# Photos and B-physics

E.Barberio (University Melbourne)

Work done in coll. with P.Urquijo, Z.Was

# QED radiative corrections in B decays

The experimental precision reached for B meson decays necessitates comparison to theoretical predictions that incorporate radiative corrections

Radiative corrections affect measurements in two ways:

a) Event selection may affect such corrections: how can we estimate the size of the effect? Experiments require Monte Carlo simulations

b) Once we have the quantity of interest: how do radiative corrections modify the observables?

To what accuracy are the tools expected to work?

# Radiative Corrections in B decays

Exact analytical calculations of radiative corrections are not always available.

Experiments use PHOTOS: a MC algorithm that gives multiphoton QED radiative correction in decays. Most recent version: Leading Log, Exponentiation and soft photon region exactly covered

It provides final state with their full topology but does not include hadronic structure effects, Coulomb threshold corrections, QCD and weak corrections, but in principle corrections can be added.

# Radiative Corrections in B decays

From the experimental side:

a) Is PHOTOS adequate?
b) What error do we assign to missing higher orders and missing effects?
c) Can we use data to assess radiative corrections?
d) Up to what precision do we need photos to upgrade? In principle photos can reach a precision better than 0.1% but it requires a lot of work, do we need it?

Some of the answers are related to the size of the radiative corrections and total error…

# Theory and MC algorithm

$$d\sigma^{R}\left(P \to ch\ y\ (\gamma)\right) = d\sigma^{Born}\left(P \to ch\ y\right) f\left(k, \cos\theta_\gamma \phi_\gamma\right) k dk d\Omega_\gamma d\Omega_y$$

$$d\sigma^{exact}\left(P \to ch\ y\ (\gamma)\right) = W d\sigma^{R}\left(P \to ch\ y\ (\gamma)\right)$$

$$W \approx \frac{\lambda^2\left(m_p^2, m_{ch}^2, m_y^2, k\right)}{f(k, \cos\theta_\gamma \phi_\gamma)}$$

f chosen such that $W \to 1$ when $m_{ch} \to 0$

**A photon cut-off energy divides real from virtual corrections:** it depends on the detector's ability to distinguish a charged particle from its brem photon

# Theory

Universal weight $W = W_1 W_2 W_3$

$W_1$ and $W_2$ modify the original distribution in the soft photon region

$W_3$ accounts for the difference between the Lipatov-Altarelli-Parisi kernel for spin 1/2 and kernels for other spins

For multi-charge final states an additional weight is introduced to reproduce the infrared limit

# Photos in W/Z/kaon decays

- Z/W decays: precision of better than 0.1%
  For W a process dependent weight was used (hep-ph/0303260)

- Kaon decays: ~1% precision (hep-ph/0506026, theoretical issues in hep-ph/0406045)

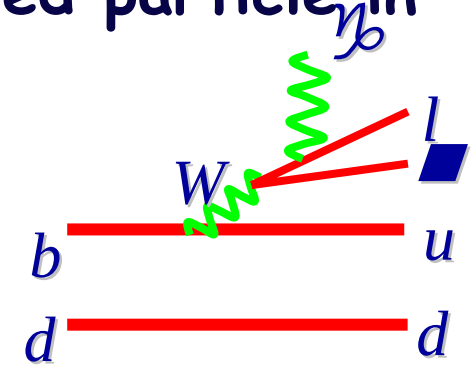
- Recently the weight approach has been standardised
  hep-ph/0508015

- This weight approach is what we are following in Belle for B->hh (e.g. $\pi^+\pi^-$) and semileptonic B decays

# Semi Leptonic B decays

Semileptonic B decays allow the determination of CKM elements $V_{cb}$ and $V_{ub}$

Radiative corrections alter observables from semileptonic decays: photons are emitted by any charged particle in the B decay chain



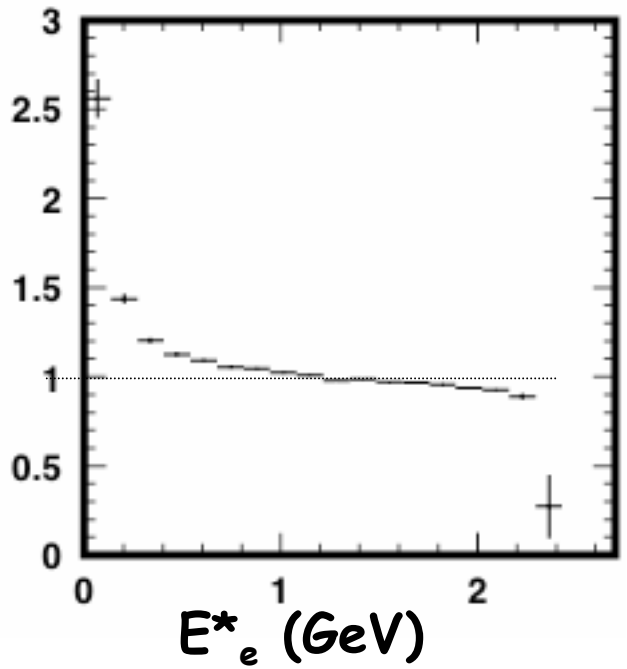

Photos is used to extract observables:
but we need to assign the correct error!

b→c transition: exclusive calculations exist and the situation look stable, inclusive: see later

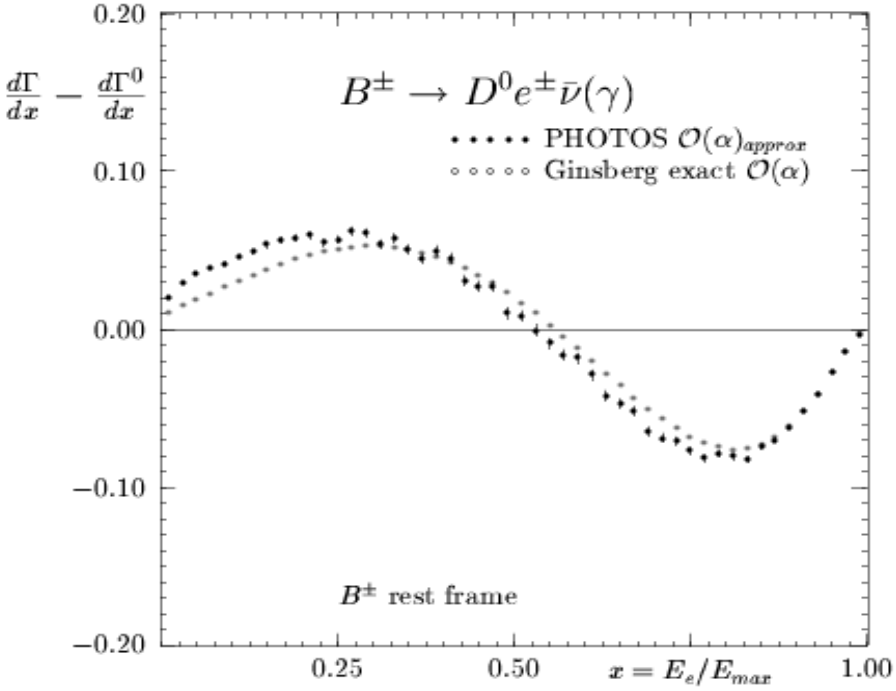
b→u transition: there are no calculations to assess the errors

# QED radiative corrections in $B^+ \to D^0 e\nu$

Large effect at low energy




Ratio PHOTOS/no PHOTOS

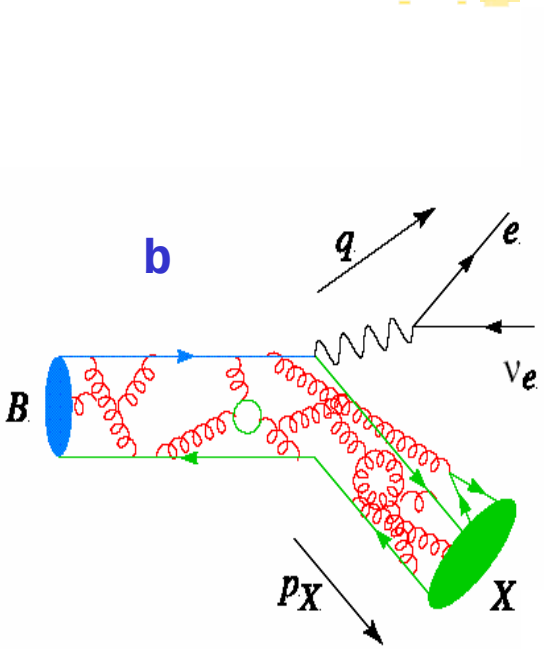


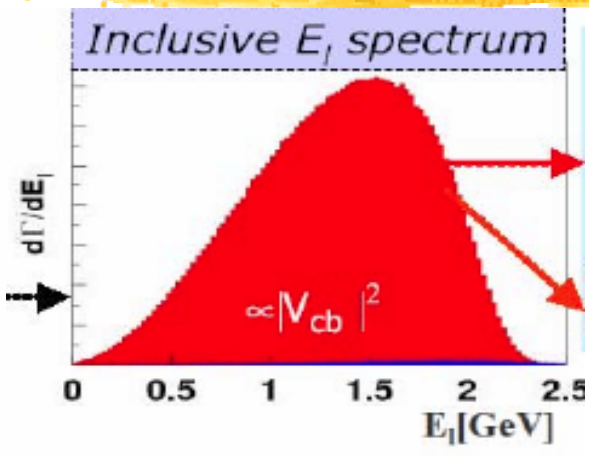

~1% agreement, larger disagreement for $E_e$<~0.6 GeV (B rest frame)

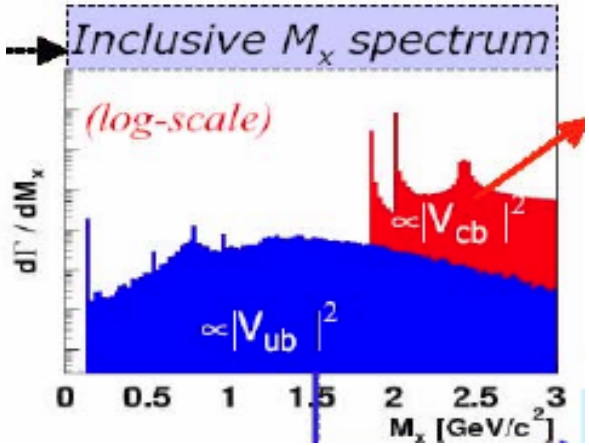
E.Ginsberg, Phys. Rev. 142, (1966)

E.Richter-Was, Phys. Lett. B 303 (1993)

# QED radiative corrections in $B \to X_c l \nu$




rate

shape

shape

$\Delta V_{cb} \sim 2\%$

$|V_{cb}|$

$m_b, m_c$
$\mu^2_G, \mu^2_\pi$

Radiative correctionss affect the shape of the lepton (hadron) energy (mass) spectrum: need to be included in the data analysis and/or in the experimental error.

# Moments of kinematic variables

Radiative corrections affect lepton and hadronic mass reconstruction and lepton identification efficiency

Experiments use Photos for efficiency corrections etc, but also to unfold QED corrections at the quark level, using Photos at the hadron level!

Calculations to extract $V_{cb}$ from the lepton/hadron energy/mass spectrum do not contain radiative corrections to the inclusive spectrum

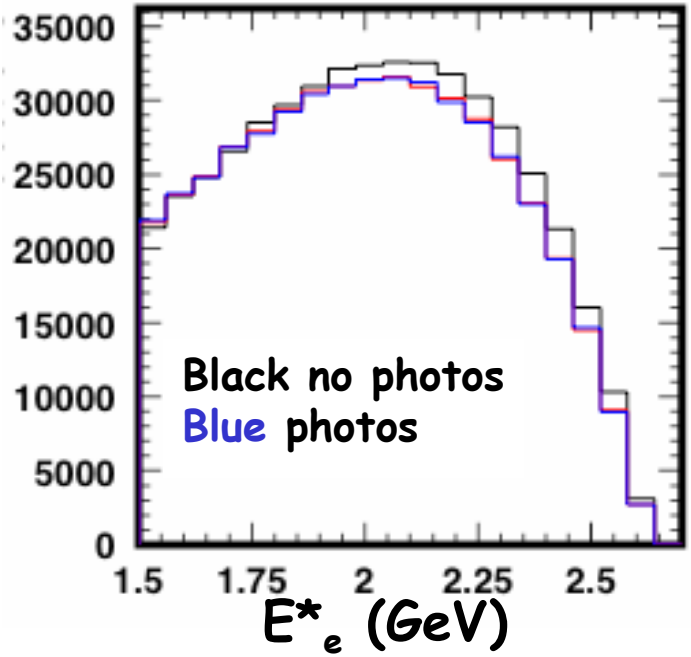
$$\Delta M_n = M_n(B \to X e \nu) - M'_n(B \to X e \nu(\gamma))/M_n(B \to X e \nu)$$

| $E_{cut}$(GeV) | $\Delta M_{mean}/M_{mean}$ | total_error$M_{mean}/M_{mean}$ |
|---|---|---|
| 0.6 | 0.013 | 0.0058 |

Calculations at quark level are in progress…. There are needed for our final measurement

# QED radiative corrections in b->u

In b->u transitions radiative corrections can be quite large e.g. $B^0 \to \pi^+ e^- \nu(\gamma)$




Ratio PHOTOS/no PHOTOS



QuickTime™ and a

E*e (GeV)

As done for kaon decays spin dependence has been added to the interference, preliminary results show a 5-10% effect on this decay

# Photos: $B \to \pi\pi$

Radiative corrections has begun to play a role also in

$B \longrightarrow \pi\pi$

Experiments use Photos for efficiency etc..

Comparison with QED calculations was performed (Baracchini/Isidori) within the context of Low theorem

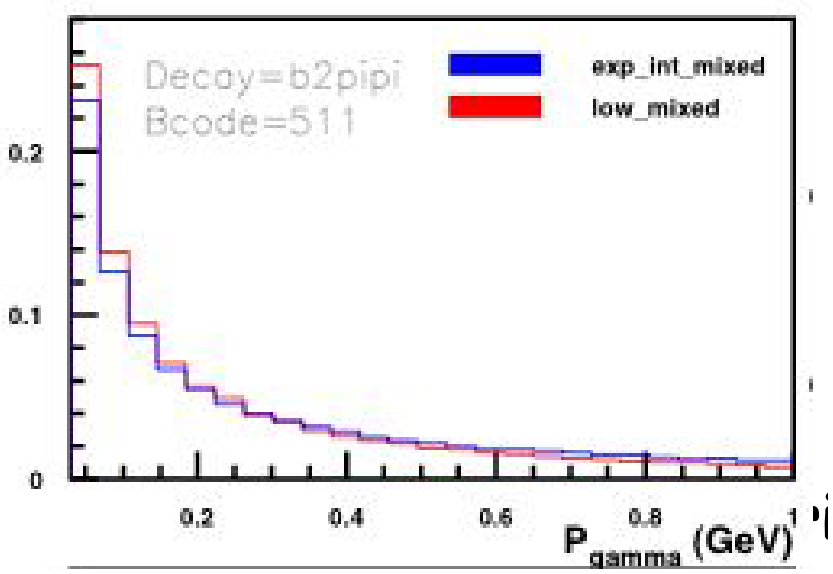
They found that the number of radiating events is of

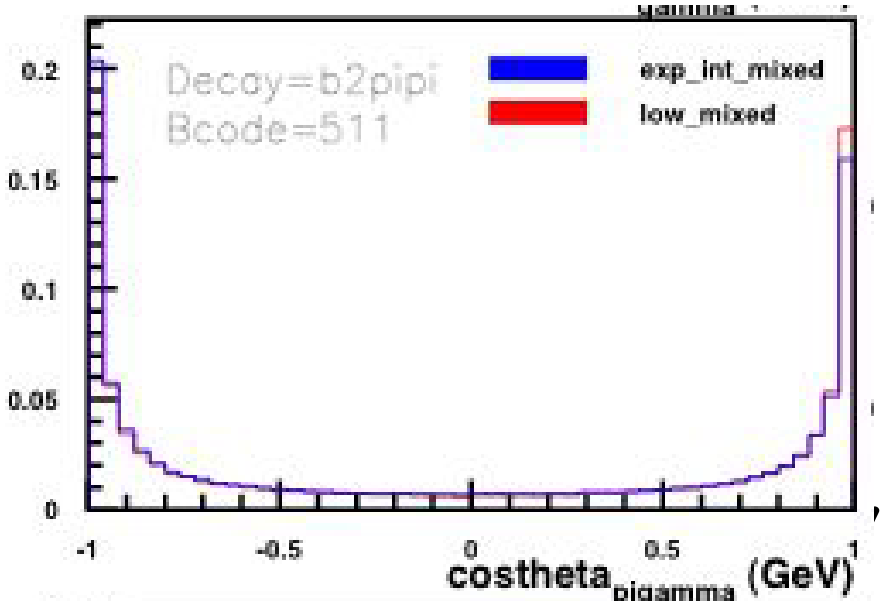
~10% for $B \longrightarrow \pi\pi$ underestimate.

# Photos: B→ππ

We observe similar effects when we compare normal Photos with 'downgraded' Photos-the Altarelli Parisi Kernel is switched off

not exactly the same conditions of Baracchini




next year.

# Outlook and Conclusions

As the errors on B-decay related quantities are getting smaller, radiative corrections can no longer be neglected.

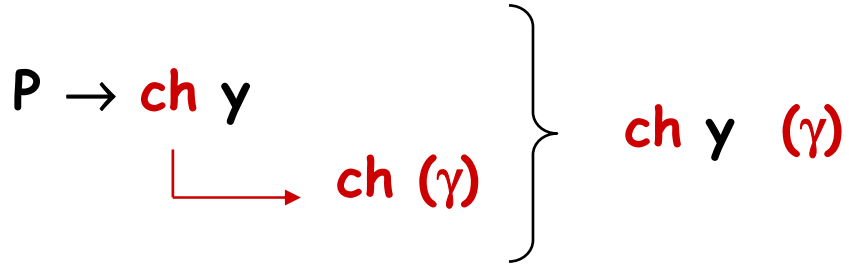
Photos is the tool for 'central' values, but we need comparisons with exact calculations to be able to assign the correct error.

In semileptonic B decays various comparisons have been already done, and new comparisons will done soon.

For B->hh the framework is ready and there are preliminary results, but work is going on to really be confident that all is under control

# Backup

# Generation of the photon




P parent particle
ch charge decay product
y neutral decay product
γ photon

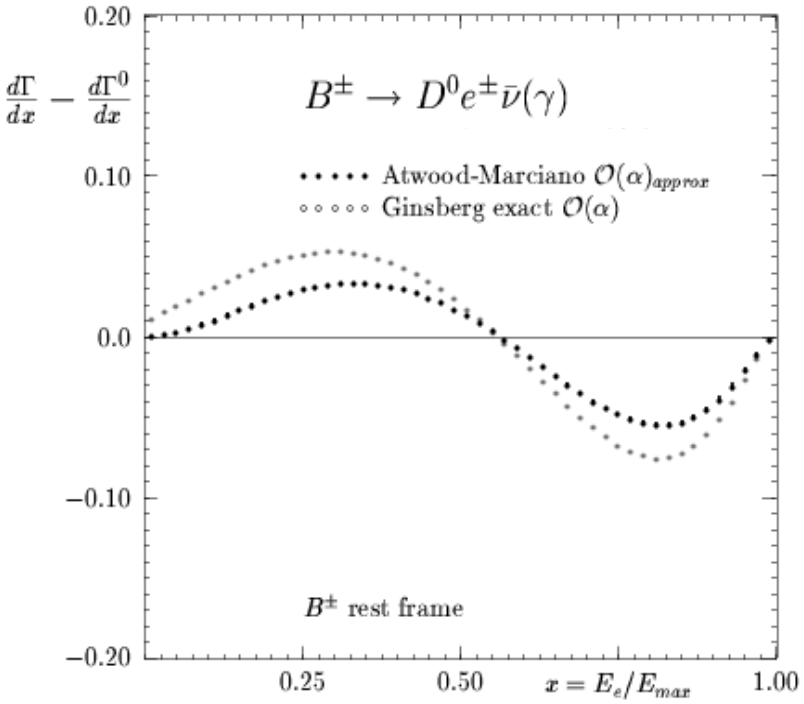
Born level for the generation of the event

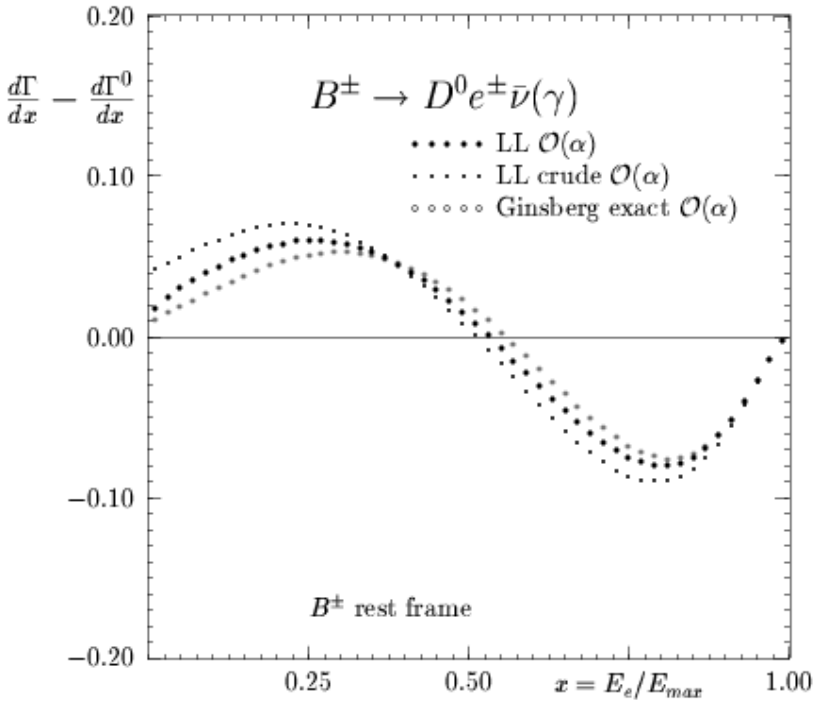
Photon variables are generated according to a structure function: the Bremsstrahlung is treated as the fragmentation of ch in itself and a photon, according to Altarelli-Parisi splitting function

The QED angular distribution is included

# Checks and systematics error

$B \to D^0 e \nu(\gamma)$

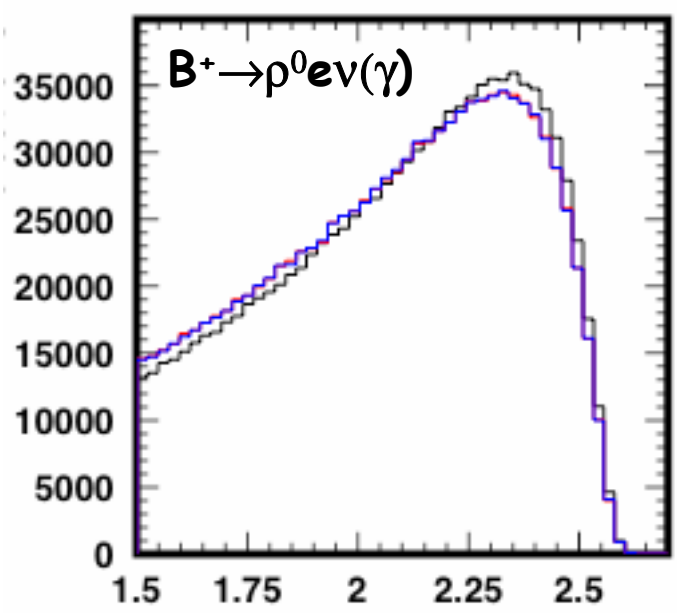



D.Atwood and J.W.Marciano, Phys. Rev. D 41 (1990), 1736
E.Richter-Was, Phys. Lett. B 303 (1993), 163

# QED radiative corrections in B→ρeν

The effect is up to 15%




Black no photos
Blue photos

QuickTime™ and a

$E^*_e$ (GeV)

Ratio PHOTOS/no PHOTOS

# QED radiative corrections: b→u endpoint

$V_{ub}$ endpoint analysis

electrons

| Momentum Region(GeV/c) In the Υ(4s) frame | PHOTOS calc. Correction to partial branching fraction measurement of b→ulν |
|---|---|
| 1.9-2.6 | 1.060±0.007 |
| 2.2-2.6 | 1.086±0.010 |
| 2.3-2.6 | 1.096±0.011 |
| 2.4-2.6 | 1.107±0.014 |