QED radiative corrections in semileptonic B decays

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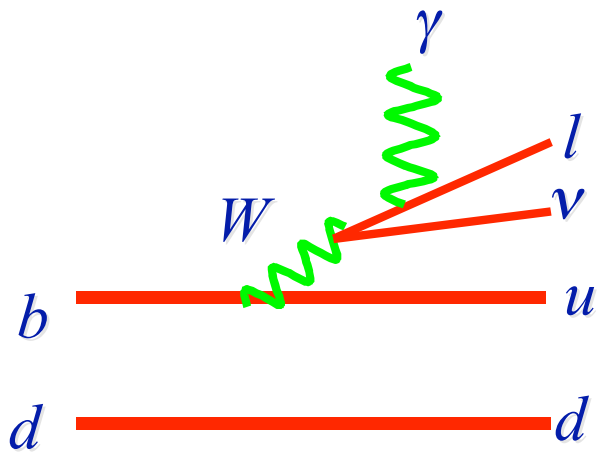
Radiative Corrections in B decays

Semileptonic decays play a crucial role in the data analysis of B decays: e.g. their uncertainty affects 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

e.g. to determine the moments of the lepton spectrum radiative corrections have to be included in the data analysis and/or in the experimental error.



Radiative Corrections in B decays

Exact analytical calculations of radiative corrections are not always available: process-independent approximate approaches are used by the experiments

The most used tool is PHOTOS (Leading Log $\mathcal{O}(\alpha)$ approximation)

PHOTOS gives pure QED radiative corrections: not including hadronic structure effects, QCD and weak corrections, Coulomb threshold corrections

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) Can we design an analysis less sensitive to radiative corrections?

Some of the answers are related to the size of the corrections and effects….

Studies of radiative corrections

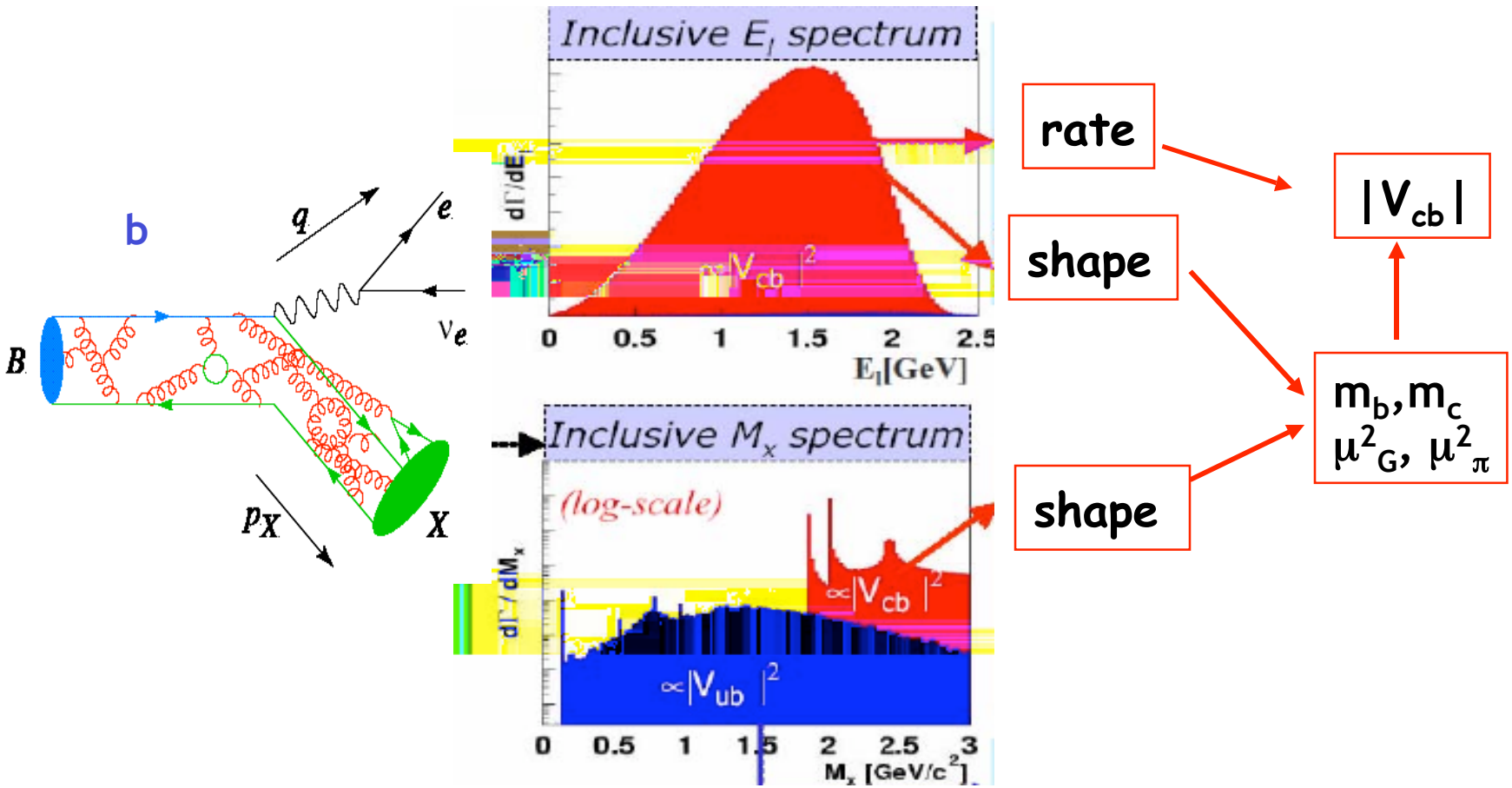
Look at the impact of radiative corrections in semileptonic B decays:

$b \to c\, \ell\, \nu$: eg. Lepton moments

$b \to u\, \ell\, \nu$: eg. Lepton endpoint

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

An example: the measurement of the $B \to X_c l \nu$ lepton energy and hadronic mass moments.



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

difficulty: go from the measured shape to the true shape:
shape in B rest frame, QED corrections, detector resolution, accessible phase space, etc

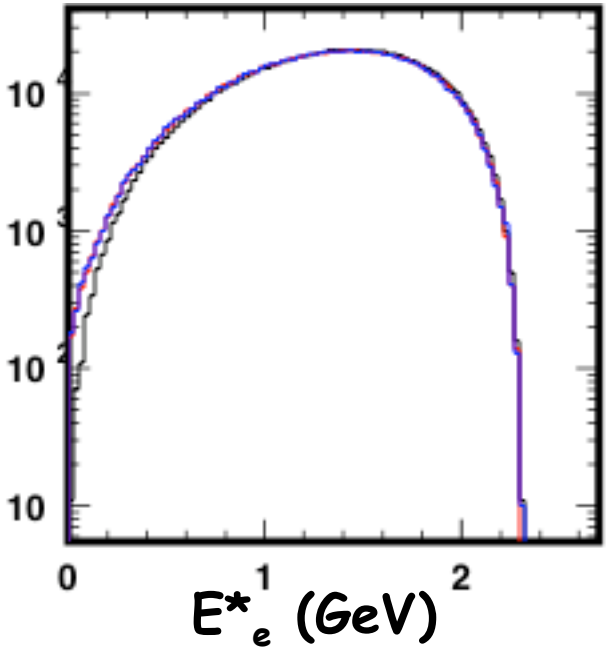
Radiative corrections affect lepton reconstruction and identification efficiency

Bremsstrahlung makes the spectrum softer, e are more affected than μ: lepton energy 'cut-off' is affected

Calculations to extract non-perturbative parameters from the moments do not contain radiative corrections

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

electron energy spectrum
(B rest frame)



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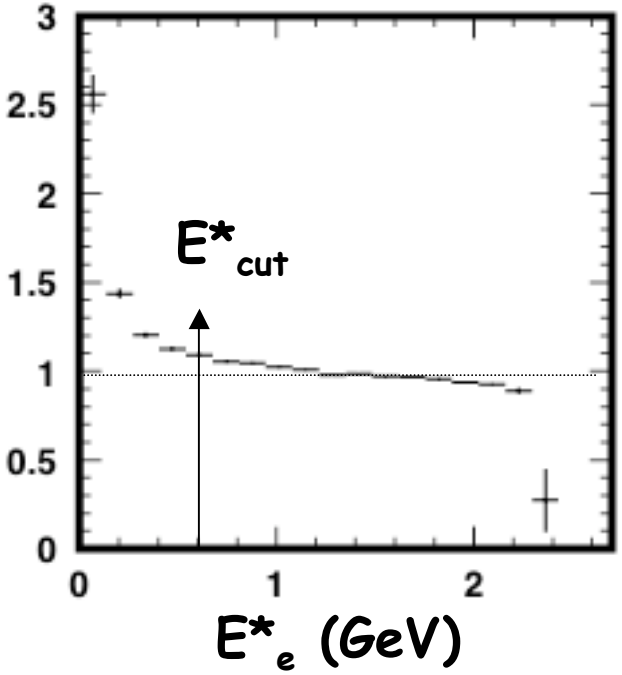
Blue/red photos

Large effect at low energy, but still few % effect over the cut-off!

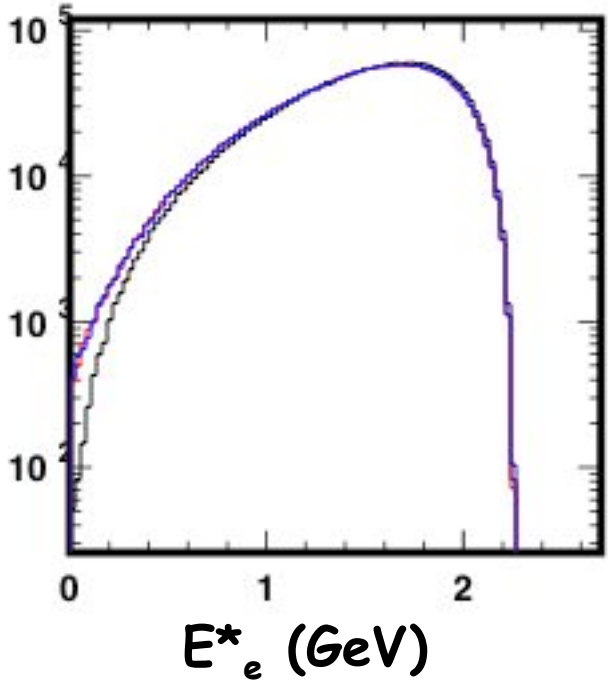


Ratio PHOTOS/no PHOTOS

similar effect for $B^0 \to D^+ l\nu$

QED radiative corrections in $B^+ \to D^* l \nu$

electron energy spectrum
(B rest frame)



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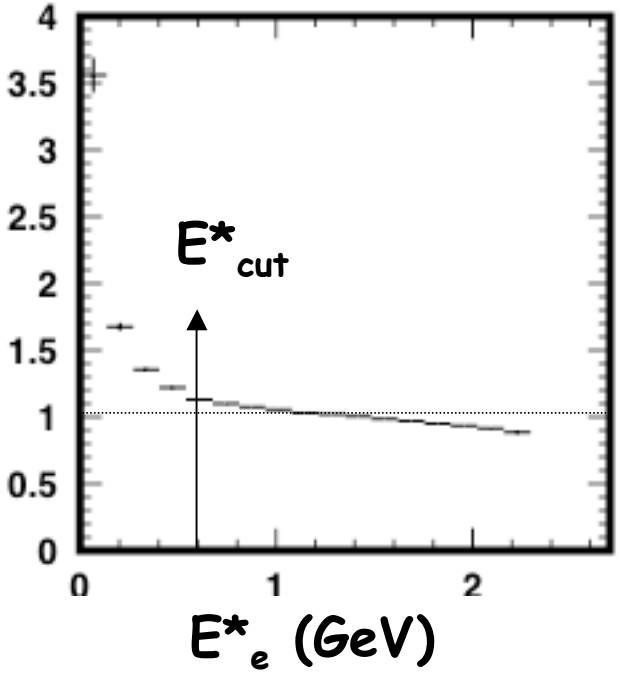
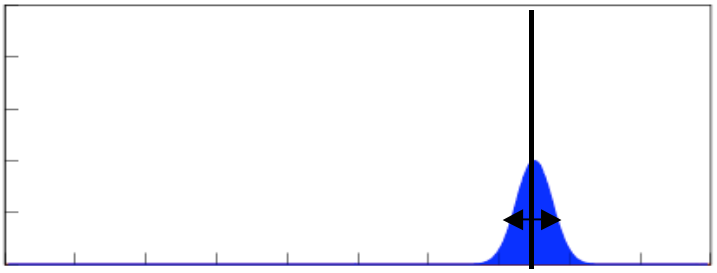


Ratio PHOTOS/no PHOTOS

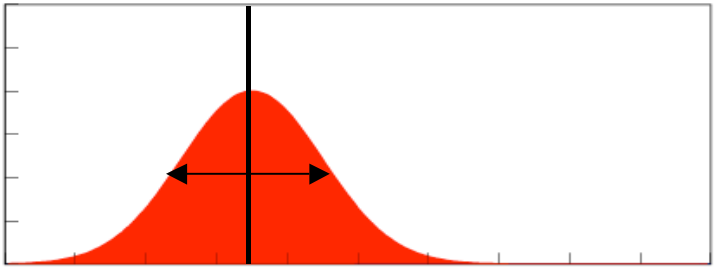
Moments of kinematic variables

where is it? (mean)

$$1^{st}\text{moment} = \frac{\int x^1 f(x)dx}{\int f(x)dx} = \langle O \rangle$$



A Distribution



Another Distribution

how wide is it? (width)

$$2^{nd}\text{ central moment} = \frac{\int x^2 f(x)dx}{\int f(x)dx} = \left\langle \left(O^2 - \langle O^2 \rangle \right)^2 \right\rangle$$

Moments of the electron energy spectrum

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

	E_{cut}(GeV)	$\Delta M_1/M_1$	$\Delta M_2/M_2$
$B^+ \to D^0 e\nu$	0.2	0.0161	-0.0285
	0.6	0.0101	-0.0052
	1	0.0075	0.0001
	1.2	0.0049	0.0055
$B^0 \to D^+ e\nu$	0.2	0.0163	-0.0292
	0.6	0.0105	-0.0077
	1	0.0071	0.0017
	1.2	0.0051	0.0047
$B^+ \to D^{*0} e\nu$	0.2	0.0167	-0.0490
	0.6	0.0118	-0.0181
	1	0.0093	-0.0084
	1.2	0.0070	-0.0009
$B^0 \to D^{*+} e\nu$	0.2	0.0175	-0.0549
	0.6	0.0121	-0.0207
	1	0.0093	-0.0090
	1.2	0.0068	-0.0004

Error to radiative corrections $B \to X_c l \nu$

What error is associated to the PHOTOS approximation?

Different experiments have different approaches:

Babar: look at photons not in Photos

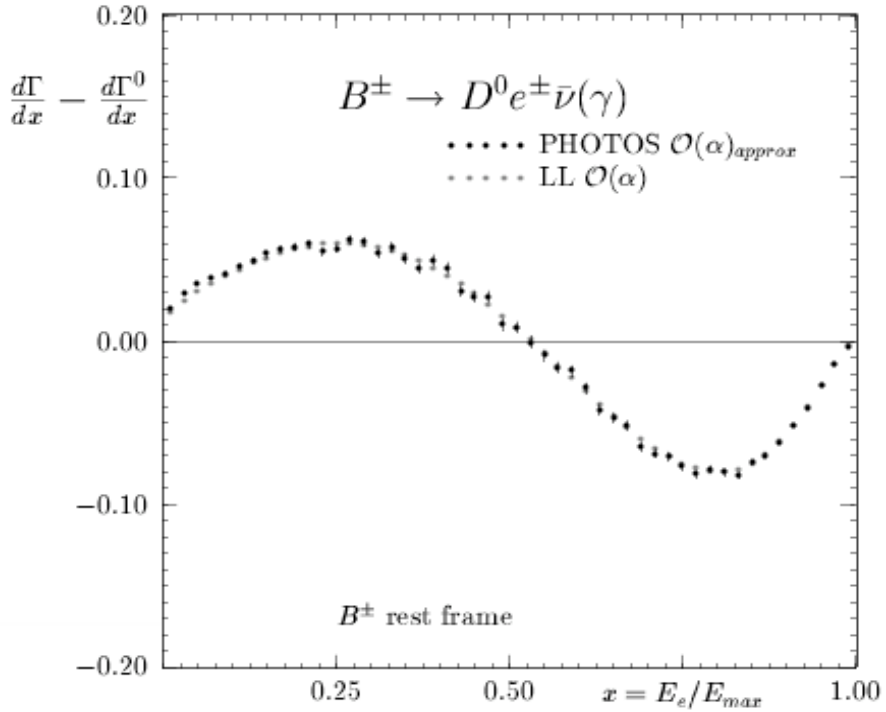
CLEO: compares Photos with Atwood & Marciano approximation and assigns as error the shift on the full spectrum

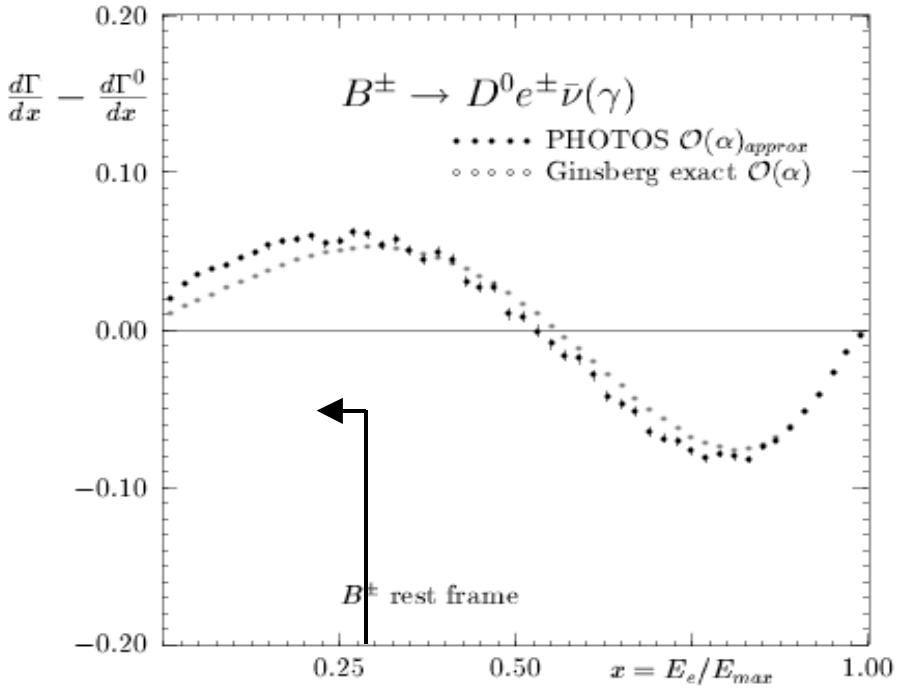
Belle: Compare photos with Ginsberg calculations and try to make a radiative correction 'insensitive' analysis

….to assign an error more work is needed (see PG talk)….

Checks and systematics error

B→D⁰eν(γ) E.Richter-Was, Phys. Lett. B 303 (1993), 163





Photos reproduces LL $\mathcal{O}(\alpha)$

~1% agreement with respect to exact $\mathcal{O}(\alpha)$ calculations. Larger disagreement for E_e<~0.6GeV (B rest frame)

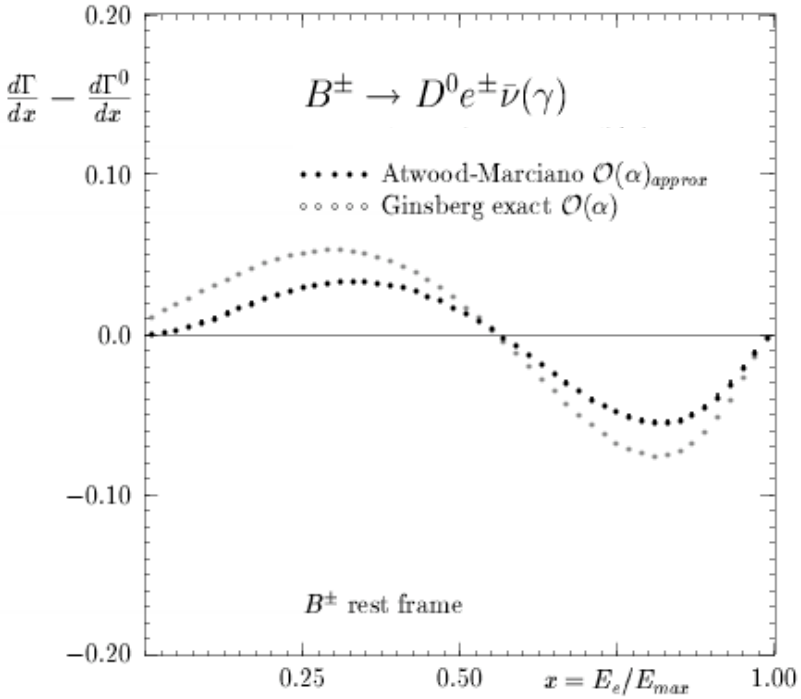
B-factories CLEO:

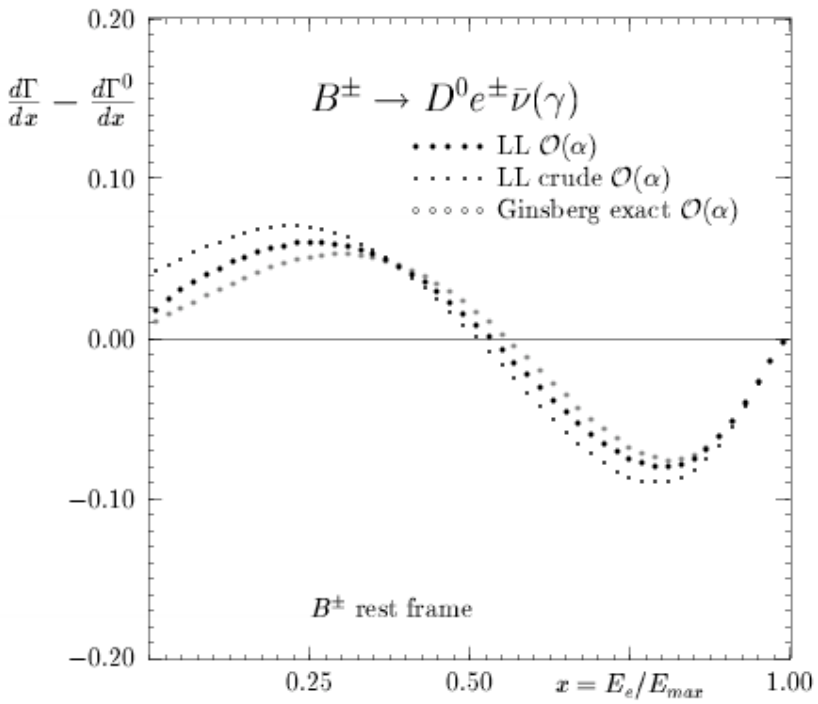
in most semileptonic B decay analyses E_e>~0.6 GeV

Checks and systematics error

E.Richter-Was, Phys. Lett. B 303 (1993), 163

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





E.S.Ginsberg, Phys. Rev. 142, (1966), 1035

D.Atwood and J.W.Marciano, Phys. Rev. D 41 (1990), 1736

QED radiative corrections in $B \to X_u e \nu$

The $b \to u l \nu$ transition is affected much more by radiative corrections.
e.g. they affect the endpoint spectrum

There are no exact QED radiative corrections available

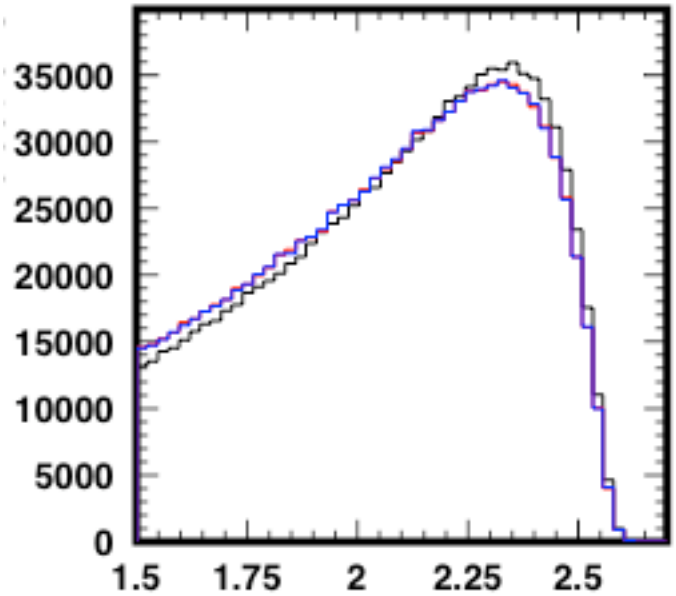
Experiments have only PHOTOS and Atwood and Marciano approximation to compare

The work done with PHOTOS for kaon decays helps, but the question is always the same:

What error do we assign to radiative corrections?

QED radiative corrections in $B \to \rho e \nu$

$B^+ \to \rho^0 e \nu(\gamma)$



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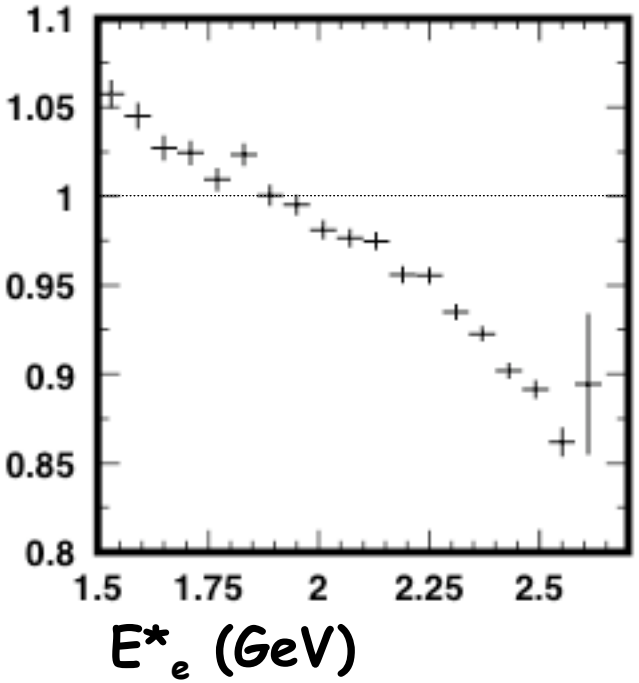
Blue/red photos

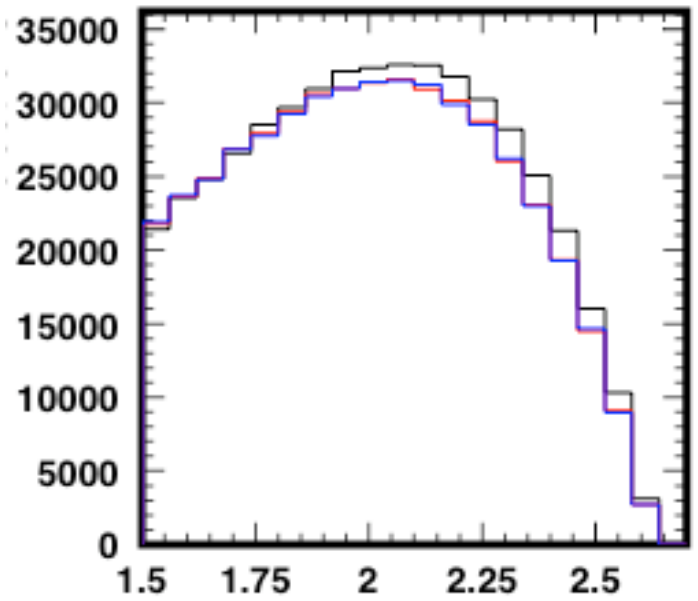
The effect on the endpoint spectra is up to 15%



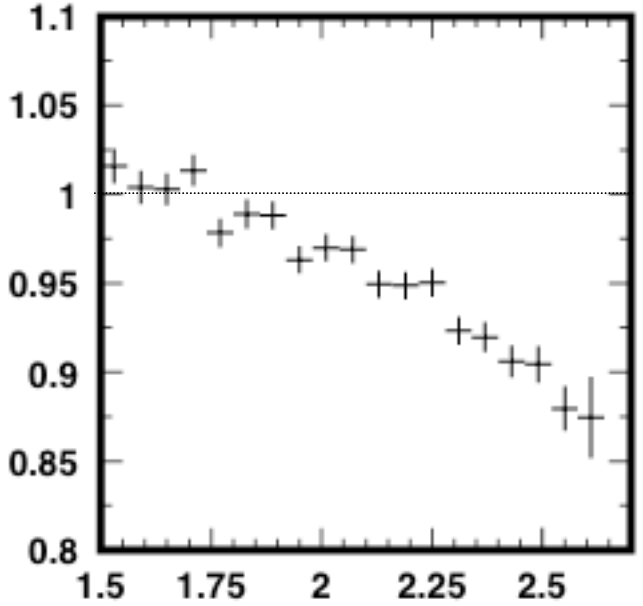
Ratio PHOTOS/no PHOTOS

QED radiative corrections in $B^0 \to \pi^+ e^- \nu$

$B^0 \to \pi^+ e^- \nu(\gamma)$



E^*_e (GeV)



E^*_e (GeV)

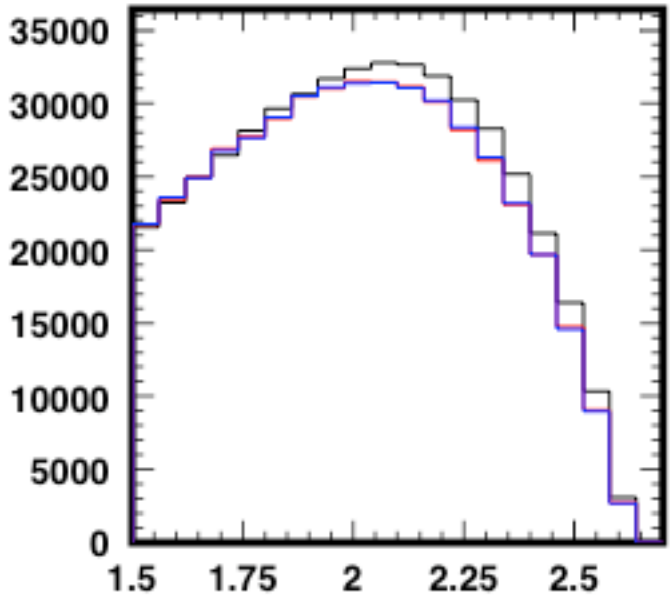
Black no photos

Blue/red photos

Ratio PHOTOS/no PHOTOS

QED radiative corrections in $B^- \to \pi^0 e^- \nu$

$B^- \to \pi^0 e^- \nu(\gamma)$

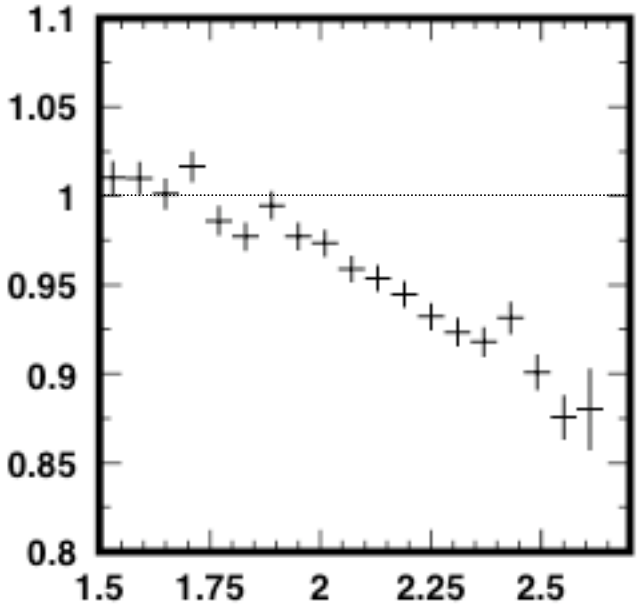


E^*_e (GeV)

Black no photos

Blue/red photos

15% effect in the endpoint



E^*_e (GeV)

Ratio PHOTOS/no PHOTOS

QED radiative corrections: b→u endpoint

V_{ub} endpoint analysis

electrons

Momentum Region(GeV/c) In the $\Upsilon(4s)$ frame	PHOTOS calc. Correction to partial branching fraction measurement of $b \to u \ell \nu$
1.9-2.6	1.060±0.007
2.0-2.6	1.066±0.007
2.1-2.6	1.074±0.008
2.2-2.6	1.086±0.010
2.3-2.6	1.096±0.011
2.4-2.6	1.107±0.014

Improvement in Photos

There is a new version of Photos (see PG talk):

Belle is starting to test/use it.

Few comparison with multiphoton emission, interference between charge particle on.

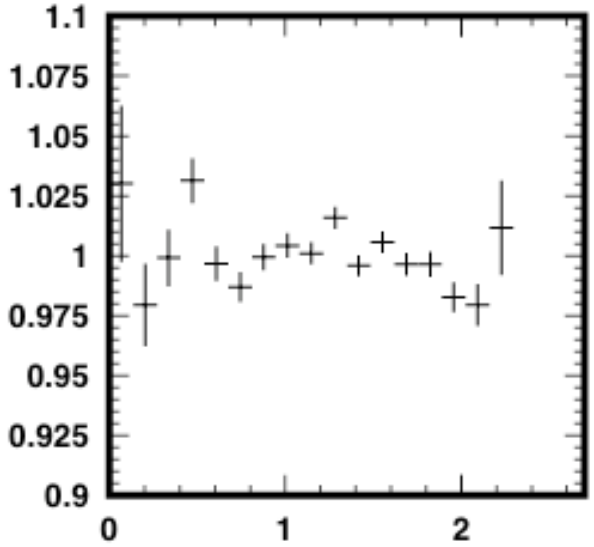
Comparison with Ginsberg is underway in Belle

For b->u transition we may need to use data…

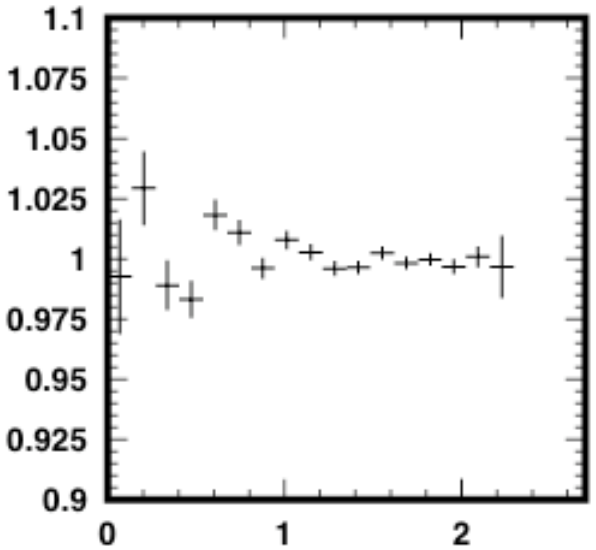
New Photos/old Photos: $B \to X_c l \nu$

Ratio PHOTOS v2.02/PHOTOS v2.13

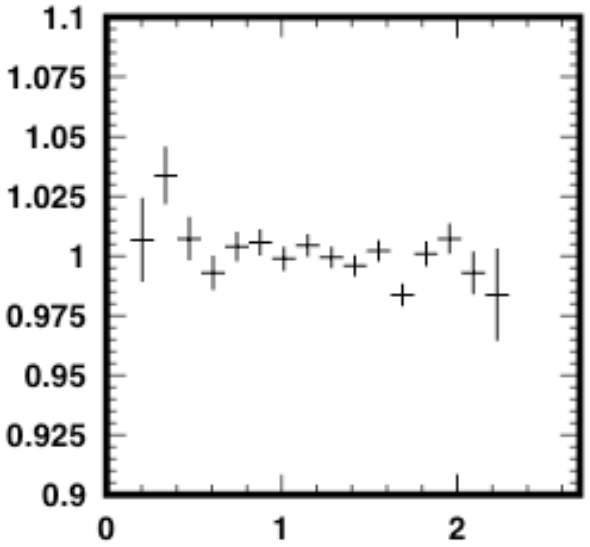
$B^+ \to D^0 \ell\nu$



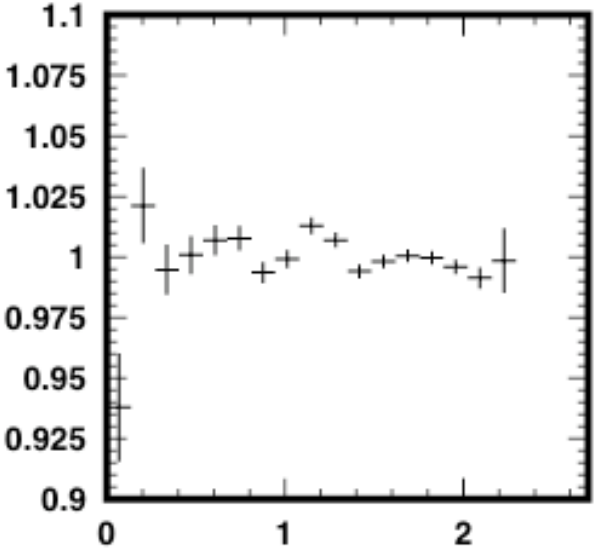
$B^+ \to D^{*0} \ell\nu$



$B^0 \to D^+ \ell\nu$



$B^0 \to D^{*+} \ell\nu$



E^*_e (GeV)

Moments of the electron energy spectrum

Comparison of shift in moments for PHOTOS v2.02 and PHOTOS v2.13

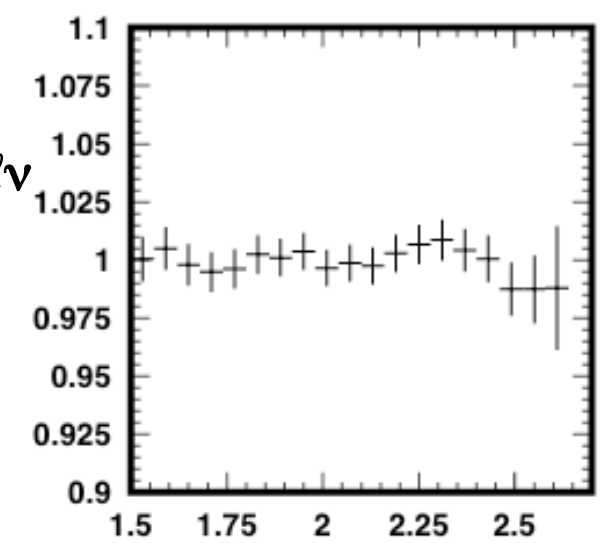
$$\Delta M_n = M_n(B \to X \ell \nu) - M'_n(B \to X \ell (\gamma) \nu)$$

		$\Delta M_1/M_1$		$\Delta M_2/M_2$	
	E_{cut}(GeV)	photos V2.02	photos V2.13	photos V2.02	photos V2.13
$B^+ \to D^0 \ell \nu$	0.2	0.0161	0.0171	-0.0285	-0.0256
	0.6	0.0101	0.0106	-0.0052	0.0007
$B^0 \to D^+ \ell \nu$	0.2	0.0163	0.0174	-0.0292	-0.0320
	0.6	0.0105	0.0108	-0.0077	-0.0067
$B^+ \to D^{*0} \ell \nu$	0.2	0.0167	0.0171	-0.0490	-0.0501
	0.6	0.0118	0.0123	-0.0181	-0.0210
$B^0 \to D^{*+} \ell \nu$	0.2	0.0175	0.0181	-0.0549	-0.0548
	0.6	0.0121	0.0127	-0.0207	-0.0207

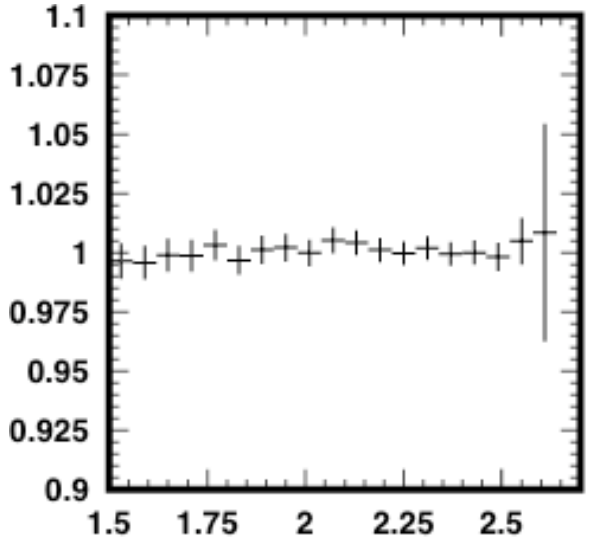
New Photos/old Photos: $B \to X_u l \nu$

Ratio PHOTOS v2.02 /PHOTOS v2.13

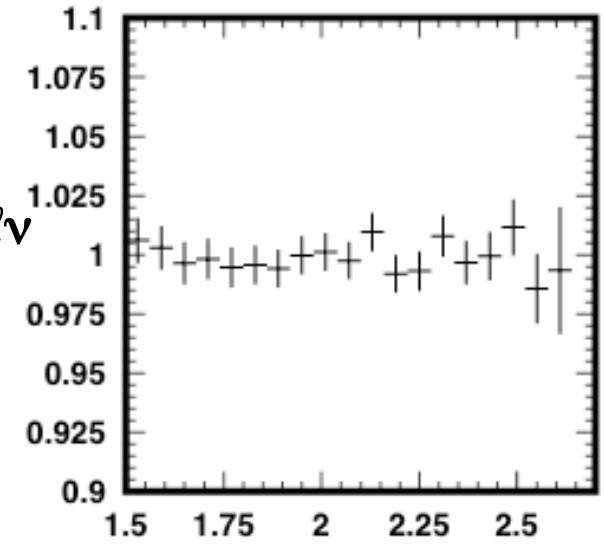
$B^+ \to \pi^0 \ell \nu$



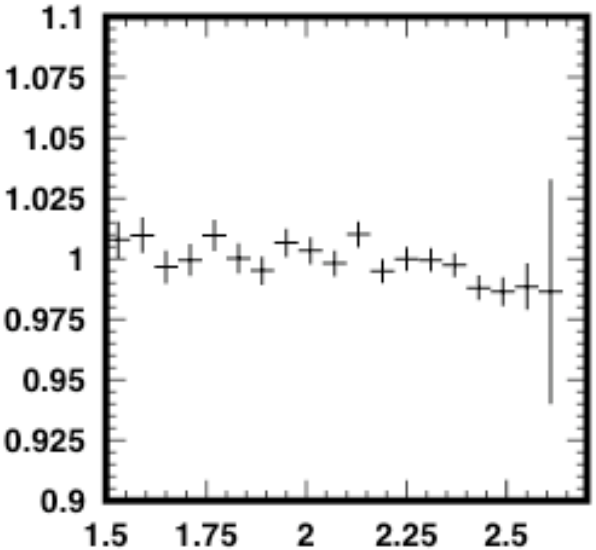
$B^+ \to \rho^0 \ell \nu$



$B^0 \to \pi^+ \ell \nu$



$B^0 \to \rho^+ \ell \nu$



E^*_e (GeV)

Outlook and Conclusions

Radiative corrections cannot be neglected in semileptonic B decays.

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

b→c transition: there are some exact $O(\alpha)$ calculations available but more work is needed for a convincing error

b→u transition: here the task is more difficult, there is need of either exact calculations and/or data to assess the error