Semileptonic and radiative B decays

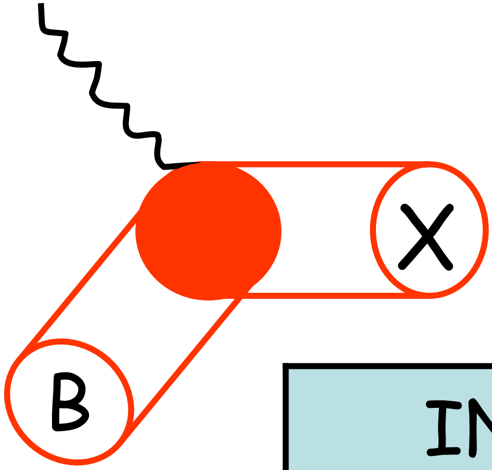
Paolo Gambino
INFN Torino

A set of interdependent measurements

$b\to c\, l\, \nu$	tree	BR~10%	$\lvert V_{cb}\rvert$
$b\to u\, l\, \nu$	tree	$\sim 10^{-3}$	$\lvert V_{ub}\rvert$
$b\to s\, \gamma$	loop	$\sim 3\ 10^{-4}$	new physics, $\lvert V_{ts}\rvert$
$b\to d\, \gamma$	loop	$\sim 10^{-6}$	new physics, $\lvert V_{td}\rvert$

There are also $b\to s,d\, l^+l^-$ to complement the radiative modes
Not only BR are relevant: various asymmetries, spectra etc

What do they have in common?



Simplicity: ew or em currents probe the B dynamics

INCLUSIVE	EXCLUSIVE
OPE: non-pert physics described by B matrix elemnts of local operators can be extracted by exp suppressed by $1/m_b^2$	Form factors: in general computed by non pert methods (lattice, sum rules,...) symmetry can provide normalization

Simplicity is almost always destroyed in practical situations...

Determination of A

$$V_{CKM} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

A can be determined using $|V_{cb}|$ or $|V_{ts}|$

Two roads to $|V_{cb}|$

EXCLUSIVE

INCLUSIVE

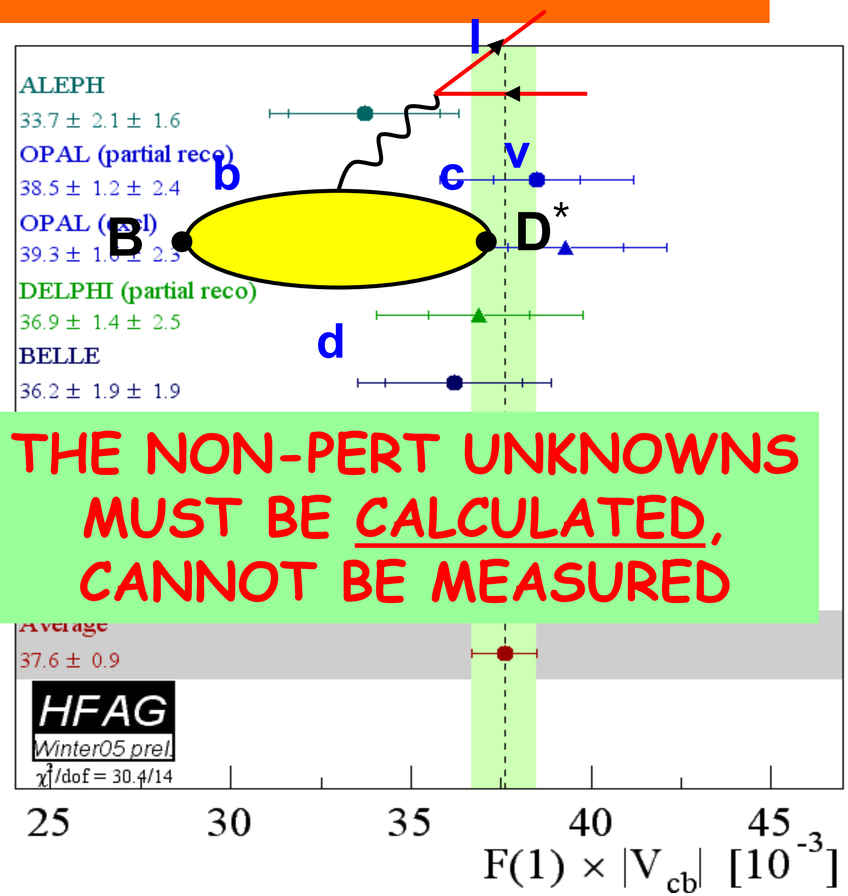
$|V_{cb}|$ from $B\to D^* l\nu$

At zero recoil, where rate vanishes.
Despite extrapolation, exp error ~ 2%
Main problem is form factor F(1)

The non-pert quantities relevant for excl decays cannot be experimentally determined Must be calculated but HQET helps.

$$F_{B\to D^*}(1) = \eta_A\,[1 - O(1/m_b, 1/m_c)^2]$$

Lattice QCD: $F(1) = 0.91^{+0.03}_{-0.04}$
Sum rules give consistent results
Needs unquenching (under way)
Even slope may be calculable...



THE NON-PERT UNKNOWNS MUST BE CALCULATED, CANNOT BE MEASURED

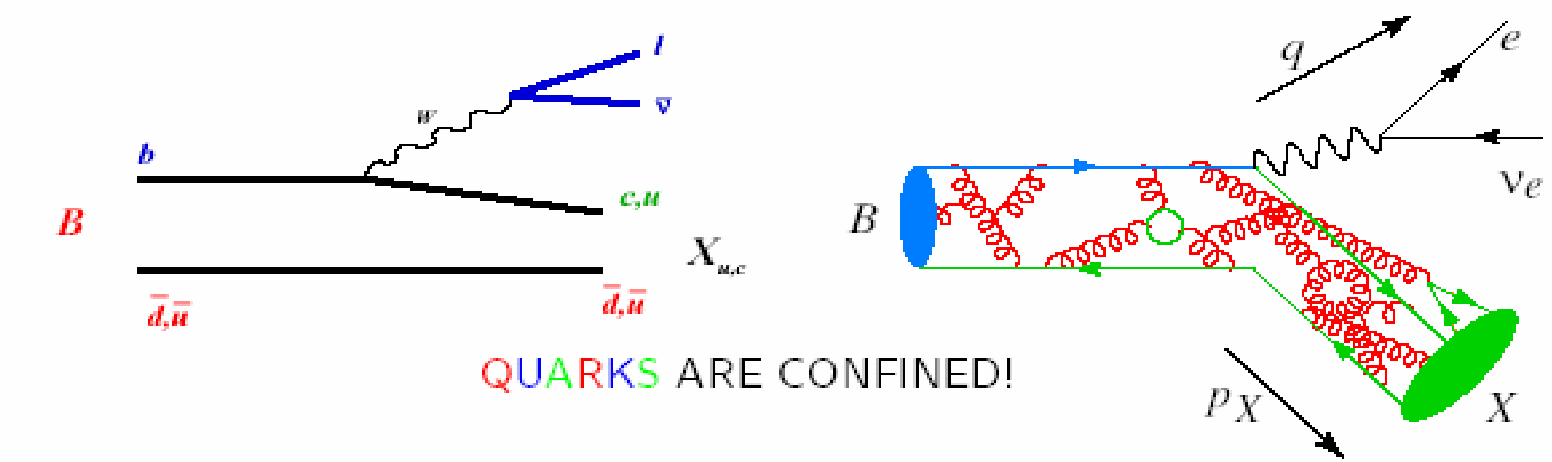
$\delta V_{cb}/V_{cb}$~ 5% and agrees with inclusive det, despite contradictory exps

$B\to Dl\nu$ gives consistent but less precise results; lattice control is better

The advantage of being inclusive

$\Lambda_{QCD} \ll m_b$: inclusive decays admit systematic expansion in Λ_{QCD}/m_b
Non-pert corrections are generally small and can be controlled

Hadronization probability =1 because we sum over all states
Approximately insensitive to details of meson structure as $\Lambda_{QCD} \ll m_b$
(as long as one is far from perturbative singularities)



$$\frac{d^2\Gamma}{dE_l\, dq^2\, dq_0}$$ can be expressed as double series in α_s and Λ_{QCD}/m_b (OPE) with parton model as leading term **No $1/m_b$ correction!**

A double expansion

$$\frac{d^2\Gamma}{dE_l dq^2 dq_0}$$ can be expressed in terms of *structure functions* related to Im of

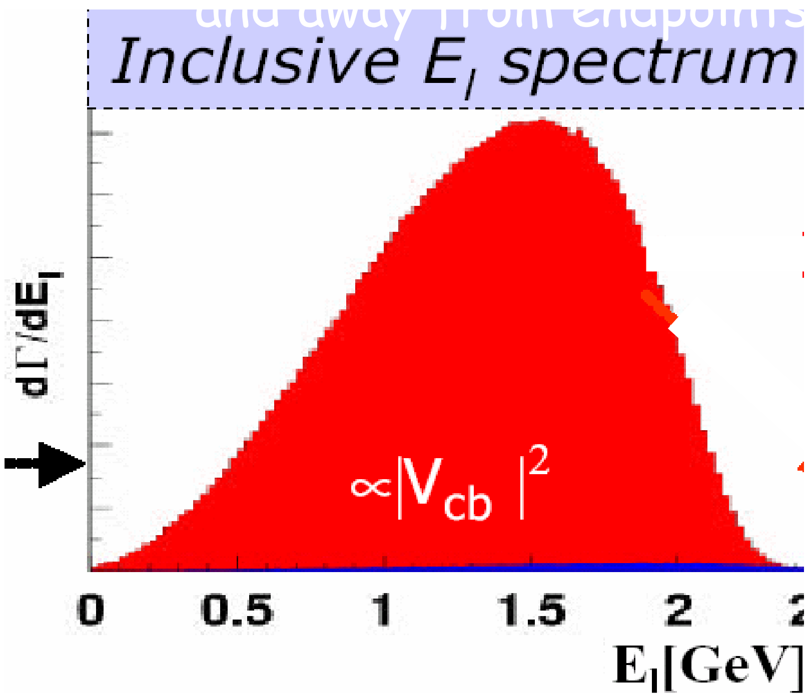
$$h_{\mu\nu}(q^2, q_0) = \frac{1}{2M_B} \langle B| \int d^4x \, e^{-iqx} \, iT \left\{ J_\mu(x), J_\nu^\dagger(0) \right\} |B\rangle$$

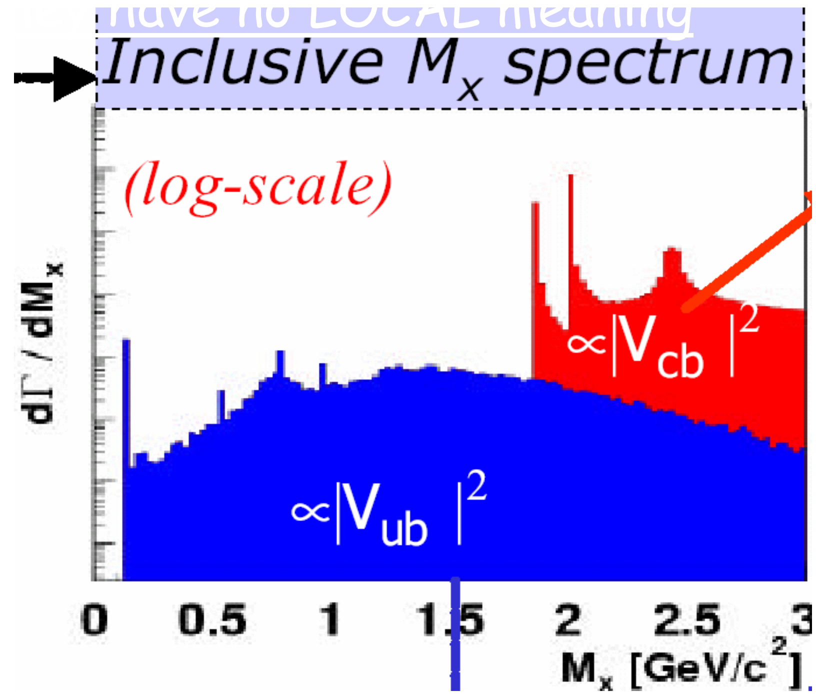
OPE (HQE): $T\, J(x)\, J(0) \approx c_1 \bar{b}b + c_2 \bar{b}\, \vec{D}^2\, b + c_3 \bar{b}\sigma \cdot G b + \ldots$

- The leading term is parton model, c_i are series in α_s
- New operators have non-vanishing expection values in B and are suppressed by powers of the energy released, $E_r \sim m_b - m_c$
- **No $1/m_b$ correction!**

OPE predictions can be compared to exp only after SMEARING and away from endpoints: they have no LOCAL meaning

Leptonic and hadronic spectra





Total **rate** gives CKM elmnts; global **shape** parameters tells us about B structure

State of the art

m_b, m_c

μ_G^2, μ_π^2 λ_1, λ_2

$O(1/m_b^2)$: mean kin.energy of b in B

he

must be

$$\mu_\pi^2(\mu) = \frac{1}{2M_B} \left\langle B \,|\, \bar{b}(i\vec{D})^2 b \,|\, B \right\rangle_\mu$$

State of the art

m_b, m_c

μ_G^2, μ_π^2 λ_1, λ_2

ρ_D^3, ρ_{LS}^3 ρ_1, ρ_2

Gremm,Kapustin...

O(1/m_b^2): mean kin.energy of b in B

$$\mu_\pi^2(\mu) = \frac{1}{2M_B}\left\langle B \,|\, \bar{b}(i\vec{D})^2 b \,|\, B \right\rangle_\mu$$

State of the art

m_b, m_c μ_G^2, μ_π^2 λ_1, λ_2 ρ_D^3, ρ_{LS}^3 ρ_1, ρ_2

Gremm,Kapustin...

$$\Gamma_{cl\nu} = \frac{G_F^2 m_b^5}{192\pi^3} |V_{cb}|^2 A_{ew} z_0(r) \left(1 + a_1(r) \frac{\mu_\pi^2}{m_b^2} + a_2(r) \frac{\mu_G^2}{m_b^2} + a_3(r) \frac{\rho_D^3}{m_b^3} + a_4(r) \frac{\rho_{LS}^3}{m_b^3} \right)$$

Recent implementation for moments of lept and hadronic spectra including a cut on the lepton energy — Bauer et al.,Uraltsev & PG

Perturbative Corrections: full $O(\alpha_s)$ and $O(\beta_0\, \alpha_s^2)$ available
For hadronic moments thanks to **NEW** calculations — Trott

Aquila,PG,Ridolfi,Uraltsev

Using moments to extract HQE parameters

We do know something on HQE par.
need to check consistency.

- $M_{B*}-M_B$ fix $\mu_G^2 = 0.35\pm0.03$
- Sum rules: $\mu_G^2 < \mu_\pi^2$, $\rho_D^3 > -\rho^3_{LS}$...

Central moments can be VERY sensitive to HQE parameters

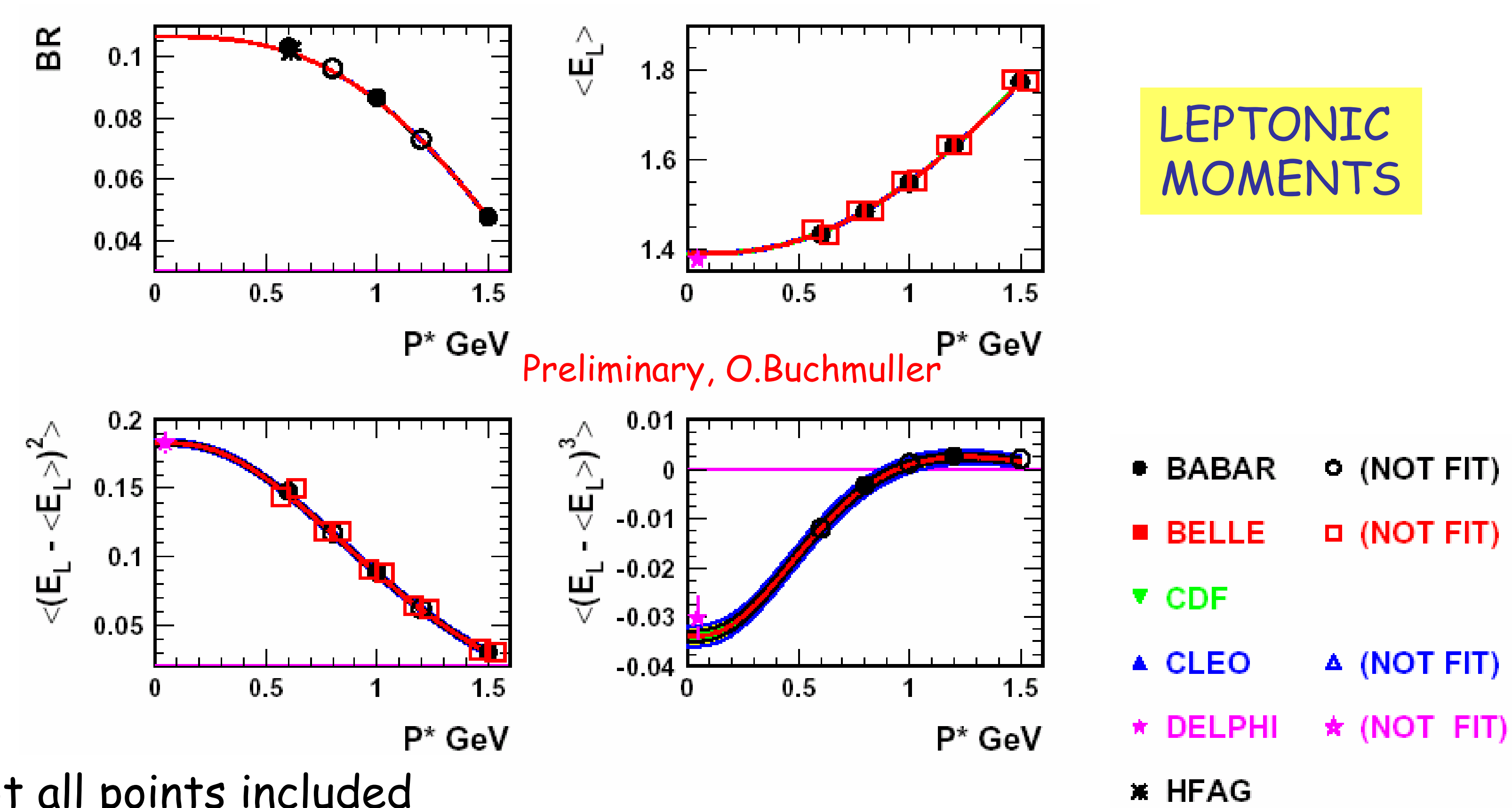
$$\left\langle \left(M_X^2 - \left\langle M_X^2 \right\rangle\right)^2 \right\rangle \approx \left[1.3 + 0.4(m_b - 4.6) - (m_c - 1.2) + 5(\mu_\pi^2 - 0.4) - 6(\rho_D^3 - 0.1) + \ldots\right] GeV^4$$

Variance of mass distribution

BUT: OPE accuracy deteriorates for higher moments (getting sensitive to local effects)

Provided cut is not too severe (~1.3GeV) the cut moments give additional info

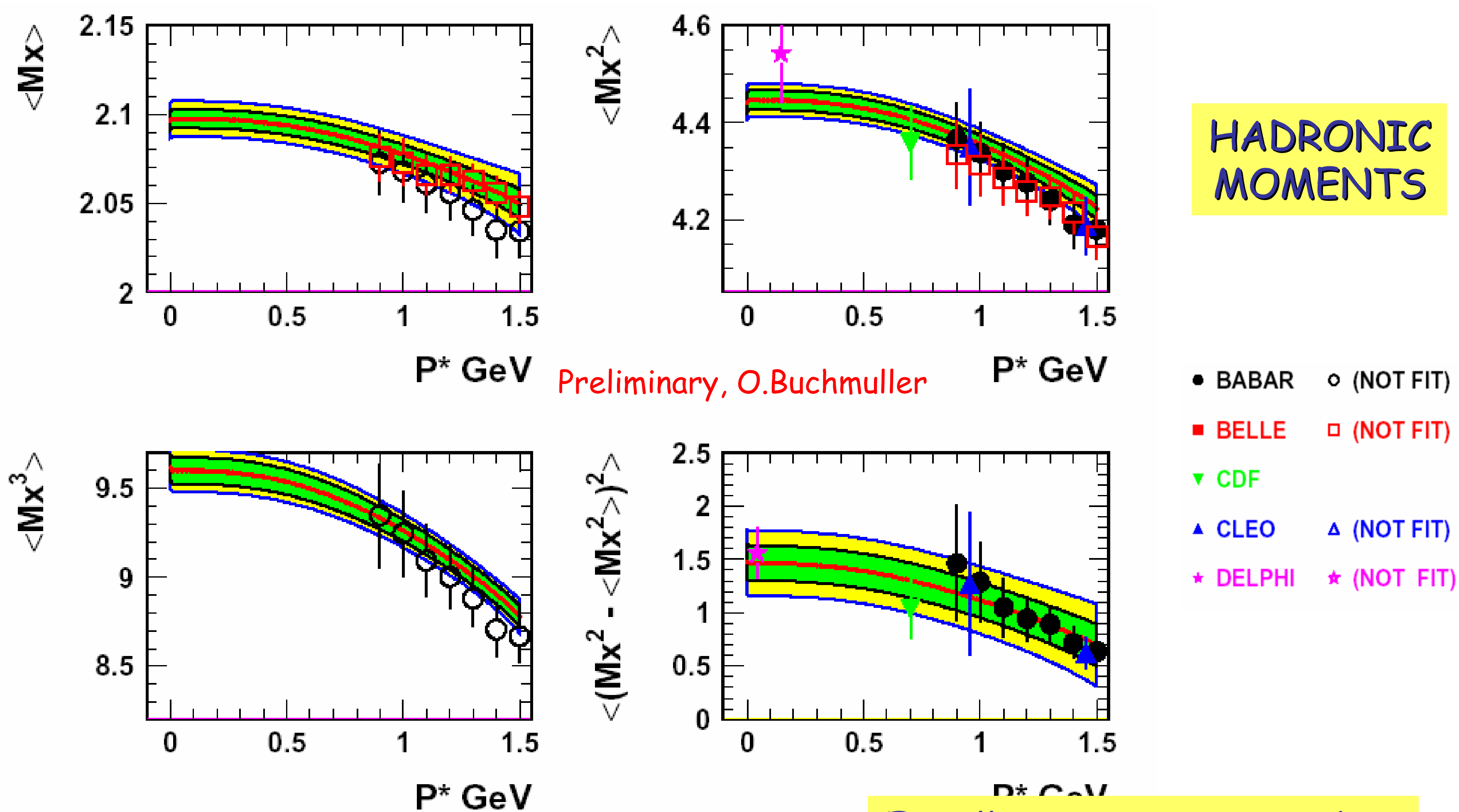
Global fit to $|V_{cb}|$, BR_{sl}, HQE parmts



Not all points included
No external constraint

Pioneer work by CLEO & Delphi employed less precise/complete data, some external constraints, and CLEO a different scheme

Global fit to $|V_{cb}|$, BR_{sl}, HQE parmts



HADRONIC MOMENTS

Preliminary, O.Buchmuller

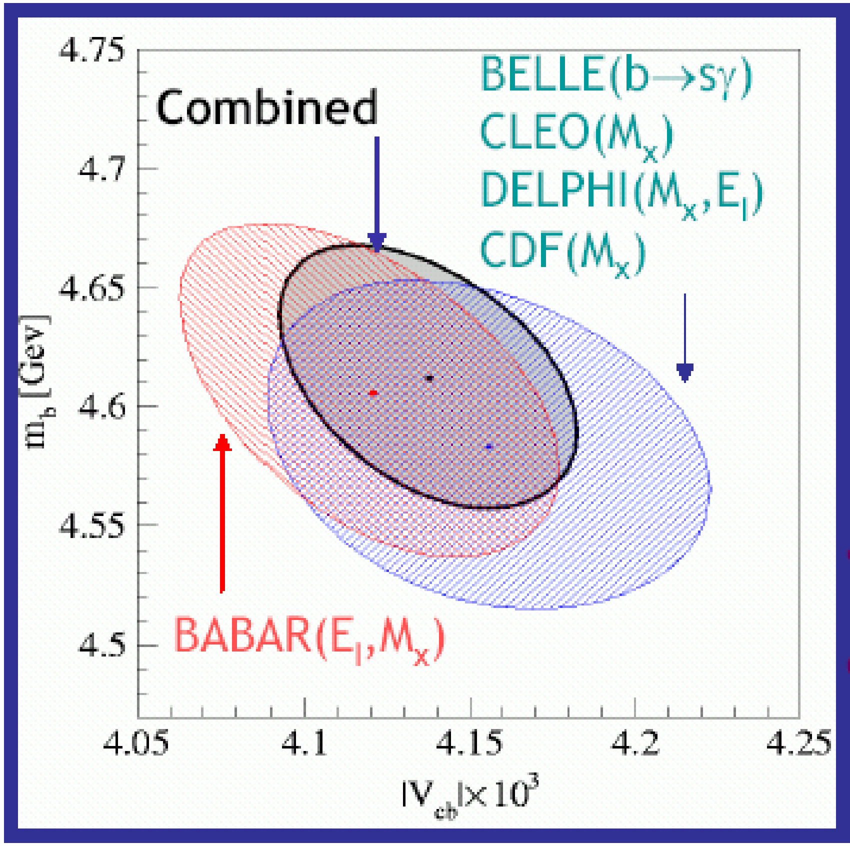
Very similar results in a different approach/scheme, Bauer et al

Excellent agreement within exp and TH errors

Combined fit in kinetic scheme

Benson, Bigi, Gambino, Mannel, Uraltsev

$|V_{cb}|$ = 41.38 +/- 0.45 10^{-3}
m_b = 4.61 +/- 0.06 GeV
m_c = 1.17 +/- 0.08 GeV
μ_π^2 = 0.40 +/- 0.04 GeV^2
μ_G = 0.29 +/- 0.05 GeV^2
ρ_D = 0.16 +/- 0.06 GeV^3
ρ_{LS} = -0.18 +/- 0.09 GeV^3
BR($B \rightarrow X l \nu$) = 10.64 +/- 0.14 %



Consistent description of all moments by HQE

- Stat., syst. and theo. (HQE,α_s) errors included.
- Error from uncertainty in Γ_{SL} (intrinsic charm) not included!
- $|V_{cb}|$ error of ≈ 1%

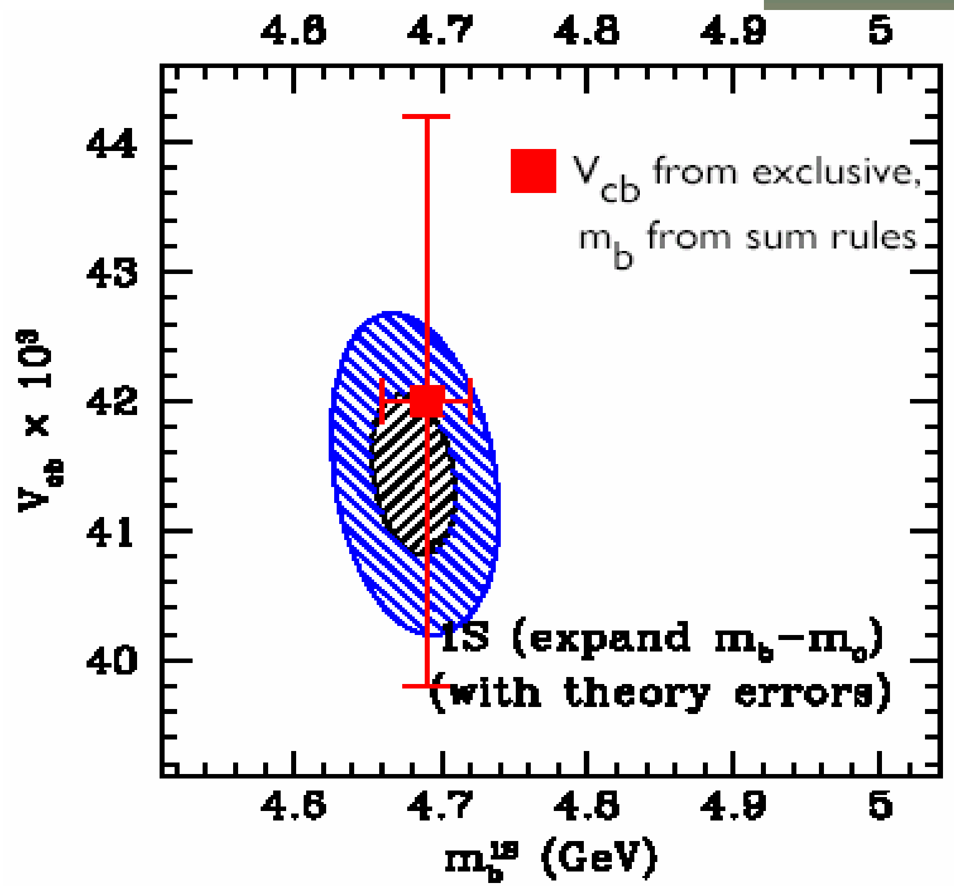
→Substantial improvement from combination!

Could also be done in alternative schemes

Results in the 1S scheme

$\chi^2/\nu = 51/86$. (no theory errors $\chi^2 = 158/86$)

$$V_{cb} = (41.4 \pm 0.6 \pm 0.1_\tau) \times 10^{-3}$$
$$m_b^{1S} = 4.68 \pm 0.03 \text{ GeV}$$
$$m_b - m_c = 3.41 \pm 0.01 \text{ GeV}$$
$$\lambda_1 = -0.27 \pm 0.04 (\text{GeV})^2$$
$$\bar{m}_c(\bar{m}_c) = 0.90 \pm 0.04 \text{ GeV}$$
$$\bar{m}_c(\bar{m}_c) = 1.07 \pm 0.04 \text{ GeV}$$

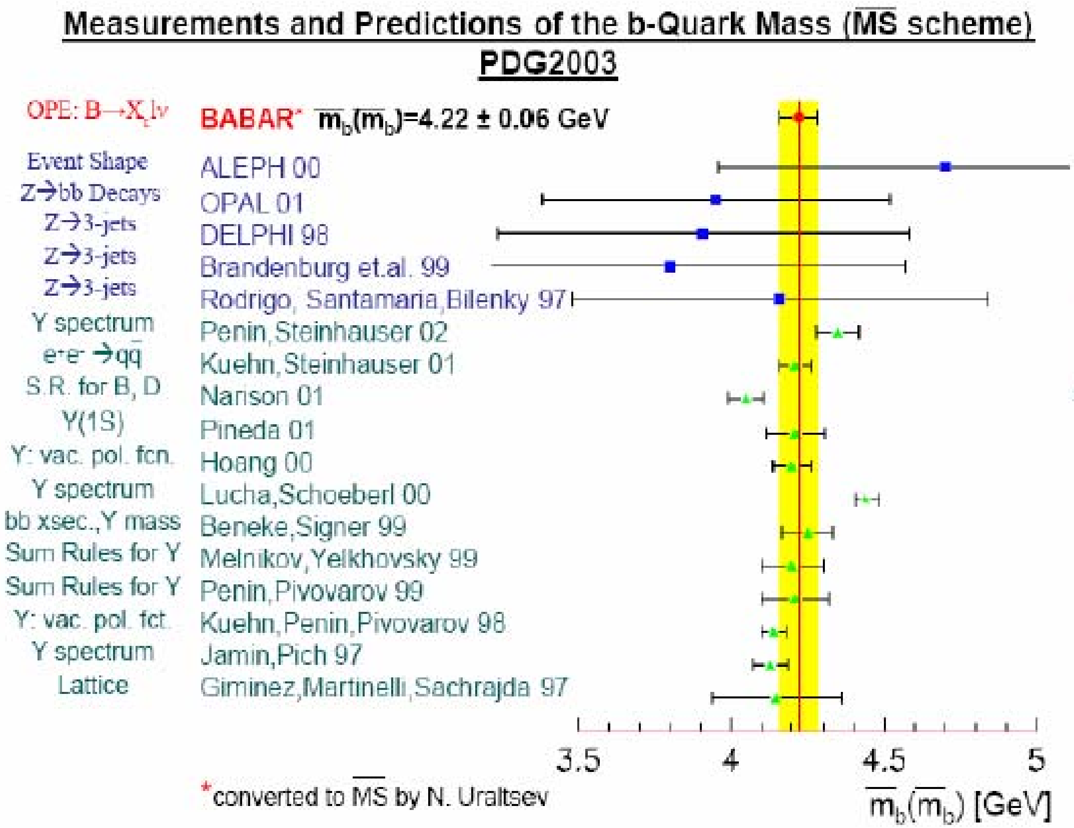


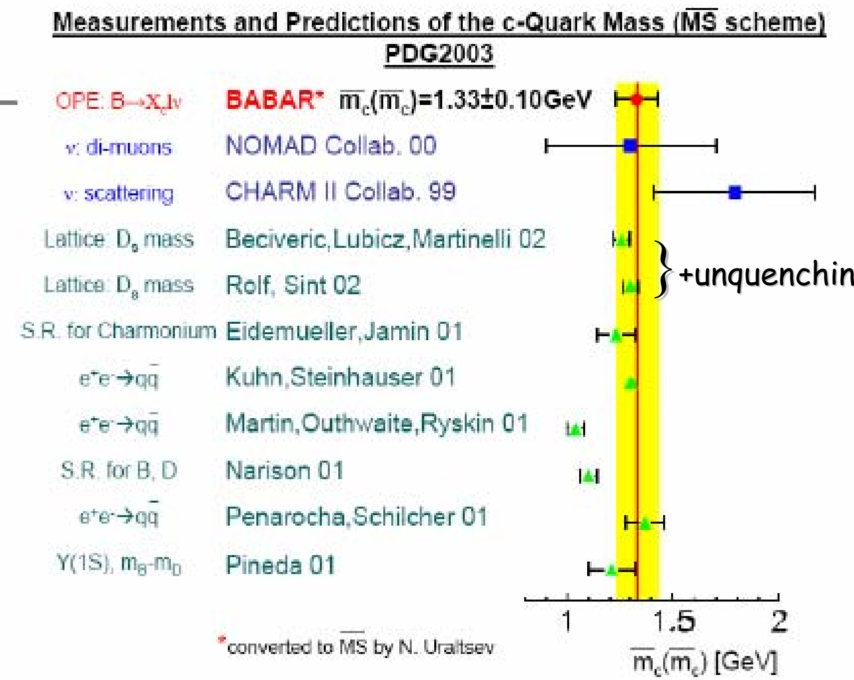
There are several differences:

- perturbative quark mass scheme
- expansion in inverse powers of m_c
- handling of higher orders
- estimate of th errors...

Bauer, Manohar, Ligeti, Luke, Trott 2005

Comparison with other Determinations





$$\overline{m}_b(\overline{m}_b) = 4.22 \pm 0.06\ \text{GeV}$$

$$\overline{m}_c(\overline{m}_c) = 1.33 \pm 0.10\ \text{GeV}$$

Conversion from kinetic mass scheme to $\overline{\text{MS}}$ scheme with hep-ph/9708372, hep-ph/0302262

See also report from CKM WS hep-ph/0304132

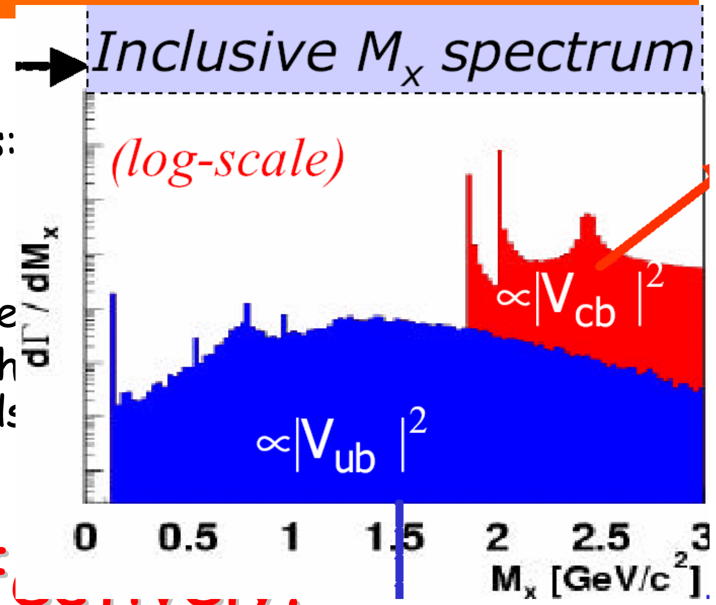
Theoretical uncertainties are crucial for the fits

- ✓ Missing higher power corrections
- ✓ Intrinsic charm
- ✓ Missing perturbative effects in the Wilson coefficients: $O(\alpha_s^2)$, $O(\alpha_s/m_b^2)$ etc
- ✓ Duality violations

How can we estimate all this?

Different recipes, results for $|V_{cb}|$ unchanged

Testing parton-hadron duality



- ✓ **What is it?** For all practical purposes:
  No OPE, no duality

- ✓ **Do we expect violations?** Ye
  because OPE must be continued analytically. th
  described by the OPE, like hadronic threshold
  decays

- ✓ **Can we constrain them eff**
  in a self-consistent way: just check the OPE predictions.
  E.g. leptonic vs hadronic moments. Models may also give hints of how it works

- ✓ **Caveats?** HQE depends on many parameters and we know only a few terms of the double expansion in α_s and Λ/m_b.

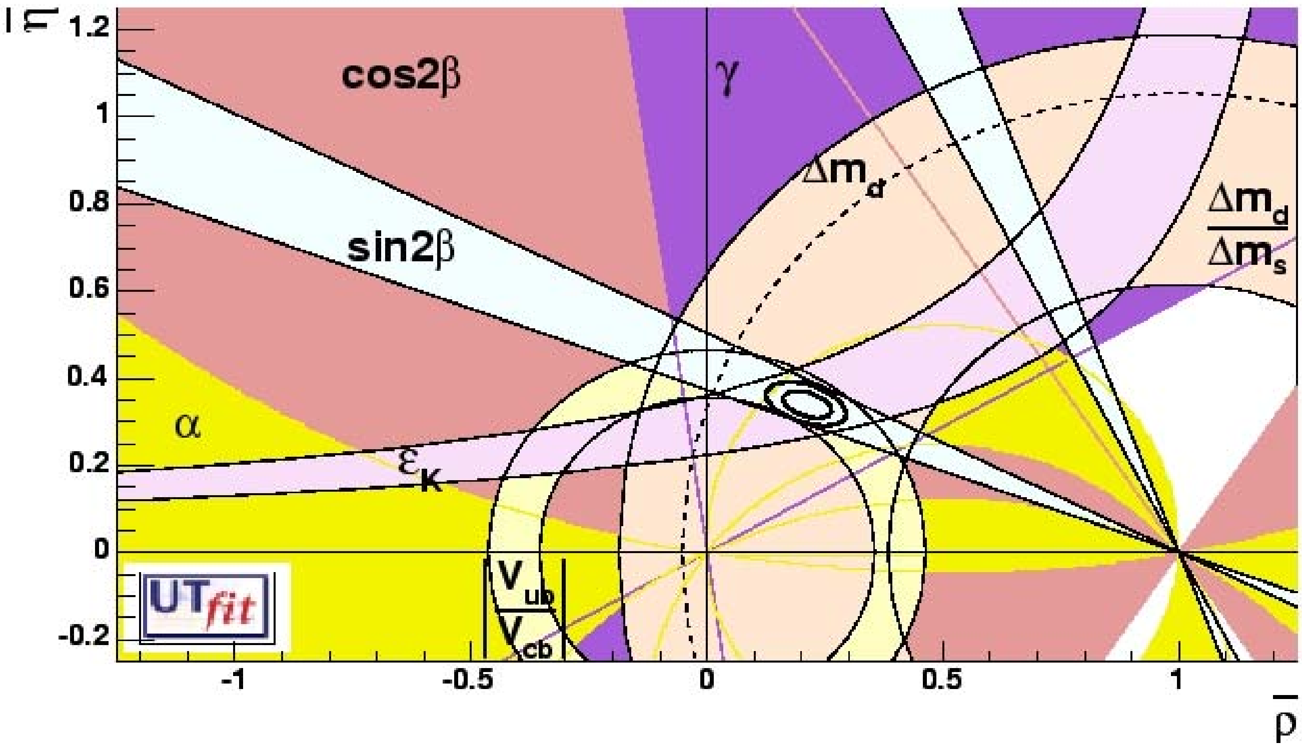
It is not just V_{cb} …

HQE parameters describe *universal* properties of the B meson and of the quarks

- c and b masses can be determined with competitive accuracy (likely better than 70 and 50 MeV) m_b-m_c is already measured to better than 30 MeV: a benchmark for lattice QCD etc?
- It tests the foundations for inclusive measurements
- most **V_{ub} incl. determinations** are sensitive to a shape function, whose moments are related to μ_π^2 etc,
- Bounds on ρ, the slope of IW function ($B\to D^*$ form factor)
- …

Need precision measurements to probe limits of HQE & test our th. framework

$|V_{ub}|$ is the priority now

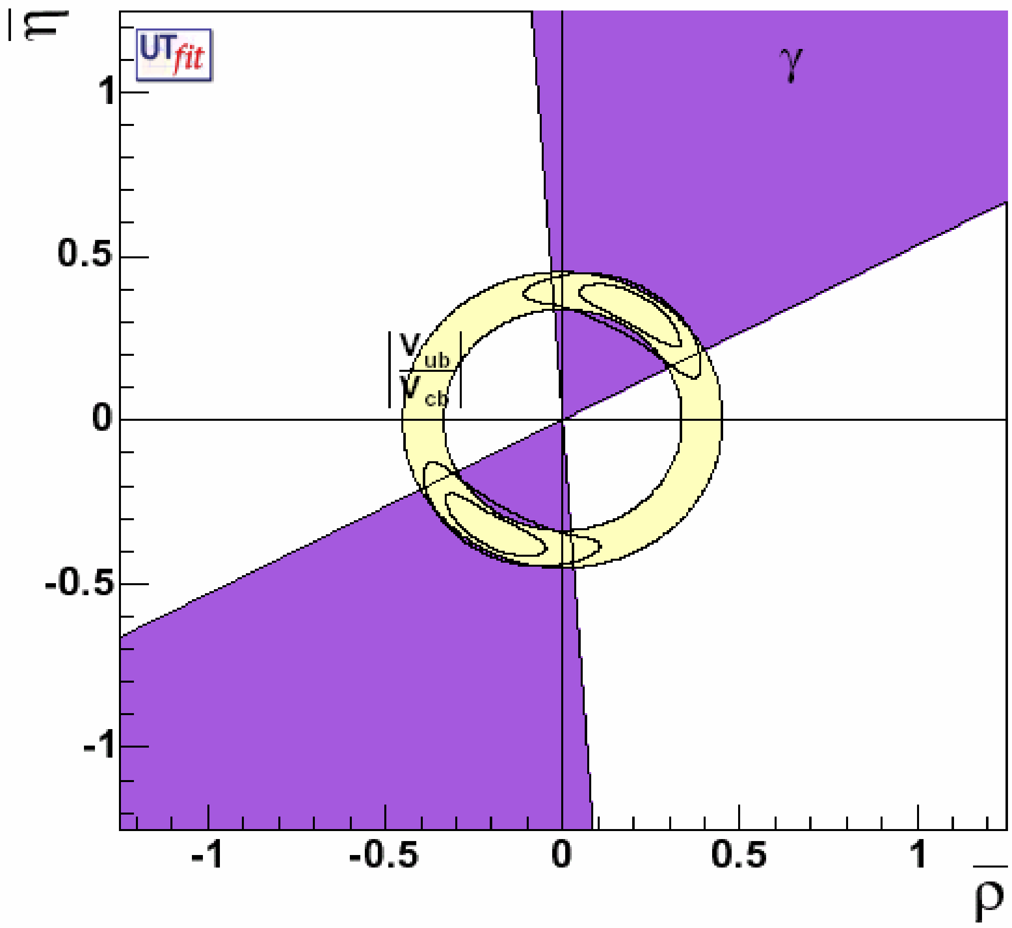


$\bar{\rho} = 0.210 \pm 0.035$

$\bar{\eta} = 0.339 \pm 0.021$

http://www.utfit.org

Strictly tree level



b→ulν exclusive

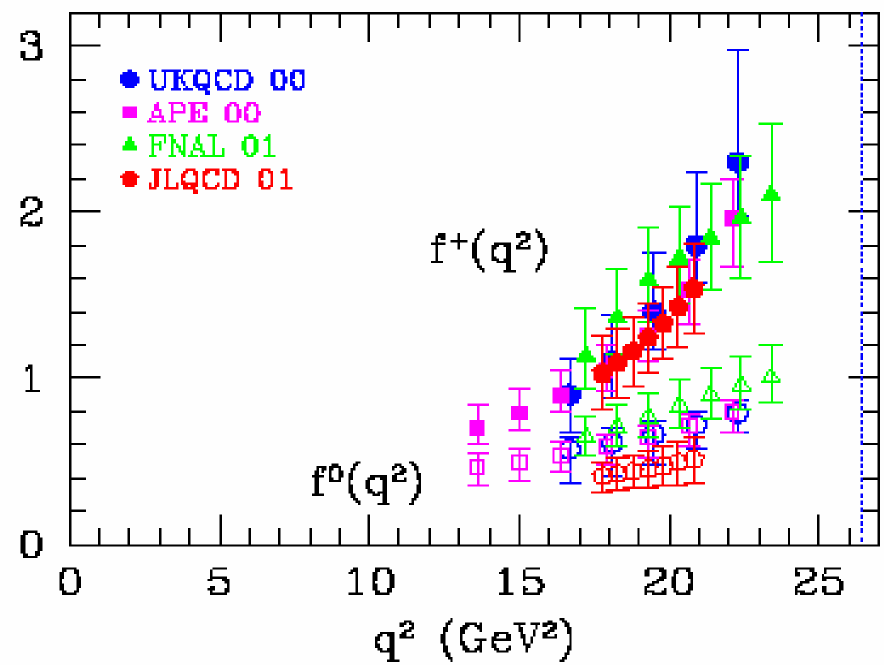
There is NO normalization of form f.s from HQ symmetry

New first unquenched results lattice errors still ~15%

Sum rules good at low q^2 lattice at high q^2: complement each other

Lattice (distant) goal is 5-6%

New strategy using combination of rare B,D decays Grinstein& Pirjol



	$\|V_{ub}\|$ Fermilab/MILC	$\|V_{ub}\|$ HPQCD
$16GeV^2 \leq q^2$	$3.0(4)(6) \times 10^{-3}$	$3.52(44)(73) \times 10^{-3}$
$0 \leq q^2 \leq q^2_{max}$		$3.86(58)(32) \times 10^{-3}$

(CLEO only)

The first error is from the lattice and second from experiment.

$|V_{ub}|$ (not so much) inclusive

$|V_{ub}|$ from total BR($b\to ul\nu$) almost exactly like incl $|V_{cb}|$ but we need kinematic cuts to avoid the ~100x larger $b\to cl\nu$ background:

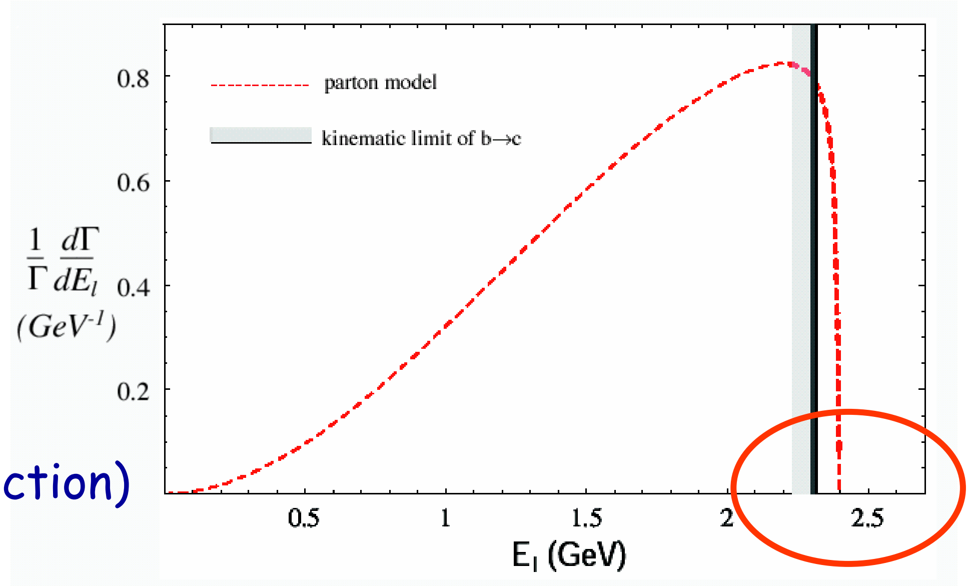
$m_X < M_D$ $\quad E_l > (M_B^2 - M_D^2)/2M_B$ $\quad q^2 > (M_B - M_D)^2$ ...

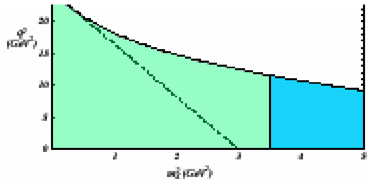
or combined (m_X, q^2) cuts

The cuts destroy convergence of the OPE, supposed to work only away from pert singularities

Rate becomes sensitive to "local" b-quark wave function properties (like Fermi motion

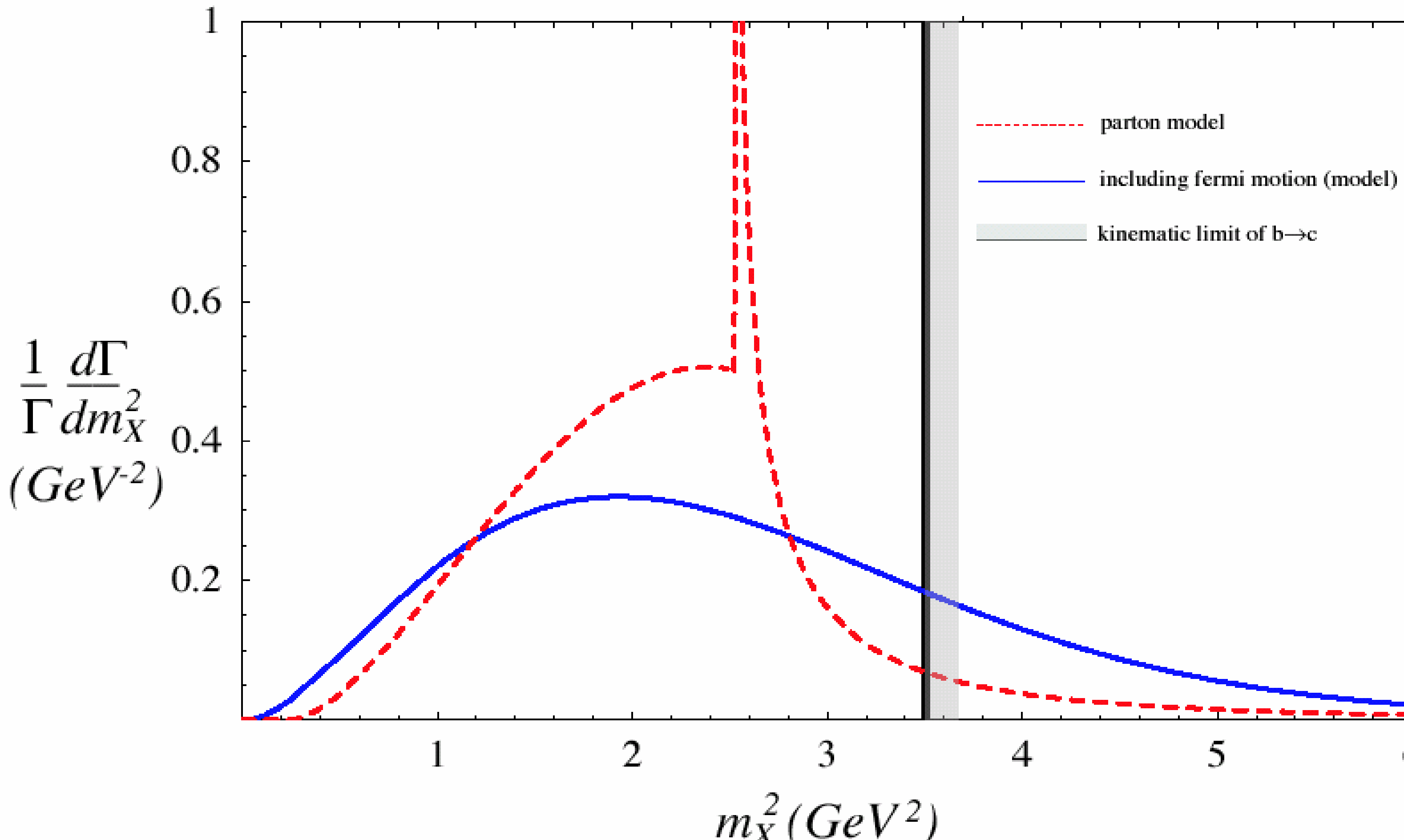
➔ at leading in $1/m_b$ SHAPE function)





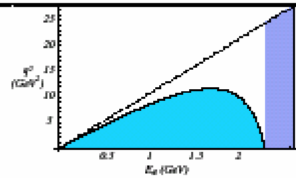
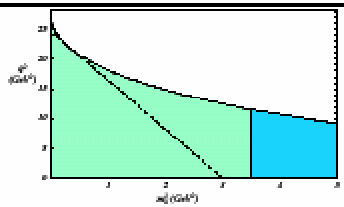
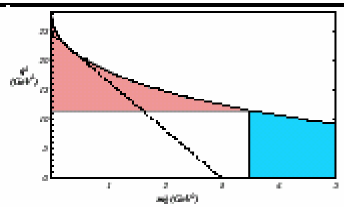
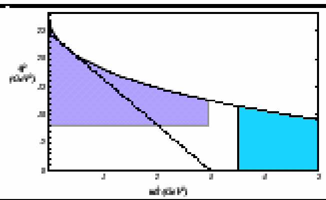
Cutting on the hadronic invariant mass spectrum gives more rate, but has the same problem with fermi motic

(Falk, Ligeti,Wise; Dikeman, Uraltsev)



Luke, CKM workshop 2005

Each strategy has pros and cons

cut		% of rate	good	bad
	$E_\ell > \frac{m_B^2 - m_D^2}{2m_B}$	~10%	don't need neutrino	- depends on $f(k^+)$ (and subleading corrections) - WA effects largest - reduced phase space - duality issues?
	$s_H < m_D^2$	~80%	lots of rate	- depends on $f(k^+)$ (and subleading corrections) - need shape function over large region
	$q^2 > (m_B - m_D)^2$	~20%	insensitive to $f(k^+)$	- very sensitive to m_b - WA corrections may be substantial - effective expansion parameter is $1/m_c$
	"Optimized cut"	~45%	- insensitive to $f(k^+)$ - lots of rate - can move cuts away from kinematic limits and still get small uncertainties	- sensitive to m_b (need +/- 60 MeV for 5% error in best case)
	$P_+ > m_D^2/m_B$	~70%	- lots of rate - theoretically simplest relation to $b \to s\gamma$	depends on $f(k^+)$ (and subleading corrections)

Luke, CKM workshop 2005

What do we know about $f(k_+)$?

- Its moments can be expressed in terms of m.e. of *local* operators, those extracted from the b->c moments
- It can be extracted from $b\to s\gamma$ (see later)
- It can also be studied in $b\to ul\nu$ spectra (see next)
- It gets renormalized and we have learned how (delicate interplay with pert contributions)

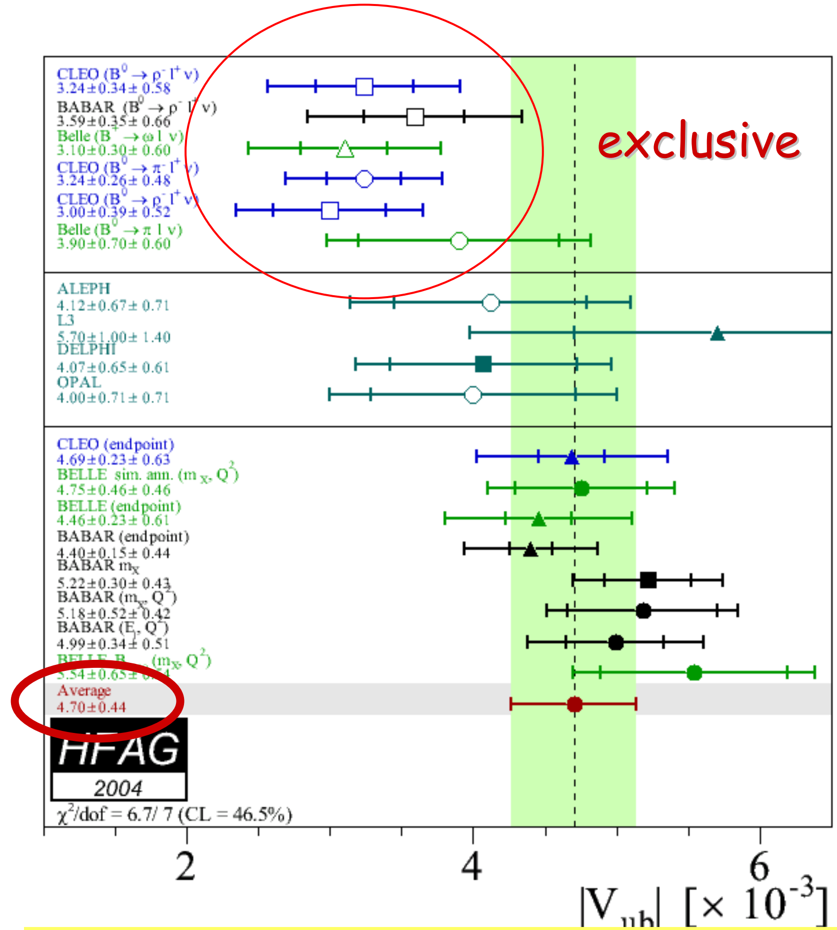
V_{ub} incl. and exclusive

Intense theoretical activity:

- ✓subleading shape functions
- ✓optimization of cuts (P_+,P_- etc)
- ✓weak annihilation contribs.
- ✓Resum. pert. effects
- ✓relation to $b \to s\gamma$ spectrum
- ✓SCET insight

<u>**A lot can be learned from exp**</u>

(on shape function from $b \to s\gamma$, WA, indirect constraints on s.f., subleading effects from cut dependence,...)



REQUIRES MANY COMPLEMENTARY MEASUREMENTS (affected by different uncert.)

There is no Best Method

WE ARE ALREADY AT 10%

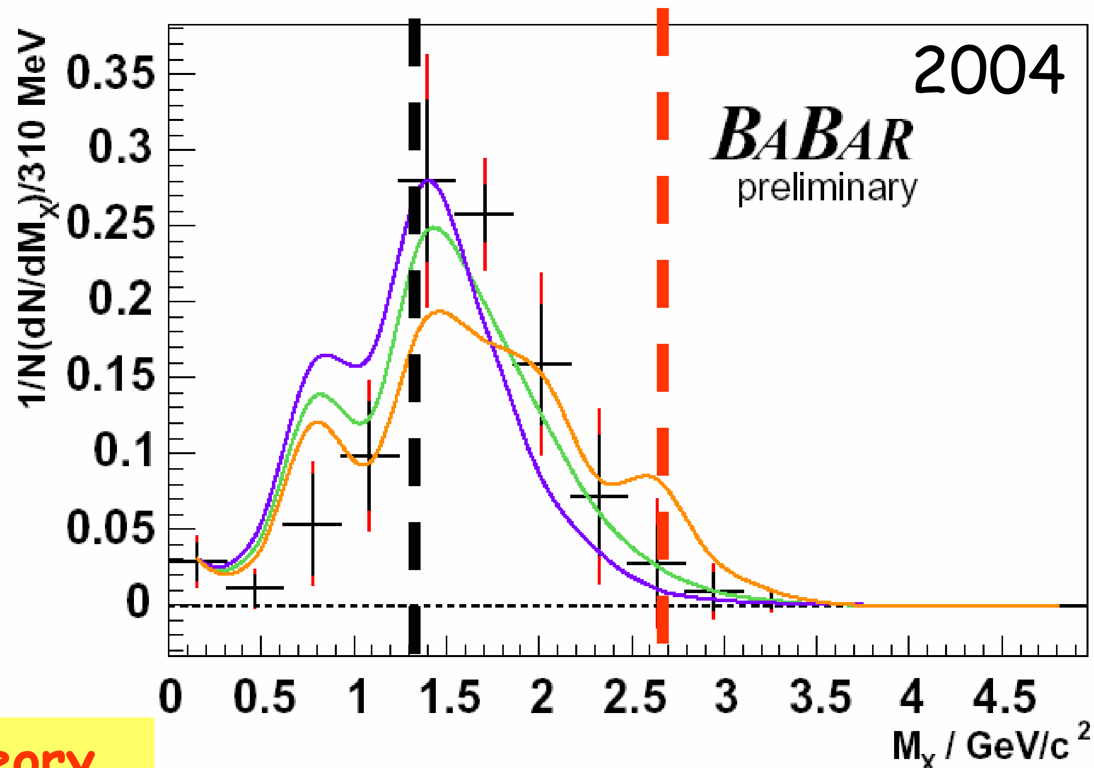
New BRECO analyses; new results soon...

Cutting the cuts...

New exp analyses based on fully reconstructed events allow high discrimination of charmed final states

Babar measured M_X moments. Results can be improved by cutting in a milder way than usual

It's time to start using b->u data to constrain sf!



Unfolded M_X spectrum

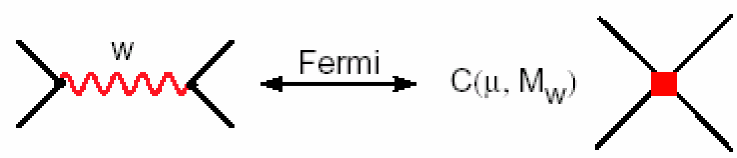
Useful to validate theory and constrain $f(k_+)$ & WA

PG,Ossola,Uraltsev

b → s transitions

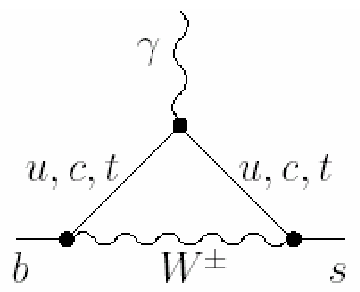
$\Lambda_{QCD} \ll m_b \ll M_W$

Large $L = \log m_b/M_W$ must be resummed.
LO: $\alpha_s^n L^n$, NLO: $\alpha_s^n L^{n-1}$



Tower of local ops
OPE

$m_b \ll M_W$



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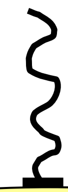


But many more operators appear adding gluons

$$O_7 = m_b \bar{b}_R \sigma_{\mu\nu} F^{\mu\nu} s_L$$

$$\mathcal{L}_{QCD\times QED}(u,d,s,c,b,e,\mu,\tau) + \frac{4G_F}{\sqrt{2}} V_{ts}^* V_{tb} \sum_{i=1}^{32} C_i(\mu) Q_i$$

The current is not conserved and runs between M_W and m_b
We have AT LEAST 3 scales

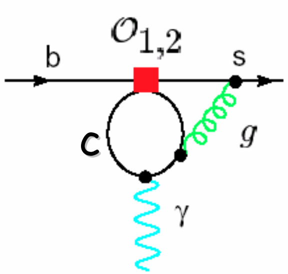
Inclusive decays are described by OPE (except charm loop contributions!)

The main ingredients

Process independent:

- **The Wilson coefficients C_i** (encode the short distance information, initial conditions)
- **The Anomalous Dimension Matrix** (mixing among operators, determines the evolution of the coefficients, allowing to resum large logs)

Process dependent: matrix elements



$B \to X_s\gamma$: NLO QCD calculation completed, all results checked, EW , power corrections

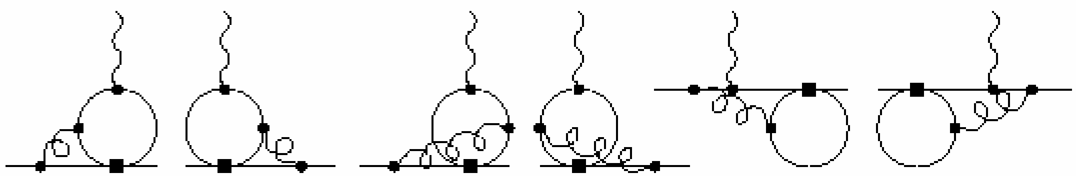
$B \to X_s ll$: NNLO & EW calculation just completed,power corrections

The charm mass problem

m_c enters the phase factor $C = \left|\frac{V_{ub}}{V_{cb}}\right|^2 \frac{\Gamma[\bar{B} \to X_c e \bar{\nu}]}{\Gamma[\bar{B} \to X_u e \bar{\nu}]}$ = 0.581±0.017
due to normalization

Misiak & PG

and the NLO matrix elements



As the related LO diagrams vanish, the definition of m_c is a NNLO issue. Numerically very important because these are large NLO contributions:

$m_c(m_c)$=1.25±0.10 GeV $m_c(m_b)$=0.85±0.11 GeV m_c(pole)~1.5GeV

But pole mass has nothing to do with these loops

Changing m_c/m_b from 0.29 (pole) to 0.22 (MSbar) increases BRγ by 11%
0.22 ±0.04 gives DOMINANT 6% theory error

Error anatomy of BRγ

$$\mathrm{BR}\left[\bar{B} \to X_s\gamma\right]_{E_\gamma > 1.6\,\mathrm{Gev}} = (3.61 \pm 0.30) \times 10^{-4},$$

$$= 3.61 \times 10^{-4}\,(1 \pm 0.06_{(m_c/m_b \text{ in } K_c)} \pm 0.04_{(\text{other NNLO})}$$

$$\pm 0.01_{(\text{pert C})} \pm 0.02_{\lambda_1} \pm 0.02_{\Delta}$$

$$\pm 0.02_{\alpha_s(M_Z)} \pm 0.02_{\mathrm{BR(semilept)_{exp}}} \pm 0.01_{m_t})$$

Misiak, PG 2001

Total error 8% dominated by charm mass
Can be partially resolved by NNLO
Update under way

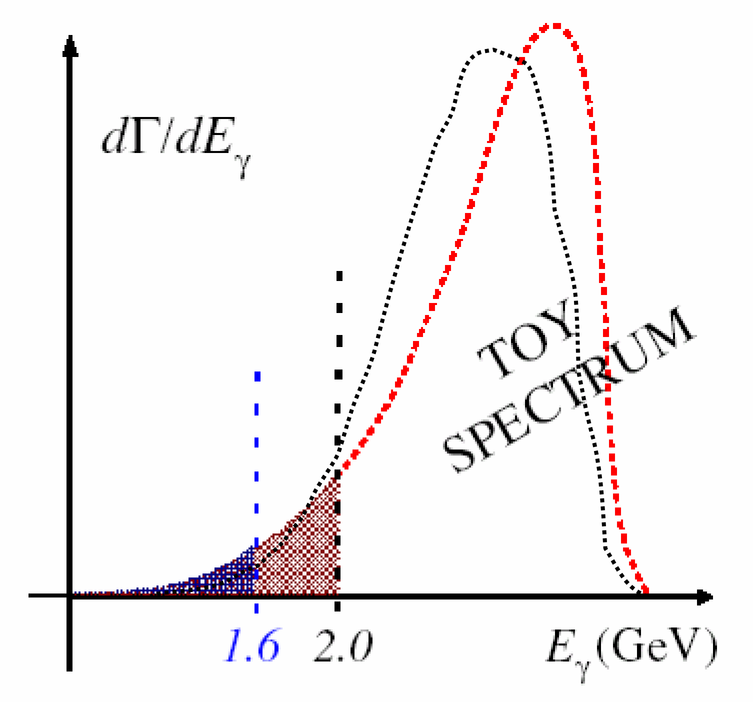
Photon spectrum vs *total* BR

The OPE does not predict the spectrum, only its *global properties*: the higher the cut the higher the uncertainty

Conversely, constraining the HQE parameters constrains the possible shape functions

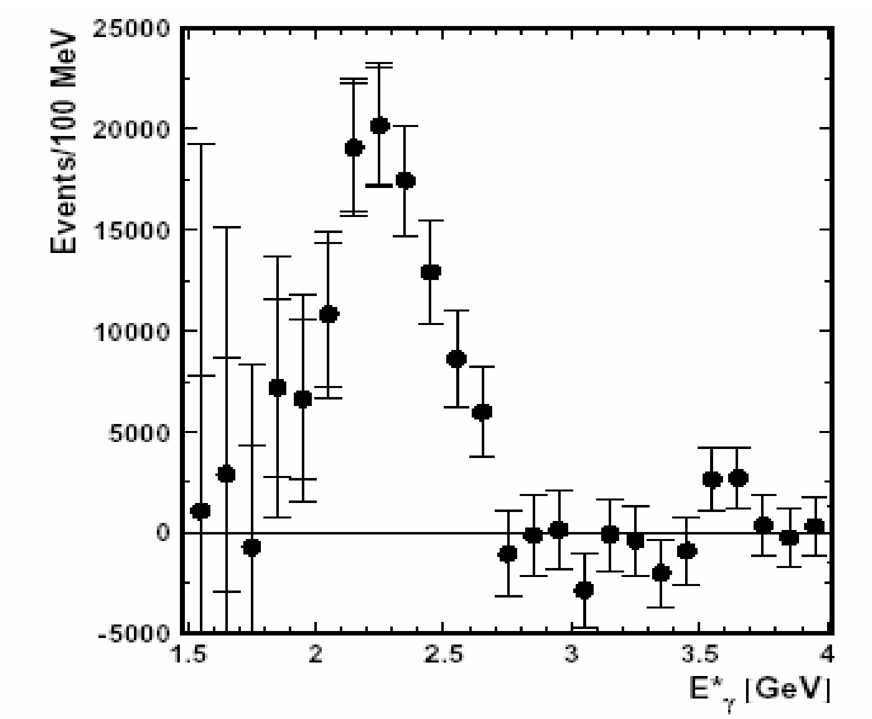
Possible subleading shape functns effects in V_{ub} applications

The shape function gets renormalized by perturbative effects: some complications may be better understood in SCET (Bauer & Manohar, Neubert et al)

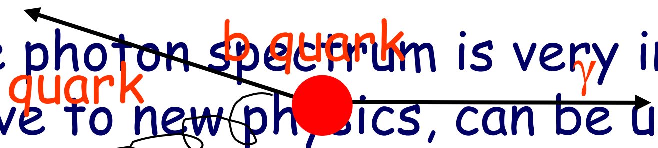


Universality: spectrum of $B \rightarrow X_s\gamma$

Motion of b quark inside B and gluon radiation smear the spike at $m_b/2$



Belle: lower cut at 1.8GeV



The photon spectrum is very insensitive to new physics, can be used to study the B meson structure

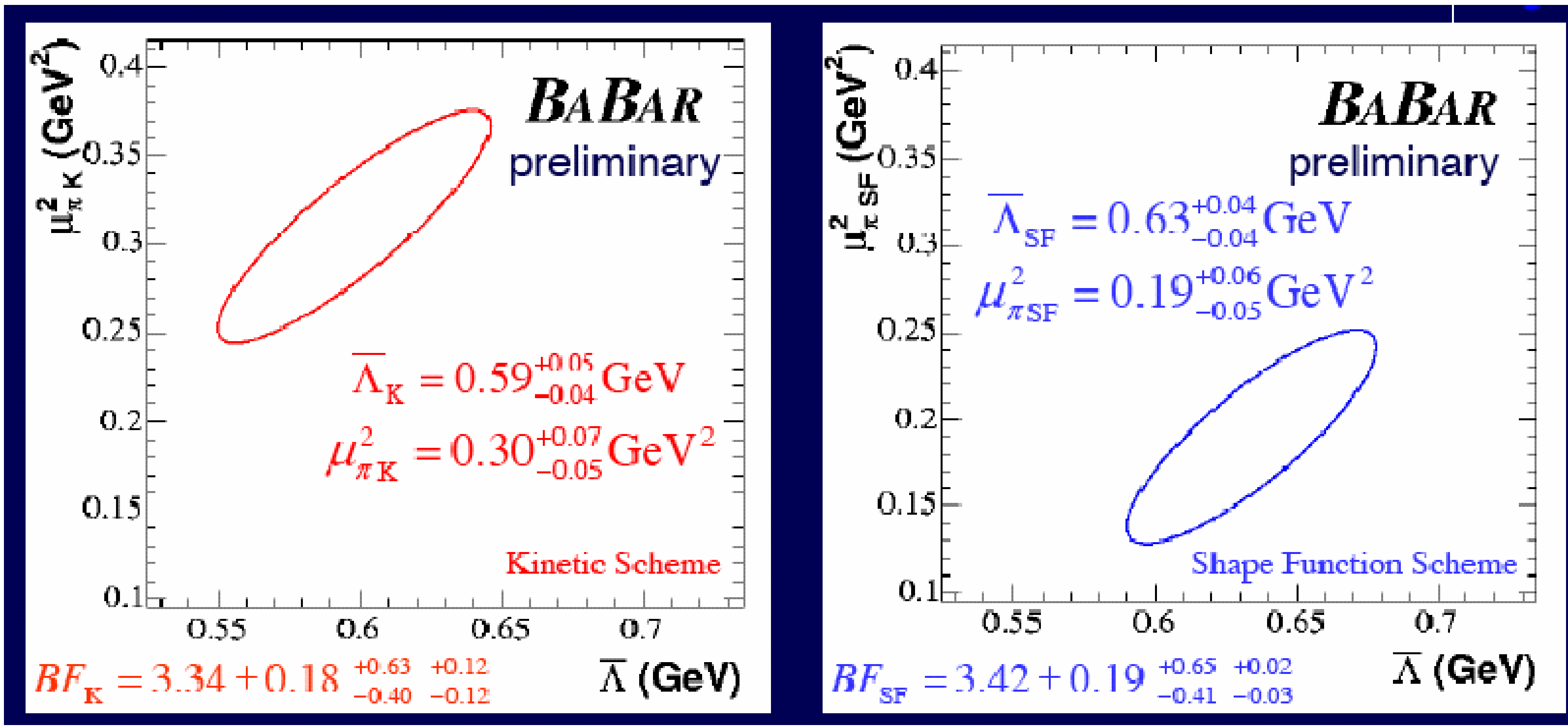
$\langle E_\gamma \rangle = m_b/2 + \ldots \quad \mathrm{var}\langle E_\gamma \rangle = \mu_\pi^2/12 + \ldots$

Importance of extending to $E_\gamma^{min} \sim 1.8$ GeV or less for the determination of both the BR AND the HQE parameters — Bigi Uraltsev

Info from radiative spectrum compatible with semileptonic moments ➔ ➔

BaBar: Fit to new b → s gamma spectrum

Erkcan Ozcan



Benson-Bigi-Uraltsev

Neubert

CKM 2005, Mar. 15-18, 2005 12

results in two different schemes, agree well with b->clv

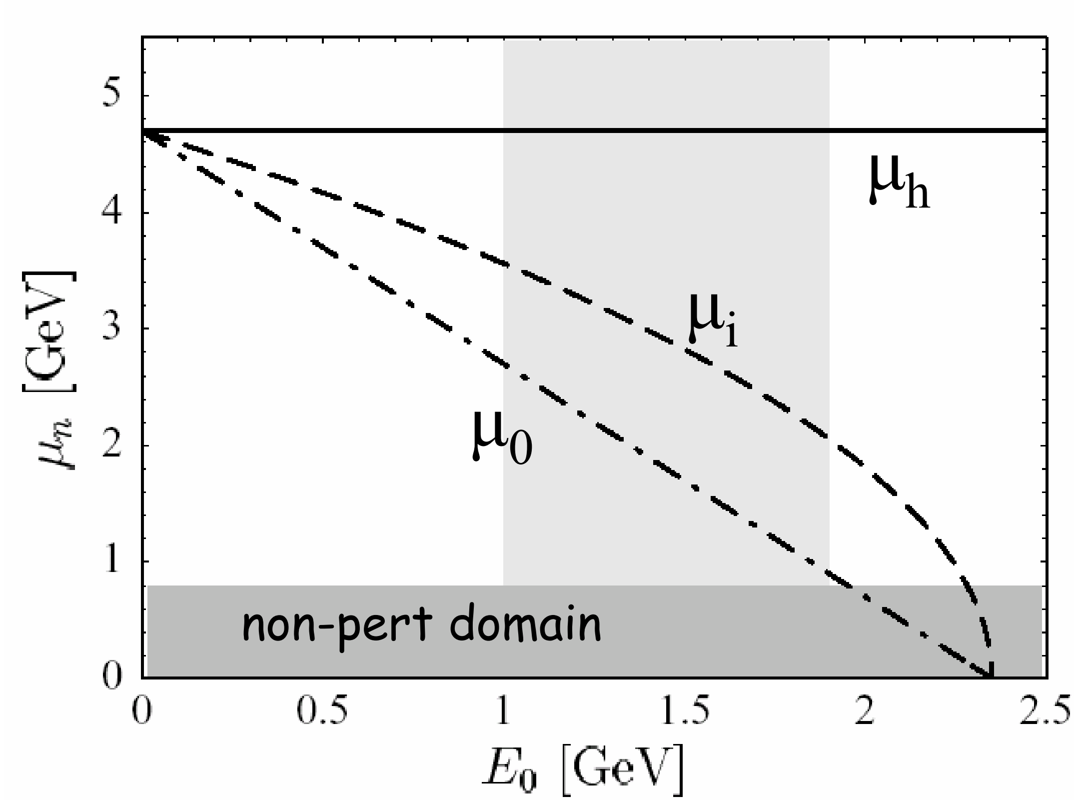
More cuts complications

Neubert 2004

$\mu_h \sim m_b$

$\mu_i \sim \sqrt{\Delta m_b}$

$\mu_0 \sim \Delta = m_b - 2E_{cut}$



The lower photon energy cut E_{cut} introduces two new scales EVEN when local OPE works fine ➔ terms $\alpha_s(\Delta)$ could be large

Neubert (II)

- Need to disentangle 3 scales → MultiScaleOPE

QCD → SCET → HQET → local OPE

μ_h μ_i μ_0

How well can we predict the radiative tail?

- Neubert finds F(E_γ >1.8GeV)=0.89±0.07, BR 3% lower, and theory error on BR 50% larger

FUNDAMENTAL LIMITATION?

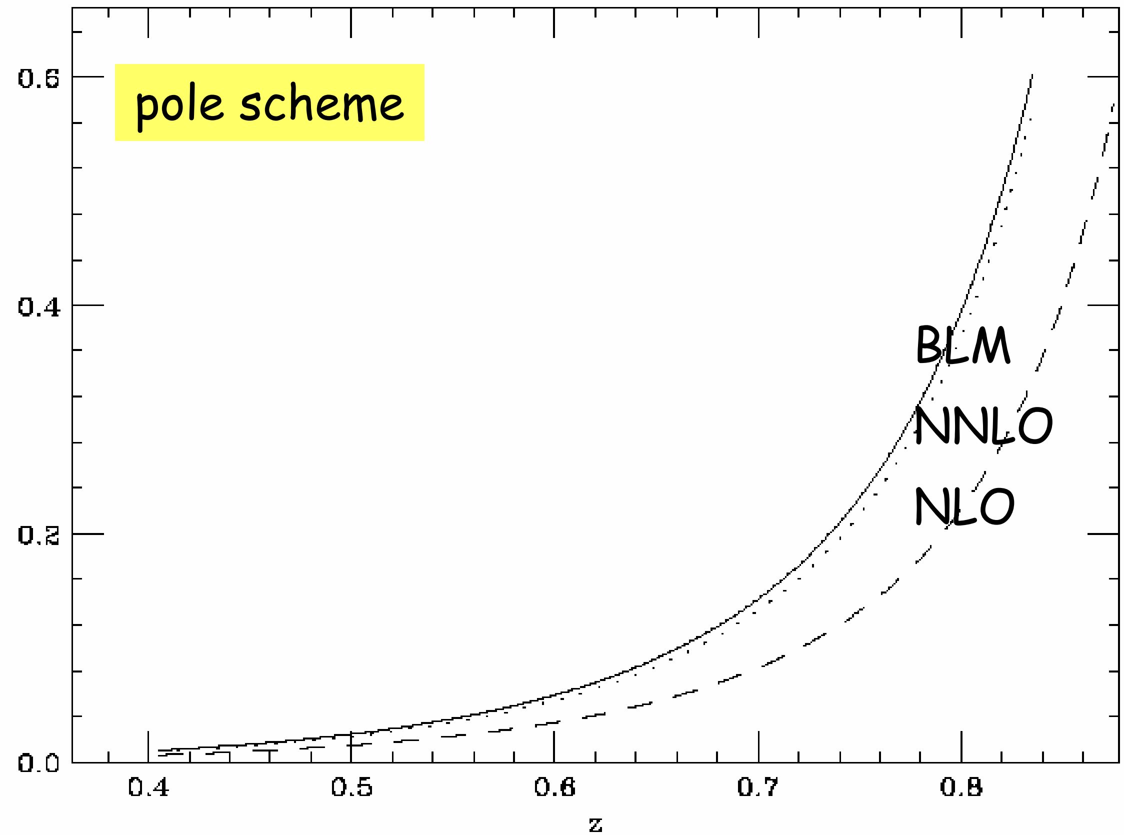
- *Main effect due to pert corrections whose scale is determined by higher orders (BLM etc): NNLO is the solution (at least to large extent)*
- Sudakov resummation is irrelevant for E_{cut}<1.8 GeV
- New result of dominant 77 photon spectrum at O(α_s^2)

The NNLO spectrum (dominant part)

NNLO calculation very close to BLM

Non-BLM corrections change BR_γ by 0.5%

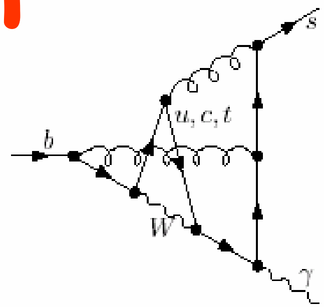
Situation seems under control



$z=2E_\gamma/m_b$

Melnikov & Mitov 2005

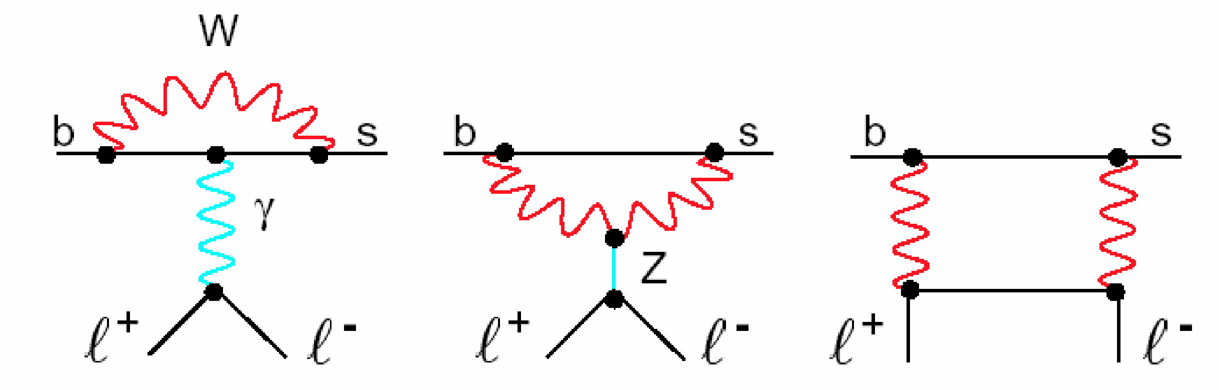
NNLO status report



- NNLO $C_{7,8}$ matching completed
  Misiak, Steinhauser
- All 3loop NNLO ADM   Gorbahn,Haisch,Misiak
- Parts of the 3loop NNLO matrix elements
  Bieri et al & Asatrian et al
- 2loop matrix element of Q_7 Czarnecki et al
- Dominant part of NNLO spectrum   Melnikov Mitov

Still missing:
- 4loop ADM
- 3loop ME with charm
- subdominant 2loop ME

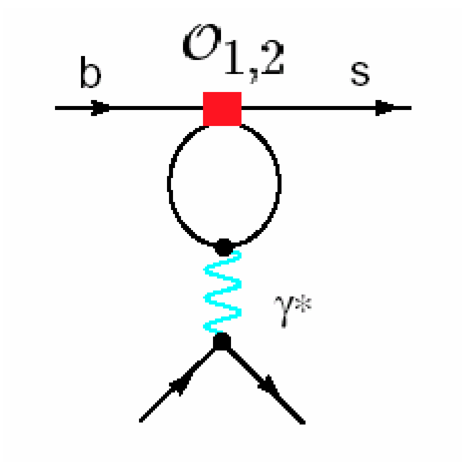
$b \to s l^+ l^-$: a more complicated case



This decay mode is sensitive to different operators, hence to different new physics

Here large logs are generated even without QCD: LO $\alpha_s^n L^{n+1}$, NLO $\alpha_s^n L^n$,...

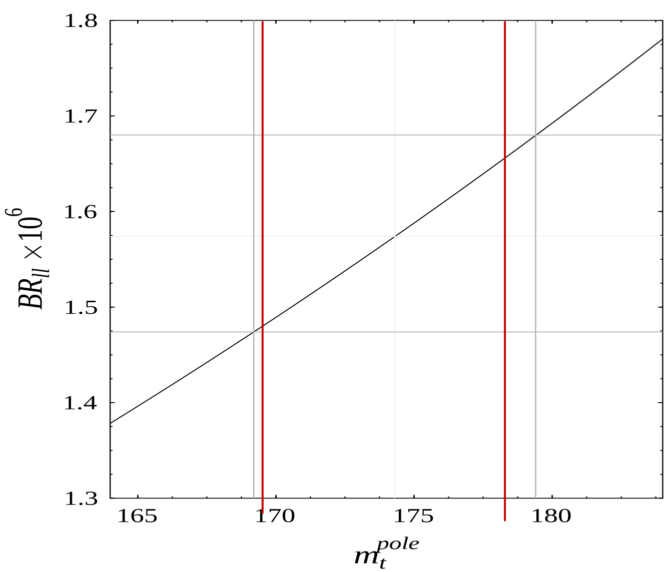
However, numerically the leading log is subdominant, yielding an awkward series:
in BR $1 + 0.7\ (\alpha_s) + 5.5\ (\alpha_s^2) + \ldots$



Error Anatomy for BR_{ll}

$$\mathrm{BR}_{\ell\ell}\left(1\,\mathrm{GeV}^2 \le q^2 \le 6\,\mathrm{GeV}^2\right) = \left[1.574 \pm^{0.106}_{0.100}\big|_{M_t} \pm^{0.059}_{0.075}\big|_{\mathrm{scale}} \pm 0.045_C \pm 0.035_{\mathrm{BR}_{sl}} \pm^{0.072}_{0.067}\big|_{m_b} \pm^{0.001}_{0.013}\big|_{m_c}\right] \times 10^{-6}$$

Bobeth,PG,Gorbahn,Haisch



- M_{top} dominant error 7%
- scale uncertainty 5%
- m_b^{pole} = 4.80±0.15 GeV →5%
- phase space factor 3%
- No m_c issue as charm enters at LO

TOTAL ERROR ~10%

BUT: bottom uncertainty is not a fundamental limitation

$\delta m_b^{\text{short distance}} \approx$ 30-50 MeV

simply change scheme!

EXP: only inclusive rate,
Belle (140fb^{-1}): $(4.4\pm0.8\pm0.8)\times10^{-6}$
Babar(80fb^{-1}): $(5.6\pm1.5\pm1.3)\times10^{-6}$
We get $(4.6\pm0.8)\times10^{-6}$ (m_{ll}>0.2GeV)

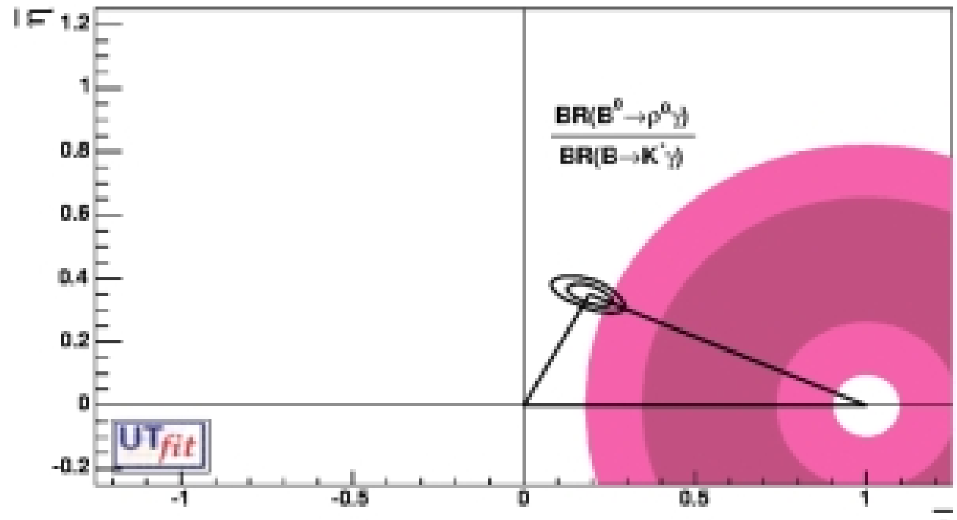
the UT from excl radiative decays

- Inclusive b->dγ experimentally impossible, but exclusive modes start being accessible
- Ratios of $B\to\rho\gamma$ / $B\to K^*\gamma$ allow a determination of $|V_{td}/V_{ts}|$ that is independent of form factors in the limit of SU(3)
- Calculations rely on QCD factorization and on lattice/sum rules for the estimate of SU(3) violation (Beneke et al, Bosch Buchalla) power corrections apparently suppressed
- Neutral modes don't have WA, ξ=1.2±0.1 (CKM 2005)
- LC sum rules errors large, Lattice calculations only exploratory...

An interesting deviation?

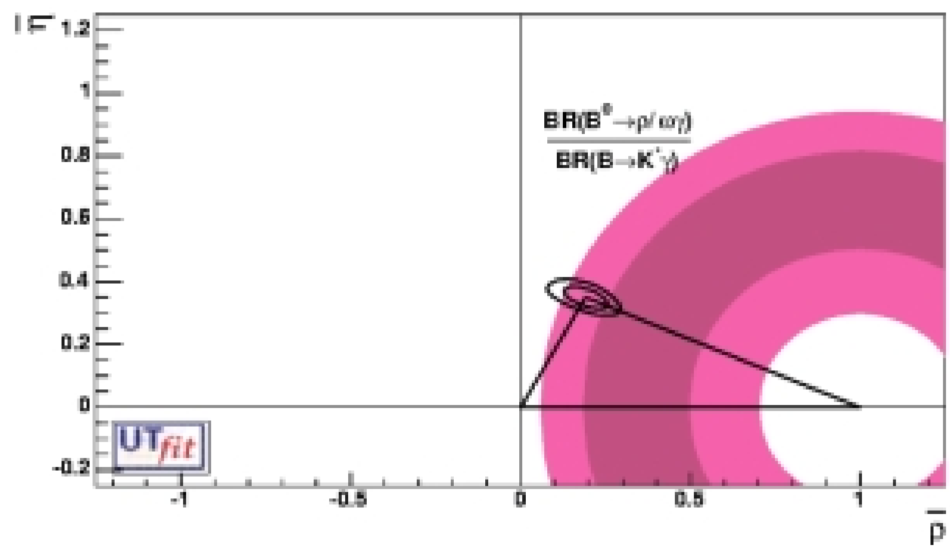
Impact on UT using only neutral modes:

$BR(B^0 \to \rho^0 \gamma) = 0.6^{+1.9}_{-1.4} \times 10^{-7}$



Impact on UT using average of neutral and charged modes:

$BR(B \to \rho/\omega\, \gamma) = (6.4 \pm 2.7) \times 10^{-7}$



Summary of main theory limitations

process	quantity	Th error	needs	goal
$B \to D^* l\nu$	$\lvert V_{cb} \rvert$	~4%	New lattice results	1%
$B \to X l\nu$	$\lvert V_{cb} \rvert$	~1.5%	New pert calculations	<1%
$B \to \pi\, l\nu$	$\lvert V_{ub} \rvert$	~15%	Lattice developments	6%?
$B \to X_u l\nu$	$\lvert V_{ub} \rvert$	~10%	More data synergy th/exp	5%
$B \to X_s \gamma$	BR	$\lesssim$10%	NNLO,MSOPE?	<5%
$B \to \rho^0 \gamma / B \to K^{*0} \gamma$	$\lvert V_{td} \rvert / \lvert V_{ts} \rvert$	10-20%	Better understanding of th errors, lattice	?

Fit Results

$$|V_{cb}| = (41.4 \pm 0.4_{exp} \pm 0.4_{HQE} \pm 0.2_{\alpha_s} \pm 0.6_{\Gamma_{SL}}) \times 10^{-3}$$
$$Br(B \to X_c e \nu) = (10.61 \pm 0.16_{exp} \pm 0.06_{HQE})\%$$
$$m_b(1\ GeV) = (4.61 \pm 0.05_{exp} \pm 0.04_{HQE} \pm 0.02_{\alpha_s})\ GeV$$
$$m_c(1\ GeV) = (1.18 \pm 0.07_{exp} \pm 0.06_{HQE} \pm 0.02_{\alpha_s})\ GeV$$

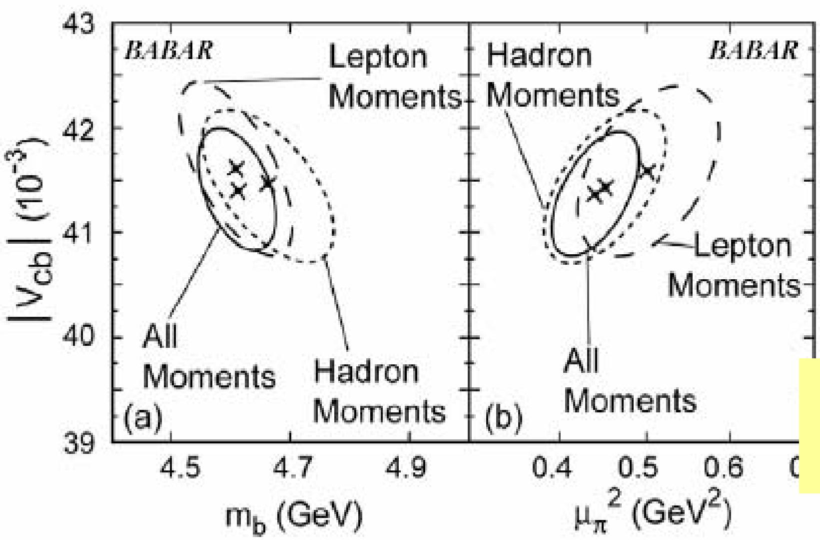
Kinetic scheme:
Small pert corrections
Minimal set of parmts
No $1/m_c$ expansion
Uraltsev & PG

kinetic mass scheme

$$\mu_\pi^2 = (0.45 \pm 0.04_{exp} \pm 0.04_{HQE} \pm 0.01_{\alpha_s})\ GeV^2$$
$$\mu_G^2 = (0.27 \pm 0.06_{exp} \pm 0.03_{HQE} \pm 0.02_{\alpha_s})\ GeV^2$$
$$\rho_D^3 = (0.20 \pm 0.02_{exp} \pm 0.02_{HQE} \pm 0.00_{\alpha_s})\ GeV^3$$
$$\rho_{LS}^3 = (-0.09 \pm 0.04_{exp} \pm 0.07_{HQE} \pm 0.01_{\alpha_s})\ GeV^3$$

Strong correlation between m_b and m_c:

$$m_b(1\ GeV) - m_c(1\ GeV) = (3.44 \pm 0.03_{exp} \pm 0.02_{HQE} \pm 0.01_{\alpha_S})\ GeV$$



2D projections of the fit result:

Δχ²=1 ellipses

No sign of deterioration for higher cuts