. $\rightarrow$ Big impact on χ^2/ndof : 420/255 $\rightarrow$ 310/250

cosBY beam energy correction (1)

- Beam energy is not well simulated.
 - Cause cosBY difference of data/MC
 - Since $\cos\text{BY} \sim 1/p_B$, $p_B = \sqrt{E_{\text{beam}}^2 - m_B^2}$
and
$$\frac{\sigma(p_B)}{p_B} = \left(\frac{E_{\text{beam}}}{p_B}\right)^2 \left(\frac{\sigma(E_{\text{beam}})}{E_{\text{beam}}}\right) \cong 264 \bullet \frac{\sigma(E_{\text{beam}})}{E_{\text{beam}}}$$
- A study was done before (BAD 482).
 - Produced **scale factor 0.96**.
- We apply same scale factor to cosBY of MC.
 - Make **MC cosBY peak narrower** to agree with data.
 - More detailed study will be done later.

cosBY beam energy correction (2)

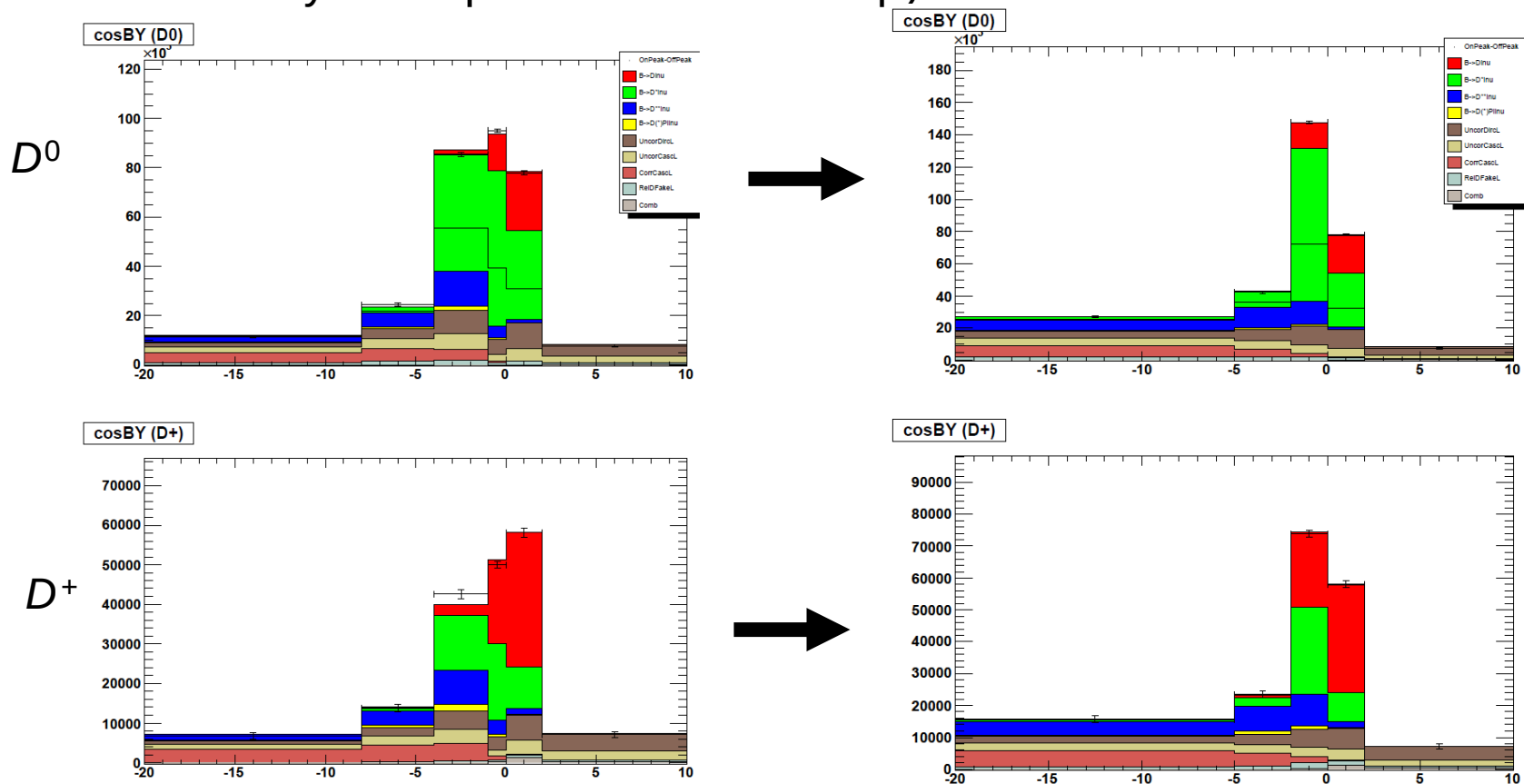
Apply a **scale factor 0.96** to make MC cosBY peak narrower.
(Sorry for different binning before and after correction.)



Effect is not really visible.

cosBY beam energy correction (3)

With binning used for fitting (Binning was changed not to have a boundary at slope of cosBY is steep)



Effect is visible. -> Big impact on χ^2/ndof : 310/255 -> 220/214

Fit Result (Run2 only)

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

$D l \nu$ FF slope	1.348 ± 0.068 (5.0 %)
$D^* l \nu$ FF slope	1.373 ± 0.081 (5.9 %)
R_1	1.527 ± 0.125 (8.2 %)
R_2	0.581 ± 0.109 (18.8 %)
$\text{BF}(B^+ \rightarrow D l \nu)$	0.02547 ± 0.00083 (3.3 %)
$\text{BF}(B^+ \rightarrow D^* l \nu)$	0.05332 ± 0.00123 (2.3 %)
$\text{BF}(B^+ \rightarrow D^{**}/D^{(*)} \pi l \nu)$	0.02120 ± 0.00106 (5.0 %)

- Chi-square/ndof = **220/214**
- This is only Run2 data. Run1-Rnu4 has 3.5 times more statistics $\Rightarrow$ statistical error will be $\sim 1/2$.

Correlations

	D slope	D^* slope	R_1	R_2	$\text{BF}(D/\nu)$	$\text{BF}(D^*/\nu)$	$\text{BF}(\text{Other})$
D slope	1						
D^* slope	-0.252	1					
R_1	-0.175	0.822	1				
R_2	0.233	-0.911	-0.909	1			
$\text{BF}(D/\nu)$	0.371	0.045	0.045	0.052	1		
$\text{BF}(D^*/\nu)$	-0.290	0.141	0.003	-0.156	-0.003	1	
$\text{BF}(\text{Other})$	0.066	-0.186	-0.150	0.173	0.239	-0.102	1

BF re-normalization

- In principle, what we measure are absolute BF since we do luminosity normalization.
- But systematic error from efficiency etc. are large.
- It is better to re-normalize to inclusive BF for $p_l^* > 1.5$ GeV. But, this is not yet ready.
- For now we use relative BF.

$\text{RBF}(B^+ \rightarrow D/\nu)$	25.47 ± 0.83 (3.3 %)
$\text{RBF}(B^+ \rightarrow D^*/\nu)$	53.33 ± 1.23 (2.3 %)
$\text{RBF}(B^+ \rightarrow D^{**}/D^{(*)} \pi / \nu)$	21.29 ± 1.06 (5.0 %)

Systematic Error (%)

	D slope	D^* slope	R_1	R_2	Relative BF(D/ν)	Relative BF(D^*/ν)	Relative BF(Other)
$B \rightarrow D^{**}$ FF	0.61	2.14	2.44	4.28	0.87	0.99	3.48
$B \rightarrow D^{**}$ $D\pi$ BF ratios	0.27	0.69	2.28	2.22	0.65	1.12	3.58
D^{**} decay BF	0.08	0.07	0.11	0.27	0.04	0.11	0.32
t_{+0}	0.03	0.12	0.12	0.24	0.06	0.01	0.08
Trk, PID	0.49	0.43	4.14	0.65	0.19	0.41	1.26
Total	0.84	2.29	5.32	4.88	1.11	1.55	5.16

More systematic study

- We still need to do more systematic study.
 - Luminosity normalization (B counting)
 - Radiative correction (PHOTOS)
 - Background BF re-weighting
 - BF re-normalization
- Errors are expected to be the similar size as others.

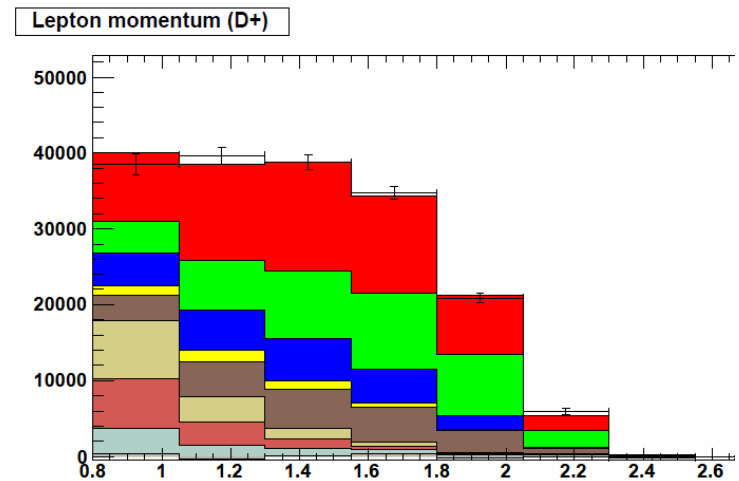
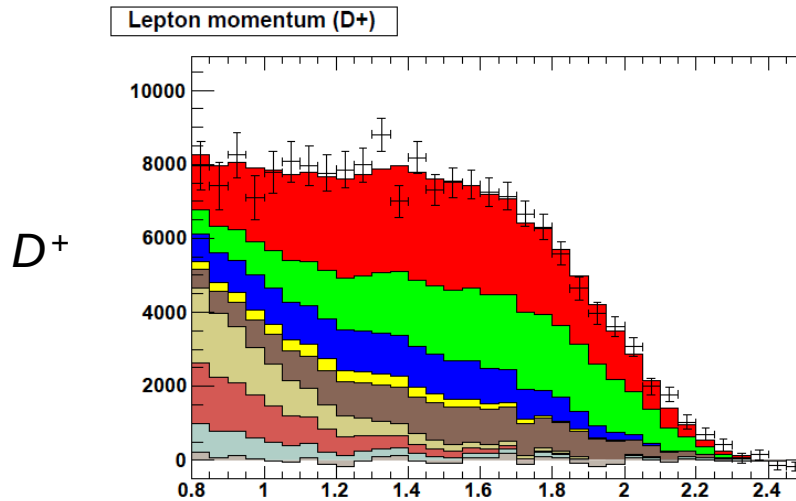
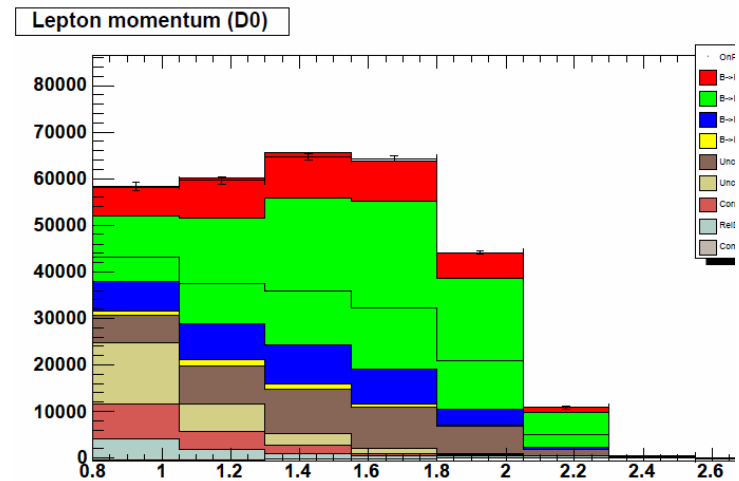
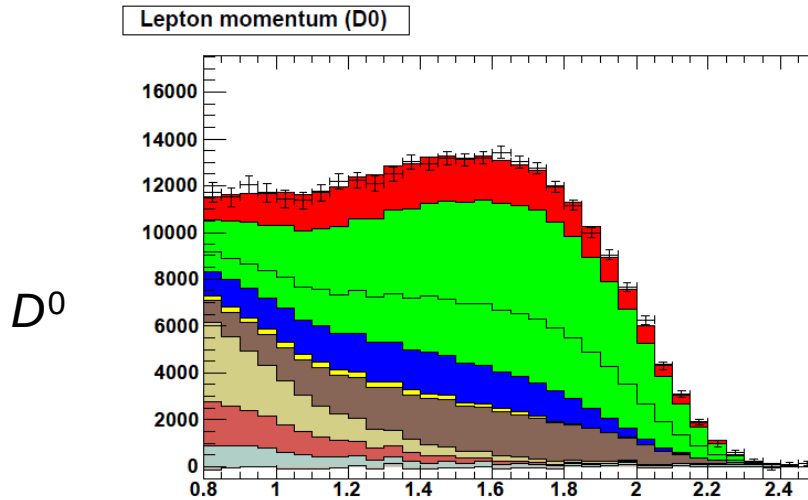
$B \rightarrow D^* \ell \nu$ isospin symmetry

- D^{*+} decay BF was not the only BF of relevance to the apparent isospin violation.
- The cause may be a combination of small deviation of
 - $\text{BF}(D^{*+} \rightarrow D^0 \pi^+) : 0.677 \rightarrow 0.678 (0.2 \sigma \text{ off})$
 - $\text{BF}(D^+ \rightarrow K^- \pi^+ \pi^-) : 0.0951 \rightarrow 0.0909 (1.2 \sigma \text{ off})$
 - $\text{BF}(D^0 \rightarrow K^- \pi^+) : 0.0380 \rightarrow 0.0384 (0.6 \sigma \text{ off})$
 - $f_{+-}/f_{00} : 1.024 \rightarrow 1.064 (1.25 \sigma \text{ off})$(These were floated in the fit with Gaussian constraints from PDG values.)
- $\text{BF}(D^+ \rightarrow K^- \pi^+ \pi^-)$ and f_{+-}/f_{00} are more responsible than D^{*+} decay BF.

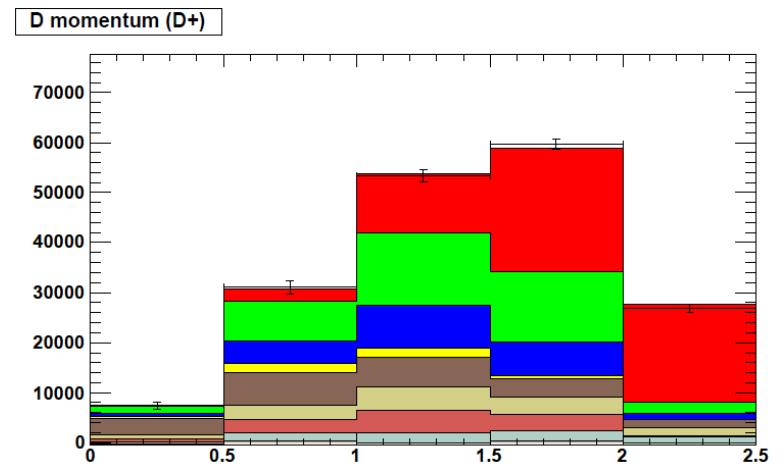
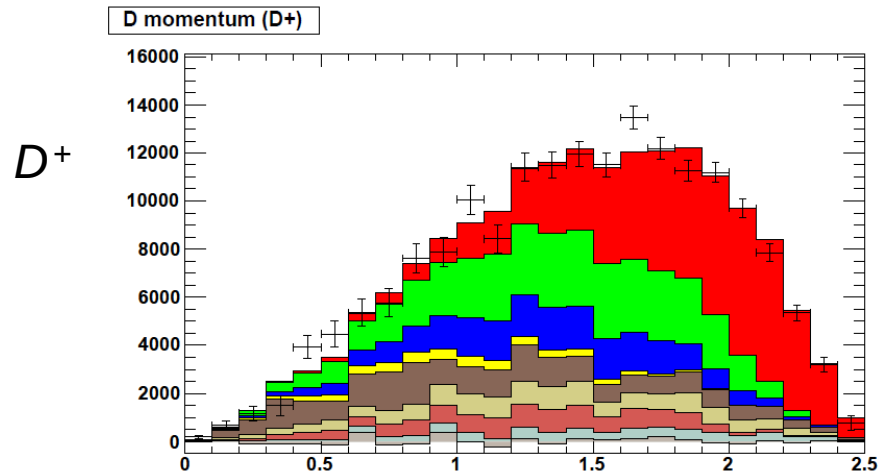
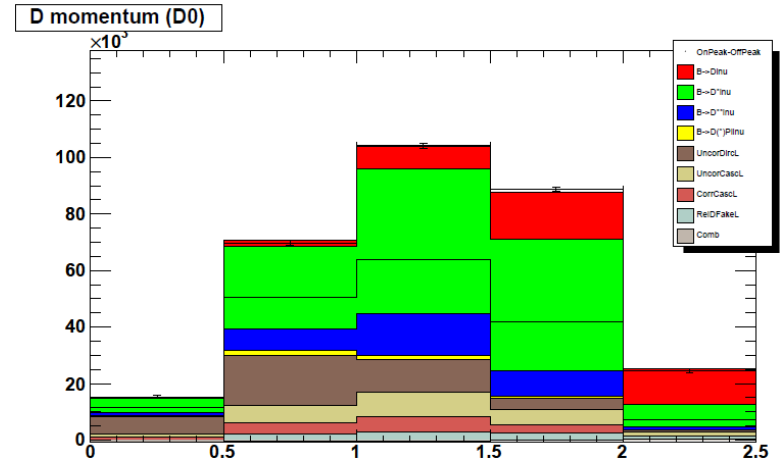
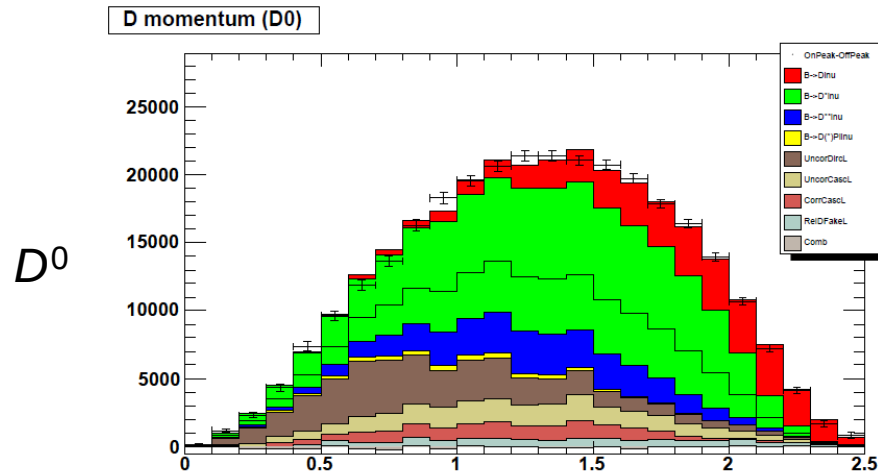
Summary

- D momentum dependent inclusive $B \rightarrow D$ BF re-weighting is done.
- cosBY beam energy correction is done.
- Good chi-square/ndof = 220/215
- Some systematic study is done.
- BAD1586 V3 is ready.
- Next steps (will be done soon)
 - More systematic study.
 - More validation fits.
 - Toy MC study
 - BF re-normalization.
 - Extraction of $F(1)V_{cb}$ and $G(1)V_{cb}$
- We would like to request RC.

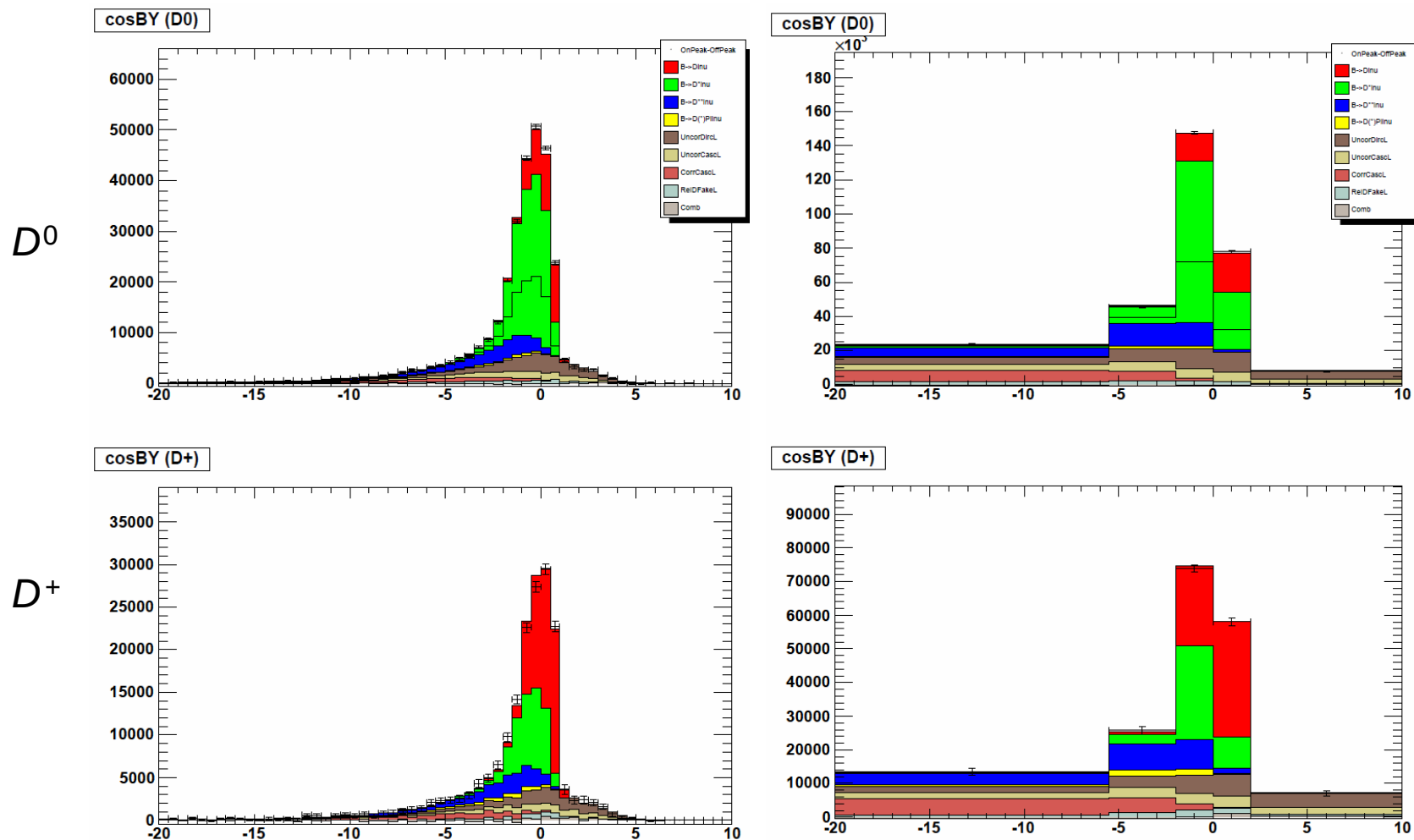
Fitted p_l^*



Fitted p_D^*



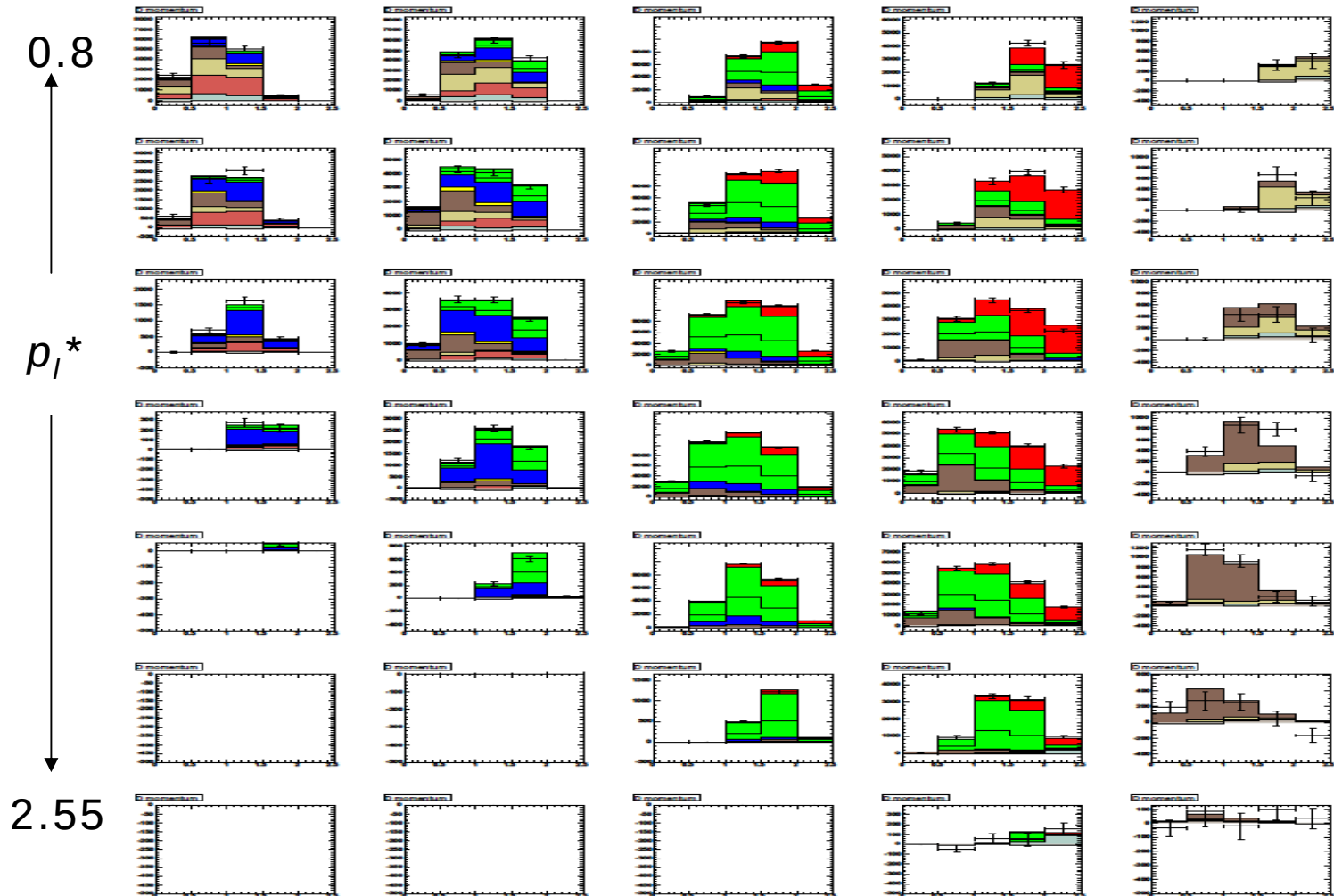
Fitted cosBY



Bin by Bin (Fitted): D^0

cosBY = -20

cosBY = +10



Bin by Bin (Fitted): D^+

$\cos\text{BY} = -20$

$\cos\text{BY} = +10$

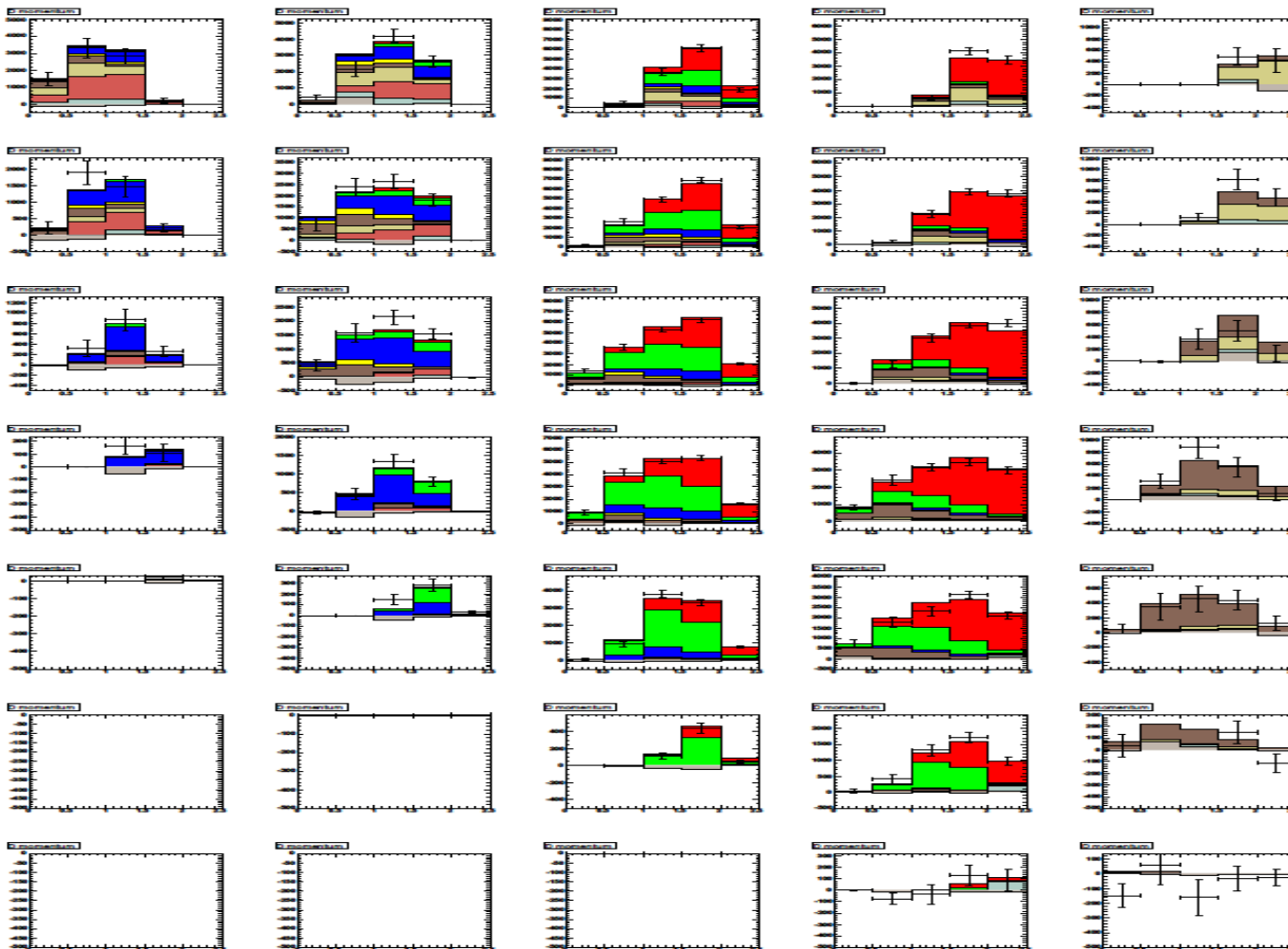
0.8



p_l^*



2.55



Fit Result (2)

$\text{BF}(D^{*+} \rightarrow D^0 \pi^+)$	0.6780 ± 0.056
$\text{BF}(D^+ \rightarrow K^- \pi^+ \pi^-)$	0.0909 ± 0.0024
$\text{BF}(D^0 \rightarrow K^- \pi^+)$	0.03842 ± 0.00065
f_{+-}/f_{00}	1.064 ± 0.028
UncorrDL background (D^0)	1.096 ± 0.060
UncorrCL background (D^0)	0.844 ± 0.079
CascL background (D^0)	0.934 ± 0.123
FakeL background (D^0)	0.870 ± 0.276
UncorrDL background (D^+)	0.904 ± 0.116
UncorrCL background (D^+)	0.809 ± 0.138
CascL background (D^+)	1.491 ± 0.261

Validation Fit (1)

parameter	Input value	Fitted value	Pull
D/ν FF slope	1.20	1.175	-0.34
D^*/ν FF slope	1.145	1.178	0.65
R_1	1.396	1.372	-0.06
R_2	0.855	0.865	0.18
$\text{BF}(B^+ \rightarrow D/\nu)$	0.0215	0.02252	1.50
$\text{BF}(B^+ \rightarrow D^*/\nu)$	0.0650	0.06638	1.10
$\text{BF}(B^+ \rightarrow D^{*+}/D^{(*)} \pi^-/\nu)$	0.0232	0.02368	0.52
$\text{BF}(D^{*+} \rightarrow D^0 \pi^+)$	0.677	0.6734	-0.68
$\text{BF}(D^+ \rightarrow K^- \pi^+ \pi^-)$	0.0951	0.944	-0.32
$\text{BF}(D^0 \rightarrow K^- \pi^+)$	0.0380	0.03842	0.68
f_{+-}/f_{00}	1.024	1.049	0.93

Validation Fit (2)

parameter	Input value	Fitted value	Pull
D/ν FF slope	1.348	1.313	-0.65
D^*/ν FF slope	1.373	1.423	0.76
R_1	1.526	1.496	-0.30
R_2	0.581	0.542	-0.43
$\text{BF}(B^+ \rightarrow D/\nu)$	0.0255	0.02656	1.41
$\text{BF}(B^+ \rightarrow D^*/\nu)$	0.0533	0.05447	1.10
$\text{BF}(B^+ \rightarrow D^{*+}/D^{(*)} \pi^+/\nu)$	0.0212	0.02151	0.35
$\text{BF}(D^{*+} \rightarrow D^0 \pi^+)$	0.678	0.6755	-0.46
$\text{BF}(D^+ \rightarrow K^- \pi^+ \pi^-)$	0.0909	0.0899	-0.46
$\text{BF}(D^0 \rightarrow K^- \pi^+)$	0.0384	0.03885	0.73
f_{+-}/f_{00}	1.064	1.071	0.26