Global fit overview

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The semileptonic width

- $\Gamma(B \to X_c l \nu)$ can be systematically calculated with the operator production expansion (OPE)

$$\Gamma_{sl}(b \to c) = \frac{G_F^2 m_b^5(\mu)}{192\pi^3} |V_{cb}|^2 (1+A_{ew}) A^{pert}(r,\mu) \left[z_0(r) \left(1 - \frac{\mu_\pi^2(\mu) - \mu_G^2(\mu) + \frac{\rho_D^3(\mu) + \rho_{LS}^3(\mu)}{m_b(\mu)}}{2m_b^2(\mu)} \right) - 2(1-r)^4 \frac{\mu_G^2(\mu) - \frac{\rho_D^3(\mu) + \rho_{LS}^3(\mu)}{m_b(\mu)}}{m_b^2(\mu)} + d(r) \frac{\rho_D^3(\mu)}{m_b^3(\mu)} + \ldots \right]$$

from [Benson et al., Nucl. Phys. B665, 367 (2003)]

$$r = m_c^2(\mu)/m_b^2(\mu)$$

○ … HQ parameters (non-calculable; contain soft QCD physics)

- At each order in $1/m_b$, the expectation values of local operator products (heavy quark parameters) are multiplied by perturbatively calculable coefficients

Other observables in B decays

- Moments of the lepton energy spectrum in $B \to X_c l \nu$

$$R_n(E_{\rm cut},\mu) = \int_{E_{\rm cut}} (E_\ell - \mu)^n \frac{{\rm d}\Gamma}{{\rm d}E_\ell}\,{\rm d}E_\ell\,, \quad \langle E_\ell^n \rangle_{E_{\rm cut}} = \frac{R_n(E_{\rm cut},0)}{R_0(E_{\rm cut},0)}$$

- Moments of the hadronic mass spectrum in $B \to X_c l \nu$

$$\langle m_X^{2n} \rangle_{E_{\rm cut}} = \frac{\displaystyle\int_{E_{\rm cut}} (m_X^2)^n \frac{{\rm d}\Gamma}{{\rm d}m_X^2}\,{\rm d}m_X^2}{\displaystyle\int_{E_{\rm cut}} \frac{{\rm d}\Gamma}{{\rm d}m_X^2}\,{\rm d}m_X^2}$$

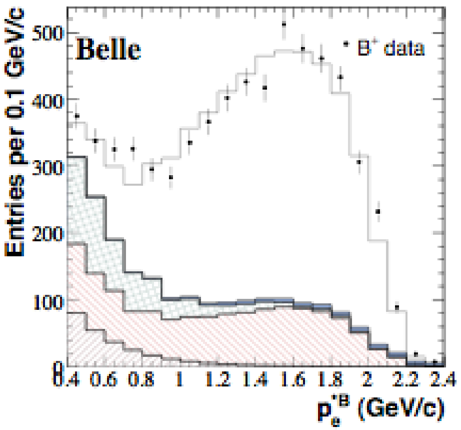
- Moments of the photon energy spectrum in $B \to X_s \gamma$

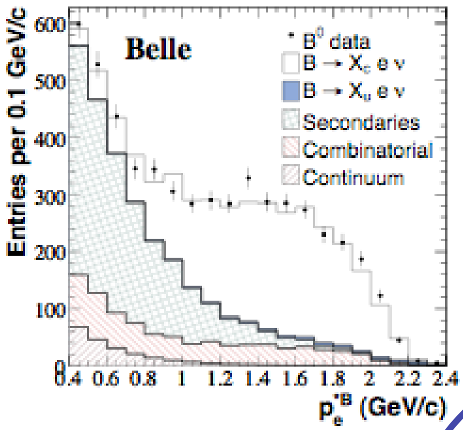
$$\langle E_\gamma^n \rangle_{E_{\rm cut}} = \frac{\displaystyle\int_{E_{\rm cut}} E_\gamma^n \frac{{\rm d}\Gamma}{{\rm d}E_\gamma}\,{\rm d}E_\gamma}{\displaystyle\int_{E_{\rm cut}} \frac{{\rm d}\Gamma}{{\rm d}E_\gamma}\,{\rm d}E_\gamma}$$

The OPEs of these inclusive observables contain the same HQ parameters

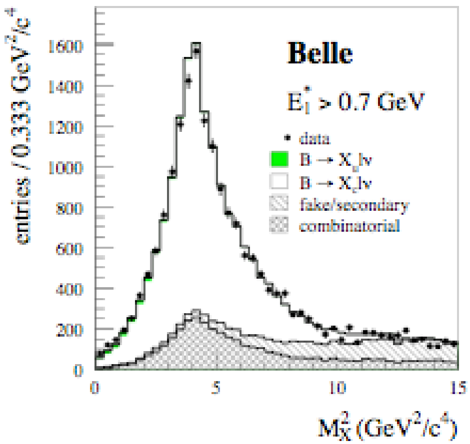
- Non-perturbative parameters can be measured from inclusive observables in B decays

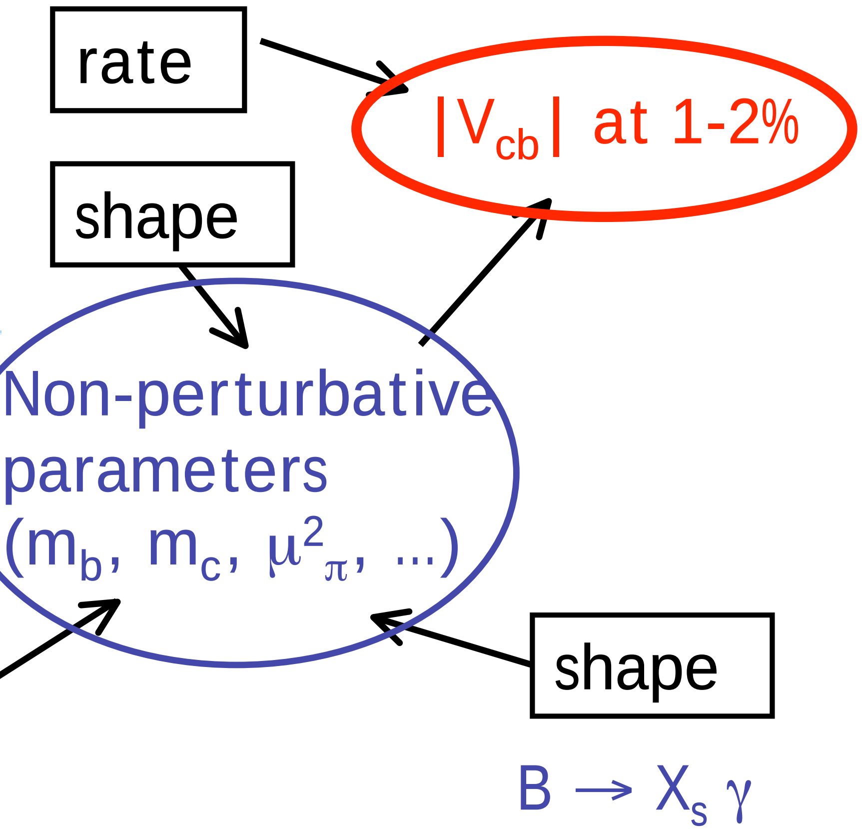
Inclusive E_l spectrum





Inclusive M^2_X spectrum





Global analysis of B decays

- Dedicated predictions for each observable
  - $<E^n_l>_{El>Ecut} = f^{(n)}(E_{cut}, m_b, \text{HQ param.})$
  - $<M^{2n}_X>_{El>Ecut} = g^{(n)}(E_{cut}, m_b, \text{HQ param.})$
  - $<E^n_\gamma>_{E\gamma>Ecut} = h^{(n)}(E_{cut}, m_b, \text{HQ param.})$

- Determine HQ parameters by performing a minimum χ^2 fit to all available moment measurements

- Take into account correlated experimental and theoretical errors

- External input: average B lifetime τ_B = (1.585 +/- 0.006) ps

Available calculations

- Kinetic running mass
  - [P.Gambino, N.Uraltsev, Eur.Phys.J. C34, 181 (2004)]
  - [D.Beson, I.Bigi, N.Uraltsev, Nucl.Phys. B710, 371 (2005)]

both calculations up to $O(1/m^3_b)$

- 1S mass
  - [C.Bauer, Z.Ligeti, M.Luke, A.Manohar, M.Trott, Phys.Rev. D70, 094017 (2004)]

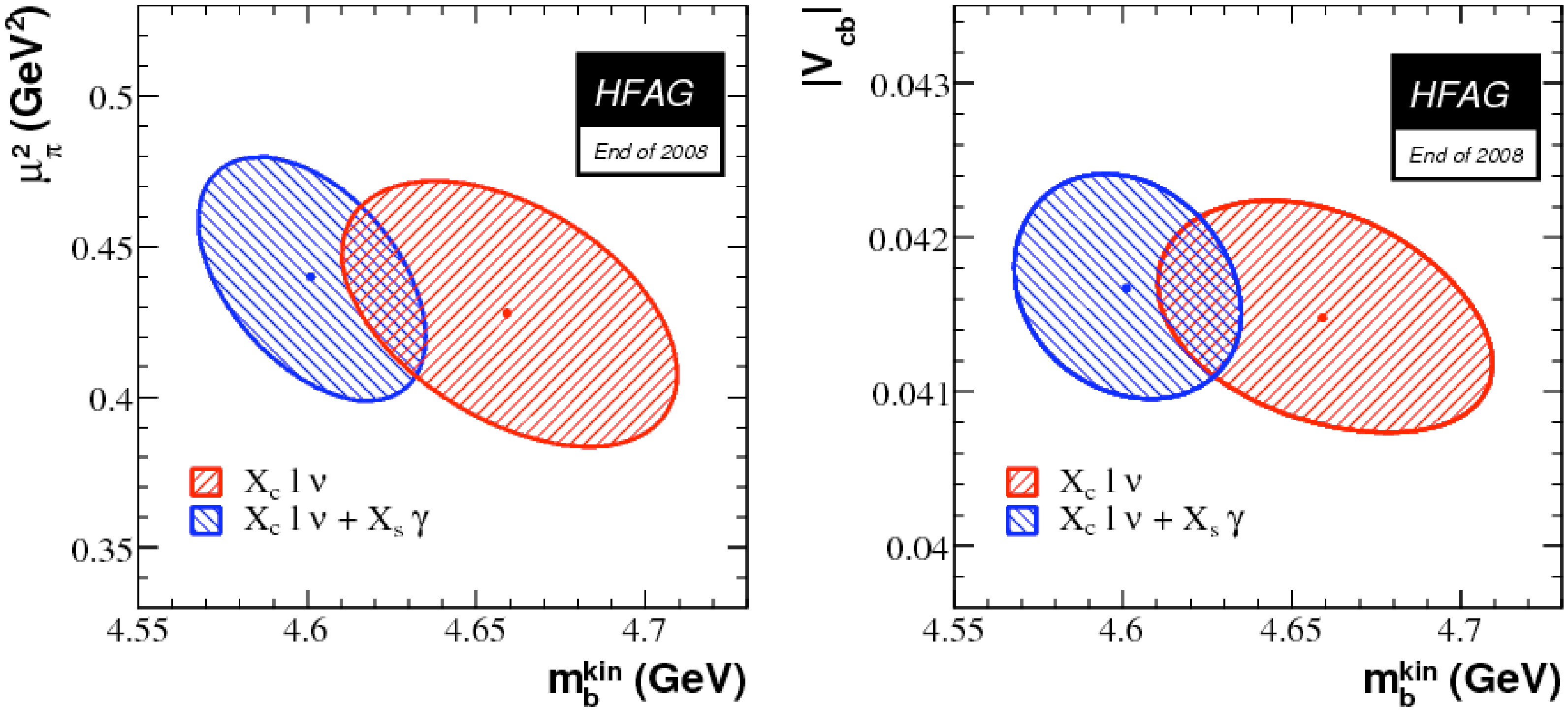
- Non-perturbative parameters in the $1/m_b$ expansion

	Kinetic scheme	1S scheme
O(1)	m_b, m_c	m_b
$O(1/m^2_b)$	μ^2_π, μ^2_G	λ_1, λ_2
$O(1/m^3_b)$	ρ_D, ρ_{LS}	ρ_1, τ_{1-3}

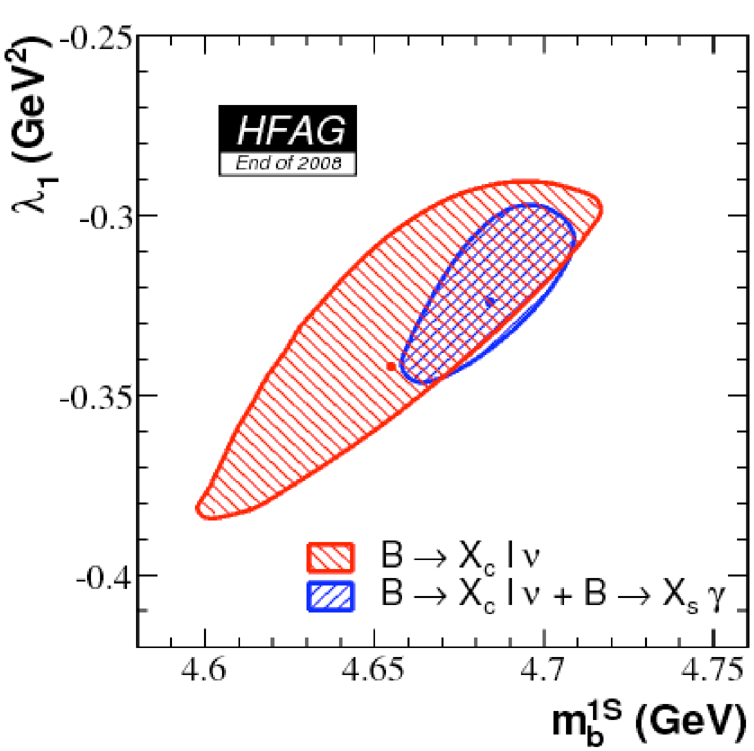
Measurements used for "end of 08"

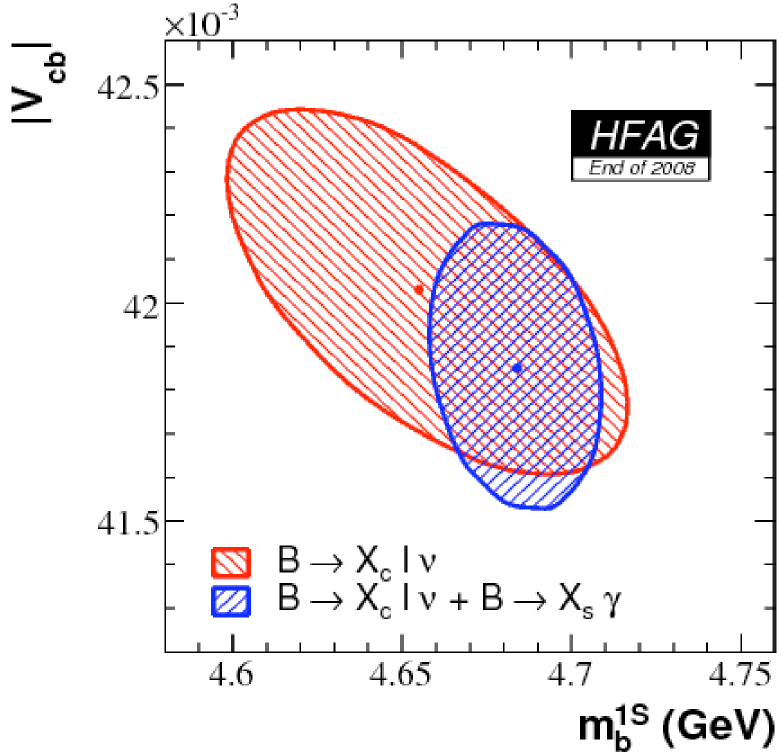
BaBar	$\langle E^n_l \rangle$: n=0,1,2,3 [PRD 69, 111104 (2004)] $\langle M^{2n}_X \rangle$: n=1,2 [arXiv:0707.2670] preliminary $\langle E^n_\gamma \rangle$: n=1,2 [PRL 97, 171803 (2006)] and [PRD 72, 052004 (2005)]
Belle	$\langle E^n_l \rangle$: n=0,1,2,3 [PRD 75, 032001 (2007)] $\langle M^{2n}_X \rangle$: n=1,2 [PRD 75, 032005 (2007)] $\langle E^n \gamma \rangle$: n=1,2 [arXiv:0804.1580] preliminary
CDF	$\langle M^{2n}_X \rangle$: n=1,2 [PRD 71, 051103 (2005)]
CLEO	$\langle M^{2n}_X \rangle$: n=1,2 [PRD 70, 032002 (2004)] $\langle E^n_\gamma \rangle$: n=1 [PRL 87, 251807 (2001)]
DELPHI	$\langle E^n_l \rangle$: n=1,2,3 $\langle M^{2n}_X \rangle$: n=1,2 [EPJ C45, 35 (2006)]

- 27 moments from BaBar, 25 moments from Belle and 12 moments from other experiments



Input	$\lvert V_{cb}\rvert$ (10^{-3})	m^{kin}_b (GeV)	μ^2_π (GeV^2)	χ^2/ndf
All moments	41.67+/-0.43(fit)+/-0.08(τ_B)+/-0.58(th)	4.601+/-0.034	0.440+/-0.040	29.7/57
$X_c l\nu$ only	41.48+/-0.47(fit)+/-0.08(τ_B)+/-0.58(th)	4.659+/-0.049	0.428+/-0.044	24.1/46





Input	$\lvert V_{cb} \rvert$ (10^{-3})	m^{1S}_b (GeV)	λ_1 (GeV^2)	χ^2/ndf
All moments	41.86+/-0.33(fit)+/-0.08(τ_B)	4.684+/-0.024	-0.324+/-0.023	27.9/57
$X_c l\nu$ only	42.03+/-0.42(fit)+/-0.08(τ_B)	4.656+/-0.059	-0.342+/-0.045	19.0/46

Backup

Measurements used

Experiment	Hadron moments $\langle M_X^n \rangle$	Lepton moments $\langle E_\ell^n \rangle$	Photons moment $\langle E_\gamma^n \rangle$
BaBar	$n = 2,\ c = 0.9, 1.1, 1.3, 1.5$ $n = 4,\ c = 0.8, 1.0, 1.2, 1.4$ [10]	$n = 0,\ c = 0.6, 1.2, 1.5$ $n = 1,\ c = 0.6, 0.8, 1.0, 1.2, 1.5$ $n = 2,\ c = 0.6, 1.0, 1.5$ $n = 3,\ c = 0.8, 1.2$ [11]	$n = 1,\ c = 1.9, 2.0$ $n = 2,\ c = 1.9$ [12, 13]
Belle	$n = 2,\ c = 0.7, 1.1, 1.3, 1.5$ $n = 4,\ c = 0.7, 0.9, 1.3$ [14]	$n = 0,\ c = 0.6, 1.0, 1.4$ $n = 1,\ c = 0.6, 0.8, 1.0, 1.2, 1.4$ $n = 2,\ c = 0.6, 1.0, 1.4$ $n = 3,\ c = 0.8, 1.0, 1.2$ [15]	$n = 1,\ c = 1.8, 1.9$ $n = 2,\ c = 1.8, 2.0$ [16]
CDF	$n = 2,\ c = 0.7$ $n = 4,\ c = 0.7$ [17]		
CLEO	$n = 2,\ c = 1.0, 1.5$ $n = 4,\ c = 1.0, 1.5$ [18]		$n = 1,\ c = 2.0$ [19]
DELPHI	$n = 2,\ c = 0.0$ $n = 4,\ c = 0.0$ [20]	$n = 1,\ c = 0.0$ $n = 2,\ c = 0.0$ $n = 3,\ c = 0.0$ [20]	

End of 08 -- kinetic scheme

	$\lvert V_{cb}\rvert$ (10^{-3})	$m_b^{\rm kin}$ (GeV)	$m_c^{\rm kin}$ (GeV)	μ_π^2 (GeV^2)	ρ_D^3 (GeV^3)	μ_G^2 (GeV^2)	ρ_{LS}^3 (GeV^3)
value	41.67	4.601	1.165	0.440	0.192	0.268	-0.193
σ(fit)	0.43	0.034	0.050	0.040	0.021	0.044	0.086
$\sigma(\tau_B)$	0.08						
σ(th)	0.58						
$\lvert V_{cb}\rvert$	1.000	-0.198	-0.065	0.160	0.312	-0.244	0.110
$m_b^{\rm kin}$		1.000	0.938	-0.478	-0.188	-0.032	-0.258
$m_c^{\rm kin}$			1.000	-0.520	-0.120	-0.294	-0.066
μ_π^2				1.000	0.455	-0.023	-0.065
ρ_D^3					1.000	-0.224	-0.314
μ_G^2						1.000	-0.210
ρ_{LS}^3							1.000

Data	χ^2/dof	$\lvert V_{cb}\rvert$ (10^{-3})	$m_b^{\rm kin}$ (GeV)	μ_π^2 (GeV^2)
All moments ($X_c\ell\nu_\ell$ and $X_s\gamma$)	$29.7/(64-7)$	41.67 ± 0.73	4.601 ± 0.034	0.440 ± 0.040
$X_c\ell\nu_\ell$ only	$24.1/(53-7)$	41.48 ± 0.75	4.659 ± 0.049	0.428 ± 0.044

End of 08 -- 1S scheme

	$\lvert V_{cb}\rvert$ (10^{-3})	m_b^{1S} (GeV)	λ_1 (GeV^2)	ρ_1 (GeV^3)	τ_1 (GeV^3)	τ_2 (GeV^3)	τ_3 (GeV^3)
value	41.86	4.684	-0.324	0.051	0.125	-0.501	0.125
σ(fit)	0.33	0.024	0.023	0.010	0.002	0.020	0.002
$\sigma(\tau_B)$	0.08						
$\lvert V_{cb}\rvert$	1.000	-0.231	-0.052	-0.052	0.004	-0.177	0.010
m_b^{1S}		1.000	0.879	-0.469	-0.035	-0.549	-0.017
λ_1			1.000	-0.650	-0.025	-0.705	-0.029
ρ_1				1.000	-0.160	0.294	-0.046
τ_1					1.000	0.119	-0.004
τ_2						1.000	0.060
τ_3							1.000

Data	χ^2/dof	$\lvert V_{cb}\rvert$ (10^{-3})	m_b^{1S} (GeV)	λ_1 (GeV^2)
All moments ($X_c\ell\nu_\ell$ and $X_s\gamma$)	$27.9/(64-7)$	41.86 ± 0.33	4.684 ± 0.024	-0.324 ± 0.023
$X_c\ell\nu_\ell$ only	$19.0/(53-7)$	42.03 ± 0.42	4.656 ± 0.059	-0.342 ± 0.045