

Monte Carlo Generator Issues

Semi-Leptonic AWG

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SLAC

Monte Carlo Workshop

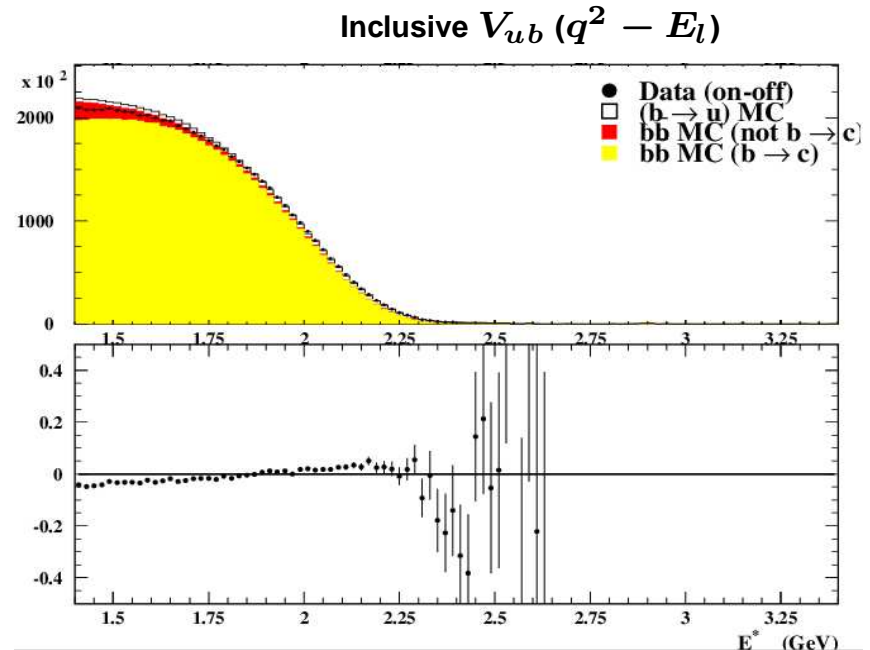
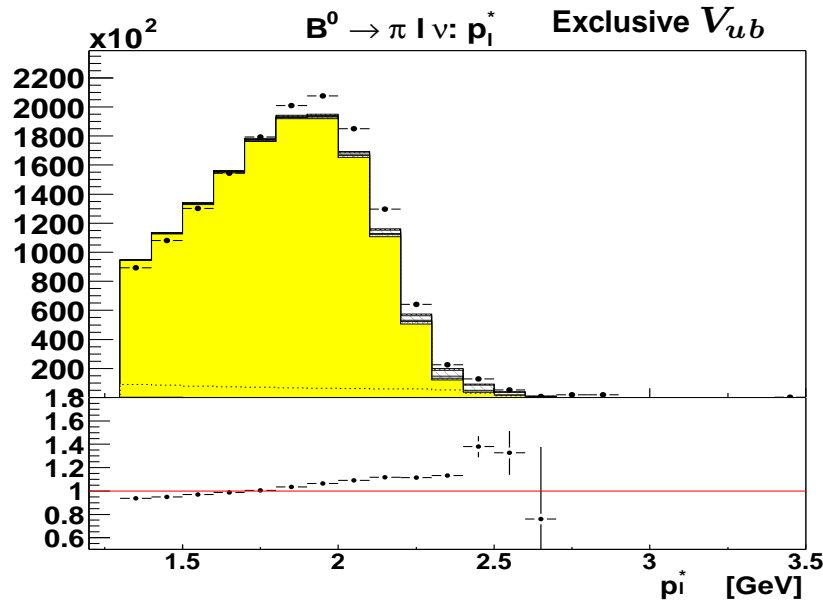
SLAC, July 12th, 2004

Overview

- **Goal:** Point at generator issues from the “semi-leptonic point of view”
 - Report data/MC discrepancies
 - Changes that should be implemented in the generators
 - Questions to be discussed
- **Contents:**
 - Charm Decays $b \rightarrow cl\nu$
 - Charmless Decays $b \rightarrow ul\nu$
 - Simulation of B Meson Momentum
 - Radiative Corrections
 - Continuum Simulation
 - B Lifetime , f_{00}
- **Numbers presented are NOT final numbers to be implemented!**

Modeling of $b \rightarrow c\ell\nu$ Decays

- Observe **mismatch** between **simulated and experimental lepton spectra (P_ℓ^*)**
 - V_{cb} analyses, affecting the $b \rightarrow c\ell\nu$ signal
 - V_{ub} analyses, affecting $b \rightarrow c\ell\nu$ as main background to $b \rightarrow u\ell\nu$ signal
- P_ℓ^* spectrum is harder in the real data ($\sim 10\%$ effect). This is seen in inclusive and exclusive analyses!



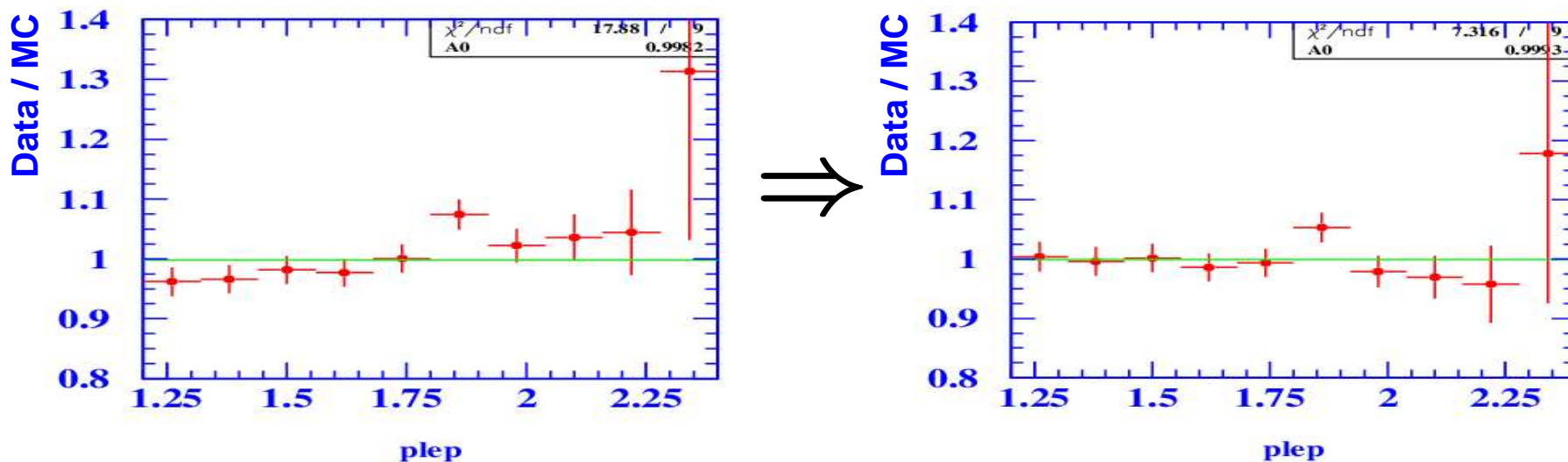
- Large uncertainties in charm modeling from:
 - Relative branching fractions of $B \rightarrow (D/D^*/D^*(n)\pi) \ell \nu$
 - Form factors (kinematics) for each decay mode

$B \rightarrow D/D^*$ Decay Form Factors

- **New prelim. measurement of $B^0 \rightarrow D^* \ell \nu$ form factors** (ICHEP'04, BAD 943)

| | R_1 | R_2 | ρ^2 |
|---------------|-----------------------------------|-----------------------------------|-----------------------------------|
| SP4 (CLEO) | 1.18 ± 0.32 | 0.71 ± 0.23 | 0.91 ± 0.16 |
| BaBar prelim. | 1.34 ± 0.07 | 0.91 ± 0.05 | 0.77 ± 0.05 |

- **New FF values (esp. higher R_1, R_2) improve Data/MC discrepancy**



- Also D form factor is under study (FF value from CLEO)
- **Relative $B \rightarrow D/D^*/D^{**}$ BF's can account for remaining discrepancies**

$B \rightarrow D/D^*/D^{**}$ Branching Fractions

- MC needs updating of $B \rightarrow D/D^*/D^{**}$ and total $B \rightarrow cl\nu$ BFs
- Difference in charged and neutral B lifetimes taken into account
- Suggested new values (not final numbers!) come from **PDG'03**, **CLEO'98**, **BaBar'04** and **fits in our inclusive $|V_{ub}|$ analysis** (“**tuning of kinematic spectra**” in BAD 755, 664; scale factors efficiency dependent).

| BF (%) | SP4 ($B^0 = B^\pm$) | New B^0 | Error range | New B^\pm | Error range |
|----------------|-----------------------|-----------|-------------|-------------|-------------|
| D | 2.10 | 2.07 | 1.92-2.22 | 2.24 | 2.08-2.39 |
| D^* | 5.6 | 5.7 | 4.68-6.23 | 6.17 | 5.04-7.0 |
| D_1 | 0.56 | 0.52 | 0.37-0.67 | 0.56 | 0.40-0.72 |
| D_2 | 0.37 | 0.23 | 0-0.46 | 0.30 | 0-0.6 |
| D_0 | 0.20 | 0.45 | 0-0.86 | 0.49 | 0-0.87 |
| D'_1 | 0.37 | 0.83 | 0-1.24 | 0.90 | 0-1.28 |
| BF ($cl\nu$) | 10.4 | 10.21 | 1.04-10.38 | 11.04 | 10.86-11.22 |

Input from Charm AWG is very welcome!

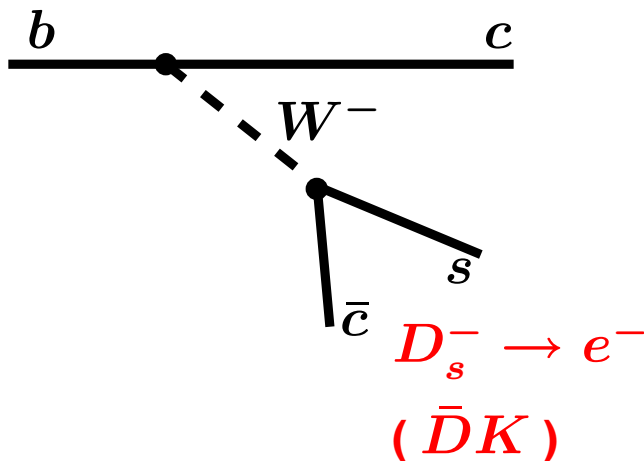
D Branching Fractions and $D\bar{D}K$, D_s Production

- Update of inclusive D decay BFs to PDG values

| BF (%) | D^0 | D^+ | D_s^+ |
|---------------------|------------------------|-----------------------|--|
| $D \rightarrow K^0$ | 42 ± 5 (39) | 59 ± 7 (62) | 39 ± 38 (39.8) |
| $D \rightarrow K^+$ | 53 ± 4 (54) | 24.2 ± 2.8 (34) | $K^- : 13_{-12}^{+14}$ (19.3), $K^+ : 20_{-14}^{+18}$ (28.2) |
| $D \rightarrow e$ | 6.87 ± 0.28 (6.73) | 17.2 ± 1.9 (13.5) | 8.1 ± 0.7 (5.9) |

(SP4 default is given in parenthesis)

- Inclusive DK and D_s upper vertex production



- Important **source of systematic error** for analyses using **lepton correlations** (e.g. electron moments meas. BAD 636)
- Uncertainty on contribution from DK (incl.) at upper vertex is large
- Also $\sim 30\%$ uncertainty on $D_s \rightarrow \phi\pi$ (new BaBar result $\rightarrow 15\%$ (BAD 935))

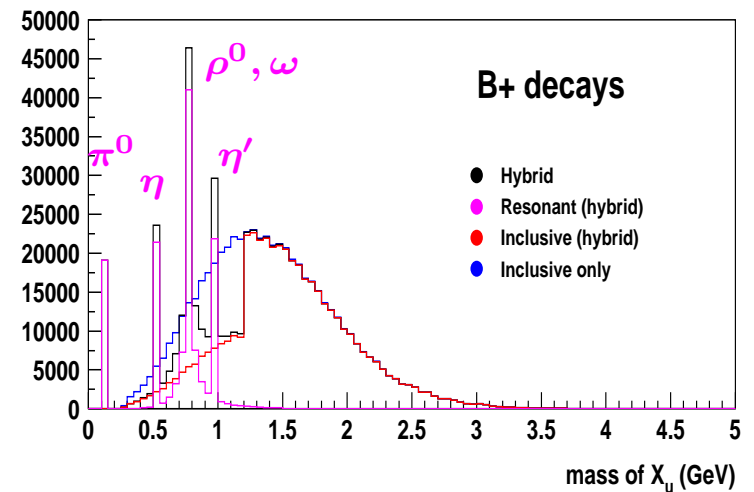
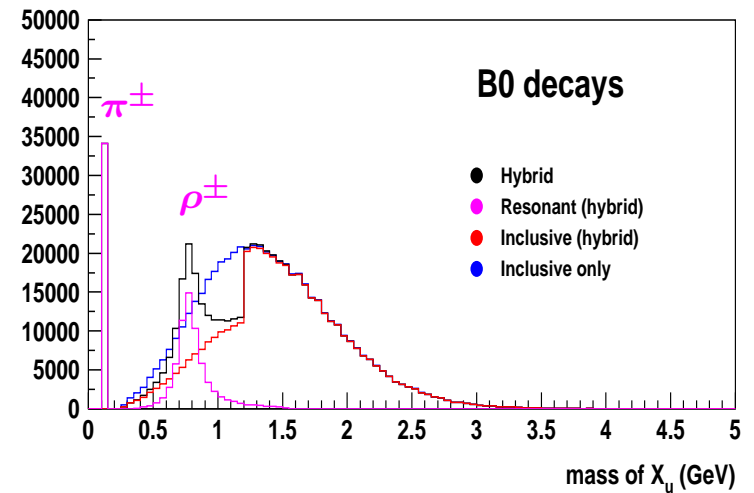
$b \rightarrow u\ell\nu$: Hybrid Model

- $B \rightarrow X_u\ell\nu$ generators:

- **Inclusive:** Continuous M_X spectrum, simulated according to DeFazio-Neubert shape function (no resonant structure, no states below $2m_\pi$)
- **Exclusive:** Resonant states generated using ISGW2 (no non-resonant decays)
- **Hybrid:** More realistic model by **combining inclusive and exclusive** modes in one **hybrid**

- So far hybrid sample is produced by mixing inclusive and exclusive samples reweighted in bins of m_X, q^2, E_e (BAD 664)

⇒ **Would be nice to directly generate events according to hybrid model (?)**



$B \rightarrow X_u \ell \nu$: Branching Fractions

- Branching fractions for resonant B decays into $X_u = \pi^{\pm,0}, \eta, \eta'$ (pseudoscalar) and $\rho^{\pm,0}, \omega$ (vector) need to be updated to **PDG'03**
- Since no measurement of **other resonances** (a, b, f, \dots) exist, they are **set to zero**
- Inclusive BF is adjusted to **preserve correct overall normalization** of hybrid sample

| BF (10^{-4}) | SP4 B^0 | New B^0 | SP4 B^\pm | New B^\pm |
|-------------------------|-----------|-----------|-------------|-------------|
| π | 1.8 | 1.33 | 0.9 | 0.72 |
| η | – | – | 0.3 | 0.84 |
| η' | – | – | 0.6 | 0.84 |
| ρ | 2.6 | 2.69 | 1.3 | 1.45 |
| ω | – | – | 1.3 | 1.45 |
| Other resonances | 2.95 | 0.00 | 5.1 | 0.00 |
| Non-resonant | 13.65 | 17.48 | 13.70 | 17.90 |
| Total | 21.0 | 21.5 | 21.0 | 23.2 |

\Rightarrow Update soon!

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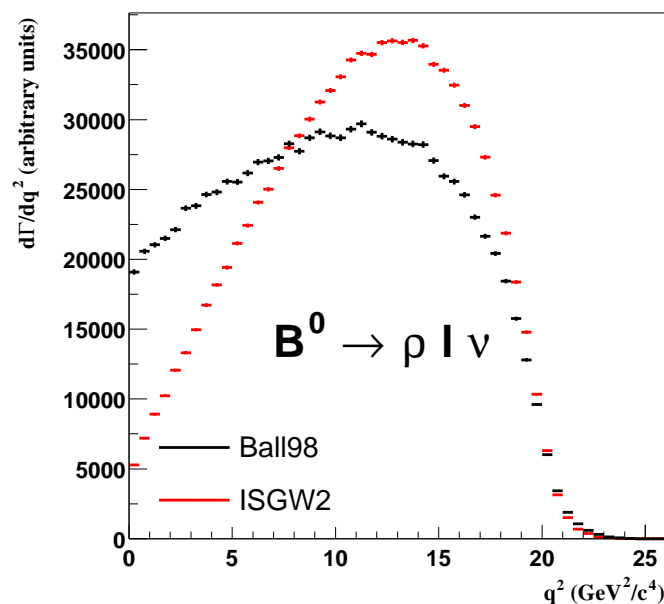
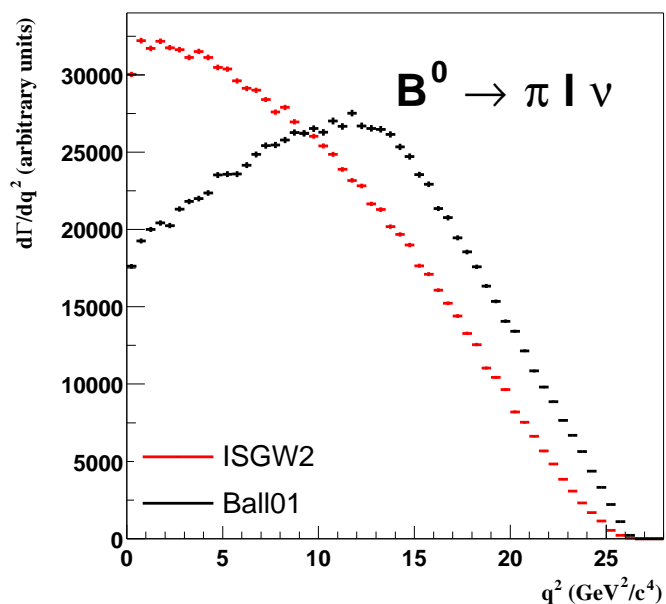
$B \rightarrow X_u \ell \nu$: B Decay Form Factors

- $B \rightarrow \pi, \rho$ decays in **SP4 MC** are generated with **ISGW2 form factor** model.

$$B \rightarrow \pi \ell \nu : \frac{d\Gamma}{dq^2 d\cos\theta_\ell} \propto |V_{ub}|^2 \sin^2\theta_\ell |f_+(q^2)|^2$$

$$B \rightarrow \rho \ell \nu : \frac{d\Gamma}{dq^2 d\cos\theta_\ell} \propto |V_{ub}|^2 \{ (1 - \cos\theta_\ell)^2 H_+(q^2) + (1 + \cos\theta_\ell)^2 H_-(q^2) + 2 \sin^2\theta_\ell H_0(q^2) \}$$

- Package to reweight kinematic spectra to different FF models (BAD 809)



- Anticipate **result on $\pi \ell \nu$ FF** (q^2 spectrum) from exclusive $|V_{ub}|$ analysis **this fall**
- **$\rho \ell \nu$ is difficult** (3 FF's, less statistics) \rightarrow results **probably later**

$B \rightarrow X_u \ell \nu$: B Decay Form Factors

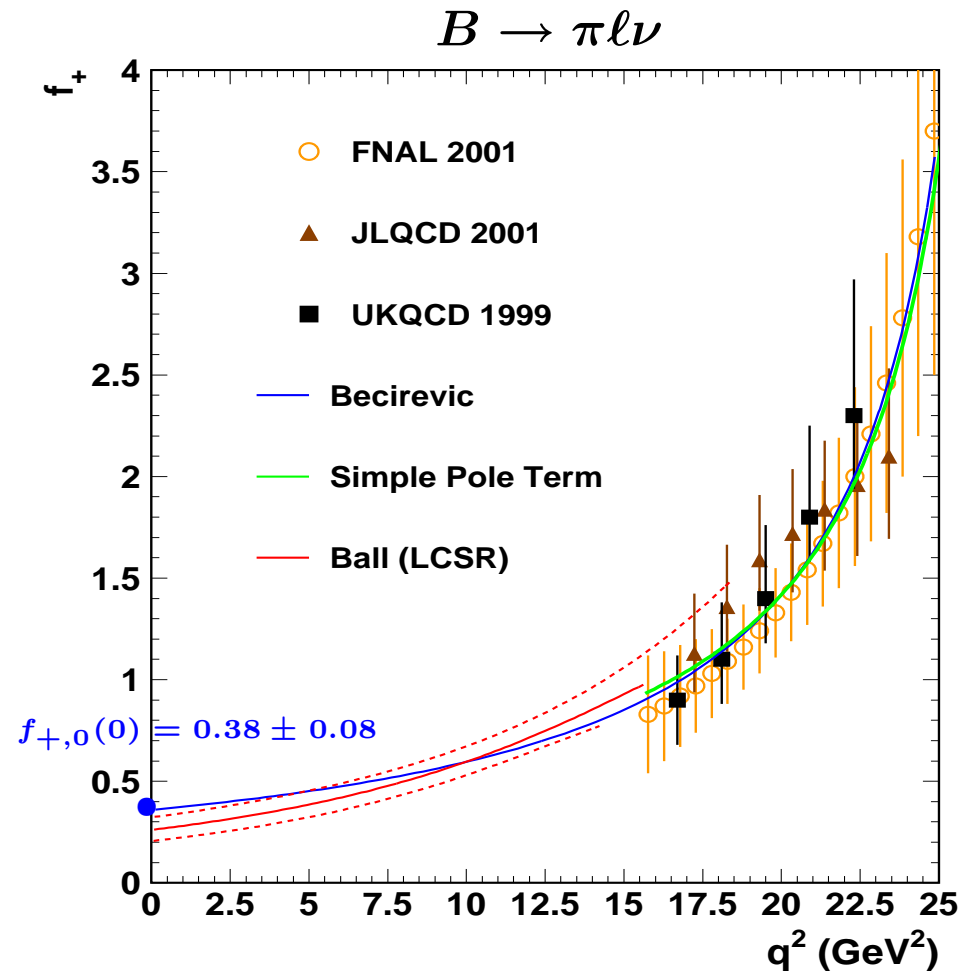
- Would be nice to have a **FF parameterization** (one function) **over whole q^2 range**
- **Performed fits to LQCD points:**

1. Pole Term:

$$f_+(q^2) = \frac{c}{1 - (q^2/m_{B^*}^2)}$$

2. Becirevic:

$$f_+(q^2) = \frac{c_B(1-\alpha)}{(1 - q^2/m_{B^*}^2)(1 - \alpha q^2/m_{B^*}^2)}$$



- For $B \rightarrow \rho \ell \nu$ use ISGW2 or parameterization (how good?)

Simulation of B Meson CMS Momentum

- Compare CM energy in data and MC:

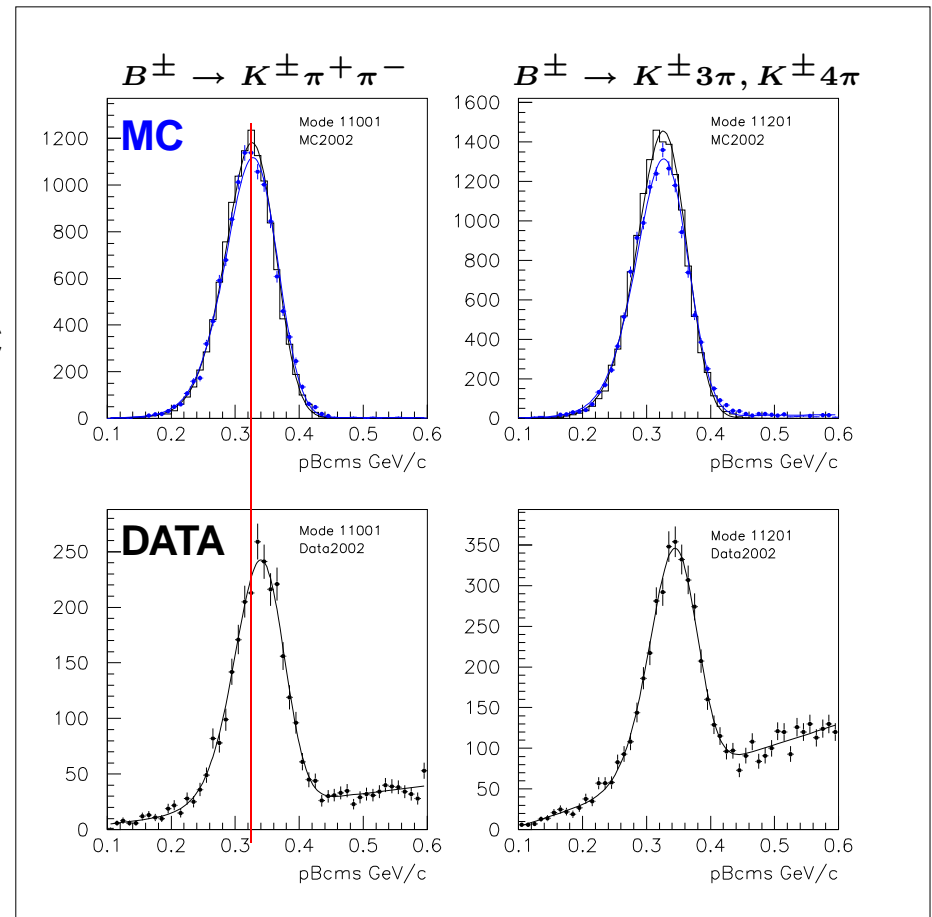
Use **B-reco sample** to obtain E_{cms} and $\sigma_{E_{cms}}$ from fits to p_B^{cms} spectrum in data and MC.

- Difference ΔE_{cms} between data and MC increases with time:

2000: 0 MeV \rightarrow 2002: 2 MeV

- $E_{cms} = 2 \text{ MeV} \Rightarrow \Delta p_B^{cms} \sim 30 \text{ MeV}$
(affects endpoint analysis, 2-body decays, ...)

P_B^{cms} in 2002



Adjustment of E_{cms} in MC would make tedious year-by-year reweighting unnecessary

Radiative Corrections

- Towards an improvement of PHOTOS:

- Current version of PHOTOS does not include **electroweak interactions on the quark level** (hard photons)
- Theorists estimate the effect to be on the **few % level**, but there are no calculations yet!
- We need to find out **what precision** we need from PHOTOS

⇒ **More studies are needed!**

⇒ **Workshop on Radiative Corrections**

together with experts from CLEO, BELLE, CDF, ... planned for this fall!

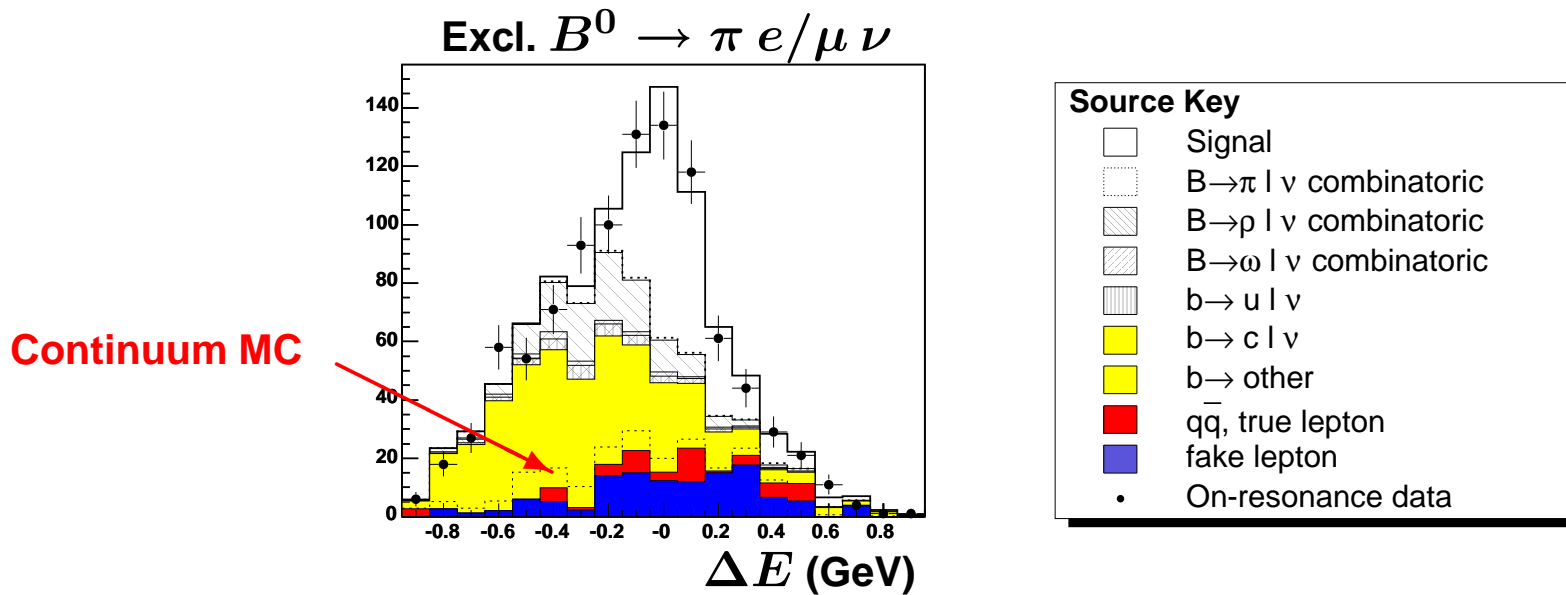
Continuum Simulation & B Decays to Kaons/Neutral Hadrons

- Continuum $q\bar{q}$ MC:

- How well is the **continuum production tuned?**

(D^0, D^*, D_s in $c\bar{c}$ events, fragmentation function, $e^+e^- \rightarrow \gamma\gamma + \text{hadrons}$?)

- We need **more continuum Monte Carlo**, s.l. analyses suffer from low statistics!



- How well are B decays into K, K_L checked (inclusive BF)?

B decays into neutral hadrons (n, \bar{n}) ?

B Meson Lifetime & f_{00}

- Update of **average B lifetime** and **neutral to charged B ratio**?

New values: $\langle \tau_B \rangle = 1.60958 \pm 0.0114922 \text{ ps}$ (PDG 2002)

$f_{00} = 0.488 \pm 0.013$ (comb. CLEO & BaBar)

Conclusions

★ **Improve Monte Carlo by updating:**

- $B \rightarrow c\ell\nu$ (D, D^*, D^{**}) BFs and FFs
- Inclusive D BFs
- $B \rightarrow X_u\ell\nu$ Hybrid Model
- $B \rightarrow \pi(\rho)$ FFs
- E_{cms} in MC to agree with data
- Tuning of continuum simulation, ...

★ **More results from semi-leptonic AWG this fall !**

★ **What is the deadline to fix numbers/changes for the MC?**