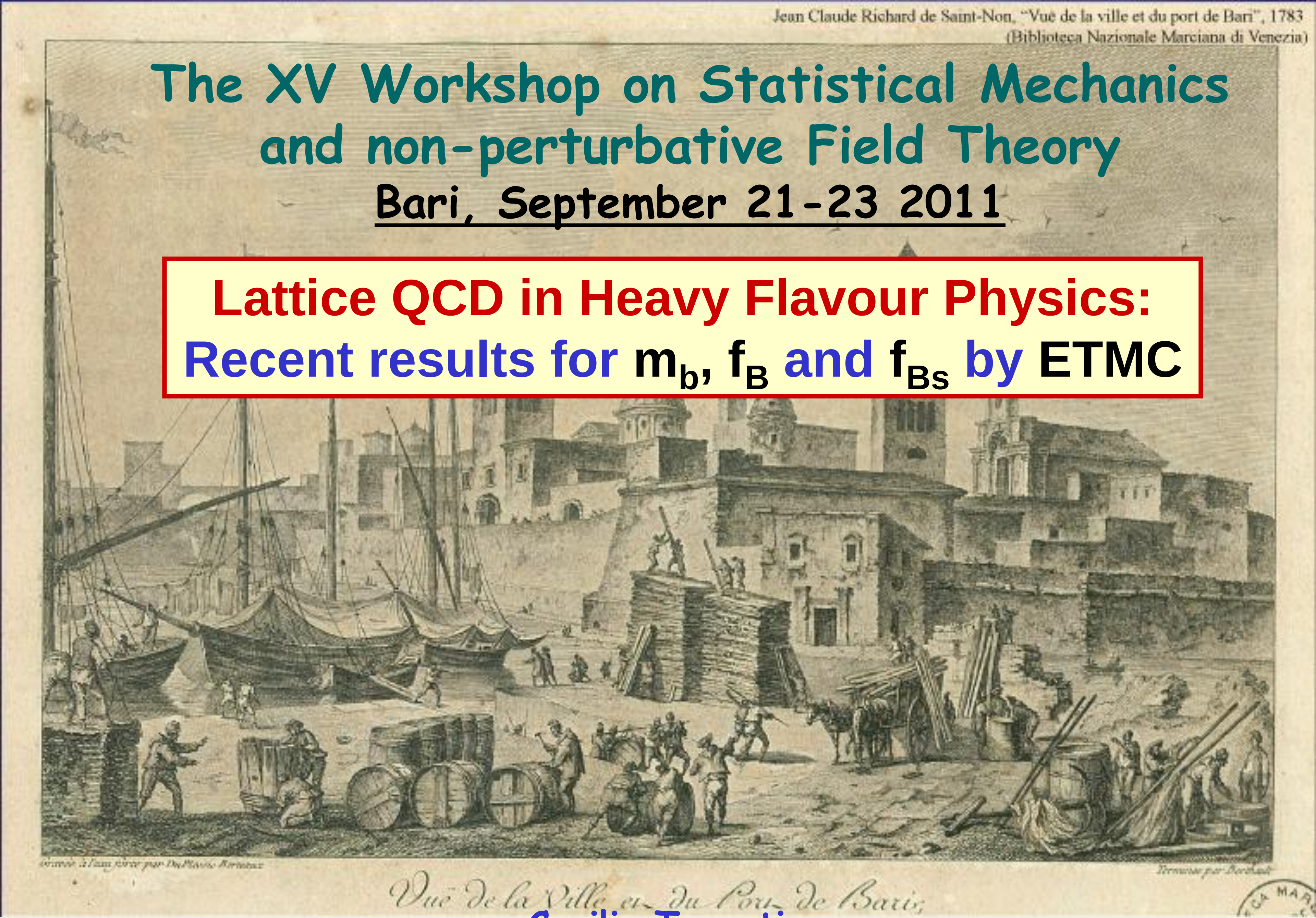

Jean Claude Richard de Saint-Non, "Vuë de la ville et du port de Bari", 1783
(Biblioteca Nazionale Marciana di Venezia)

The XV Workshop on Statistical Mechanics and non-perturbative Field Theory

Bari, September 21-23 2011

Lattice QCD in Heavy Flavour Physics: Recent results for m_b, f_B and f_{Bs} by ETMC

Cecilia Tarantino
Università Roma Tre

Success and Limits of the Standard Model

The SM turns out to be very successful
in describing essentially all processes
But
It is expected to be an effective theory valid up to a cutoff scale
as it has some important limits

- The SM is a quantum theory for strong and electroweak interactions but NOT for gravitation (quantum effecs in gravitation are expected to become important at very high energies ($M_{Pl} \sim 10^{23}$ GeV))

- There is cosmological evidence of Dark Matter (not made up of SM particles) in the Universe

- In the SM the Higgs mass receives large radiative corrections, quadratic in the cutoff $\Lambda \sim M_{Pl} \sim 10^{23}$ GeV (energy scale where the SM fails). To have a Higgs mass of O(100 GeV), indicated by electroweak precision tests, an innatural fine-tuning is required (hierarchy problem)

- …

The solution doesn’t seem to be trivial:
the FLAVOUR PROBLEM

“NP is expected at the TeV scale
(in order to solve the hierarchy problem $\delta M_H^2 \approx \Lambda^2$)
but in flavour processes NP effects are not observed
(hinting for NP at higher scales)”

The flavour structure of the NP model
cannot be generic

Important Role of Flavour Physics

In order to reveal NP and understand its nature Flavour Physics has a fundamental role besides the direct production at LHC

The next decades will see a great experimental activity,
not only in the direct NP search at LHC,
but also in the Flavour Sector

LHCb
SuperB-Factory
NA62
MEG
J-PARC
…

It is crucial to have
theoretical uncertainties well under control,
in particular those of the hadronic parameters computed on the Lattice

The peculiar role of B-physics

Within the OPE and the QCD series, the small expansion parameter Λ_{QCD}/m_b and $\alpha_s(m_b)$ helps a good convergence

The Unitarity Triangle Analsysis (UTA)

Weak eigenstates

Mass eigenstates

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = V_{CKM} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

The experimental constraints:

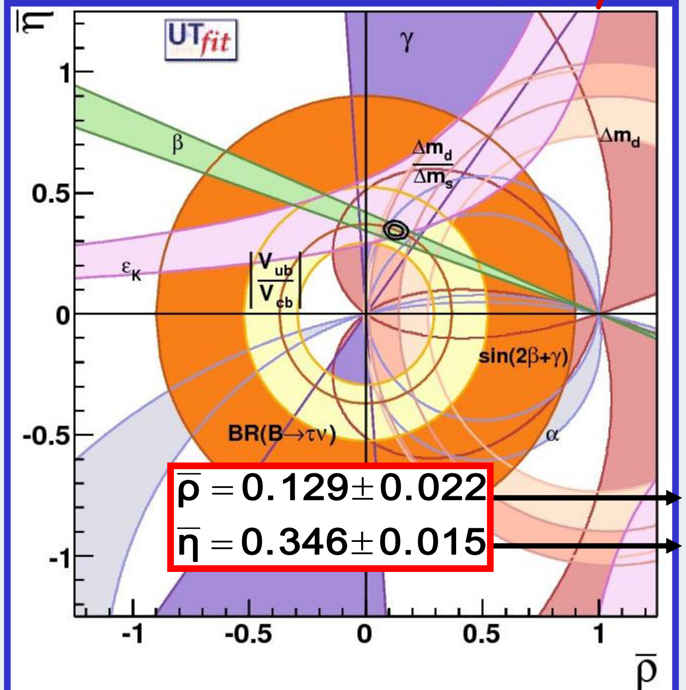
$$\varepsilon_K, \Delta m_d, \left|\frac{\Delta m_s}{\Delta m_d}\right|, \left|\frac{V_{ub}}{V_{cb}}\right|$$

$$\sin 2\beta, \cos 2\beta, \alpha, \gamma(\ 2\beta+\gamma)$$

Involving a b quark

overconstrain the CKM parameters consistently

SM analysis



$$\bar{\rho} = 0.129 \pm 0.022$$

$$\bar{\eta} = 0.346 \pm 0.015$$

~17%

~ 4%

Theorist's Golden Modes

Several involve
a b quark

Suppression within the SM ⇒ **Sensitivity to NP**

- **FCNCs forbidden at tree-level in the SM**
  (radiative and rare decays: $b \rightarrow (s,d)\,\gamma$, $b \rightarrow (s,d)\, l^+ l^-$, $b \rightarrow s\nu\bar{\nu}$, $B_{d,s} \rightarrow l^+ l^-$,…)

- **CKM-, helicity-suppression**
  (semileptonic CP-asymmetry: A^s_{SL}…, t-dep. CP-asymmetries: $A_{CP}(B \rightarrow K^*\gamma)$)

Small hadronic uncertainties ⇒ **Theoretically clean**

- **At most one hadron in the final state**
  (leptonic and semileptonic decays: $B_{d,s} \rightarrow l^+ l^-$, $b \rightarrow (s,d)\, l^+ l^-$, $b \rightarrow s\nu\bar{\nu}$,…)
- **Smearing of bound-effects in the final state**
  (Inclusive quantities: lifetimes, ΔM_q, $\Delta\Gamma_q/\Gamma_q$, A^q_{SL}, ϕ_s,…)
- **Suppression/cancellation of some hadronic uncertainties**
  (clean dominant contributions, peculiar ratios/correlations: $A_{CP}(B \rightarrow J_\psi K_S)$, $\Delta M_s/\Delta M_d$,…)

Present and next-future experiments dedicated to B-Physics

The LHC will study also the flavour structure of NP

- LHCb stands for **LHCbeauty**

- It is dedicated to the **study of b-physics**
  (**all kinds of b-hadrons** are produced)

- @LHC (p-p collider with 7 TeV for each beam)
  a **huge amount of** b-$\bar{b}$ **couples** (10^{12}/year) is produced
  but with a **high background**

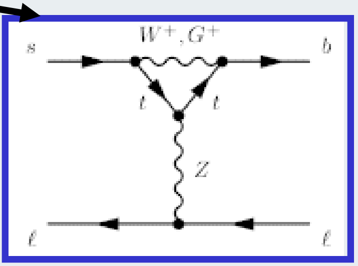
- **First, very promising, results have been obtained**

Summer 2011 Hot Topics
(EPS@Grenoble, LeptonPhoton@Mumbai)

$B_q \to l^+ l^-$

$$Br(B_s \to l^+l^-) = \tau(B_s)\frac{G_F^2}{\pi}\left(\frac{\alpha}{4\pi\sin^2\Theta_W}\right)^2 F_{B_s}^2 m_l^2 m_{B_s}\sqrt{1-4\frac{m_l^2}{m_{B_s}^2}}\,|V_{tb}^*V_{ts}|^2Y^2(x_t)$$

- **Highly sensitive to NP (loop FCNC: Z-penguin dominated)**
- **Theoretically clean (purely leptonic)**
- **F_{B_s} from Lattice QCD**



$$Br(B_d \to \mu^+\mu^-)^{SM} = (1.0\pm0.1)\cdot10^{-10}$$
$$Br(B_s \to \mu^+\mu^-)^{SM} = (3.2\pm0.2)\cdot10^{-9}$$

New Summer 2011 results

CDF (Tevatron) measures an excess

$Br(B_s \to \mu^+\mu^-) = (1.8\pm^{1.1}_{0.9})\cdot10^{-8}$ **[CDF, 7 fb^{-1}]**

But the LHC does not!

(95% C.L)

$Br(B_s \to \mu^+\mu^-) < 1.9\cdot10^{-8}$ **[CMS, 1.14 fb^{-1}]**

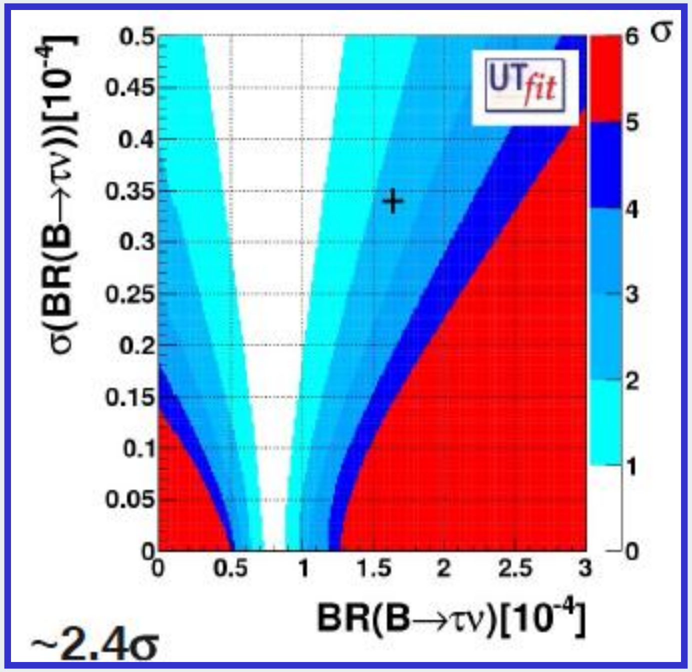
$Br(B_s \to \mu^+\mu^-) < 1.5\cdot10^{-8}$ **[LHCb, 300 pb^{-1}]**

CMS+LHCb

$Br(B_s \to \mu^+\mu^-) < 1.1\cdot10^{-8}$

B→ τ ν

BR(B→ τ ν)$_{SM}$ = (0.79 0.08)•10^{-4}
[UTfit, update of 0908.3470]
turns out to be smaller by ~2.4 σ
than the experimental value
BR(B→ τ ν)$_{exp}$ = (1.64±0.34)•10^{-4}
[Heavy Flavor Averaging Group]



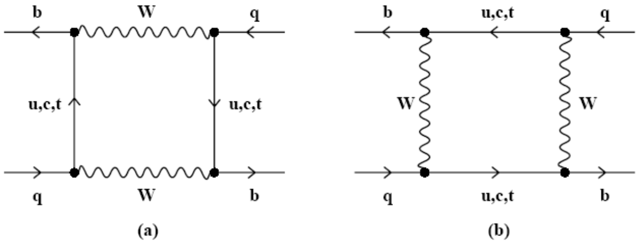
$$BR(B\to\tau\nu)=\frac{G_F^2 m_B m_\tau^2}{8\pi}\left(1-\frac{m_\tau^2}{m_B^2}\right)^2 f_B^2|V_{ub}|^2\tau_B$$

Important role of Lattice QCD

- **BR(B→ τ ν)$_{exp}$ prefers a large value for |V$_{ub}$| (close to the incl. determination)**
- **But a shift in the central value of |V$_{ub}$| would enhance the β tension**

Results for the B_s mixing amplitude:

Neutral mesons are not eigenstates of the Weak Interactions:



⇒ "particle-antiparticle oscillations":

highly sensitive to NP

=1 in SM

$$\Delta m_{q/K} = C_{B_q/\Delta m_K} \left(\Delta m_{q/K}\right)^{SM}$$

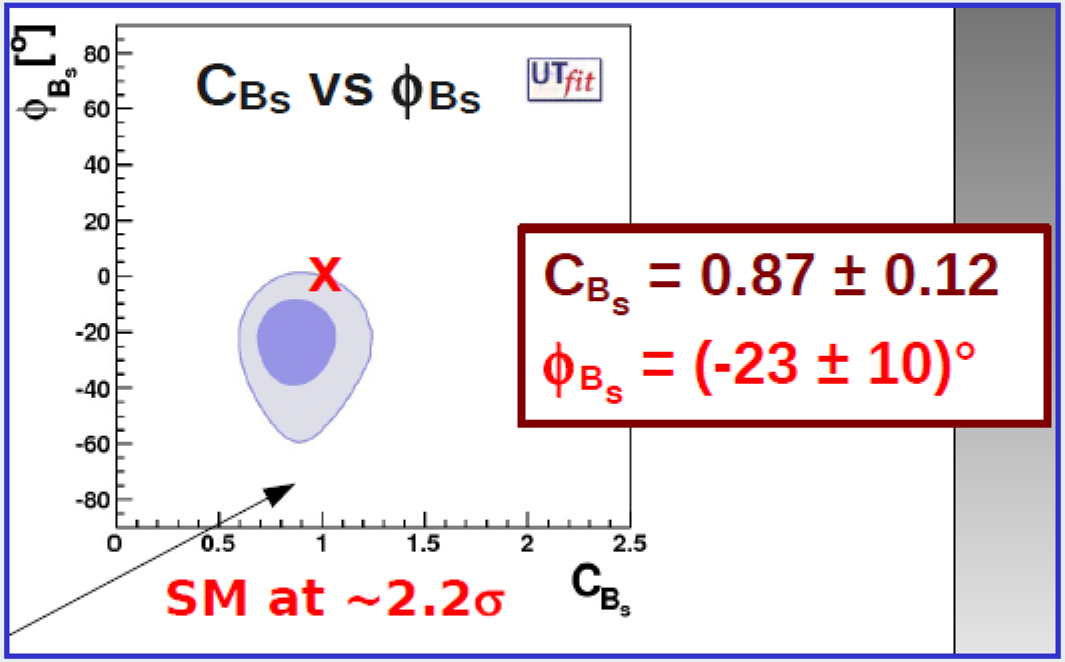
$$A_{CP}^{B_s \to J/\psi\phi} \sim \sin 2\left(-\beta_s + \phi_{B_s}\right)$$

=0 in SM

In 2009, CDF and D0 results for ϕ_{Bs}

More than 2σ deviation from the SM!

Update before summer 2011



$C_{B_s} = 0.87 \pm 0.12$

$\phi_{B_s} = (-23 \pm 10)°$

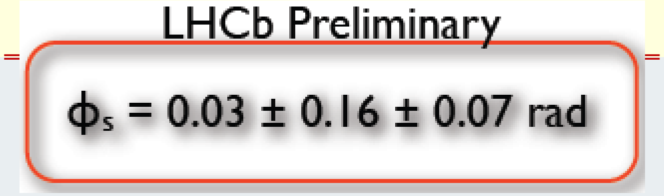
SM at ~2.2σ

Summer 2011: Bad news for NP!

- CDF ($5.2\ fb^{-1}$) and D0 ($8\ fb^{-1}$) measurements reduce the significance of the deviation to $0.8\ \sigma$ and $1.0\ \sigma$
- A combined measurement is in plan

Still, the dimuon charge asymmetry (measured by D0) $a_{\mu\mu}$ points to a large value of ϕ_{Bs}

- LHCb has performed the world most precise measurement of ϕ_{Bs}
- It is found to be compatible to the SM

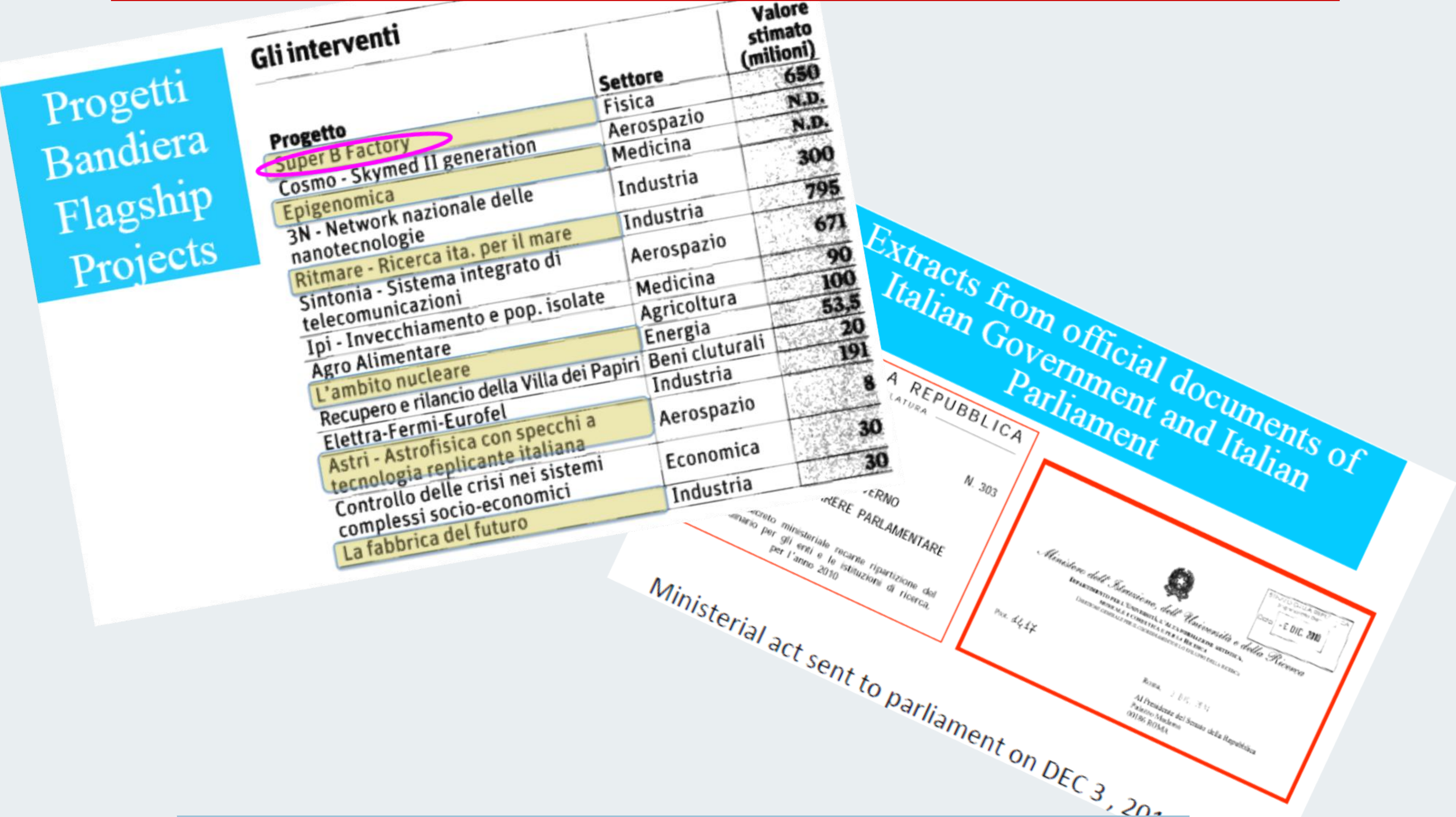


LHCb Preliminary

$\phi_s = 0.03 \pm 0.16 \pm 0.07$ rad

Further confirmations from experiments are looked forward!

The SuperB project has been approved!
(the Super KEKB project has been approved as well in Japan)



Progetti Bandiera
Flagship Projects

Gli interventi

Progetto	Settore	Valore stimato (milioni)
Super B Factory	Fisica	650
Cosmo - Skymed II generation	Aerospazio	N.D.
Epigenomica	Medicina	N.D.
3N - Network nazionale delle nanotecnologie	Industria	300
Ritmare - Ricerca ita. per il mare	Industria	795
Sintonia - Sistema integrato di telecomunicazioni	Aerospazio	671
Ipi - Invecchiamento e pop. isolate	Medicina	90
Agro Alimentare	Agricoltura	100
L'ambito nucleare	Energia	53,5
Recupero e rilancio della Villa dei Papiri	Beni cluturali	20
Elettra-Fermi-Eurofel	Industria	191
Astri - Astrofisica con specchi a tecnologia replicante italiana	Aerospazio	8
Controllo delle crisi nei sistemi complessi socio-economici	Economica	30
La fabbrica del futuro	Industria	30

Extracts from official documents of Italian Government and Italian Parliament

A REPUBBLICA
LATURA

N. 303

ERNO
RERE PARLAMENTARE

ecreto ministeriale recante ripartizione del
inario per gli enti e le istituzioni di ricerca,
per l'anno 2010

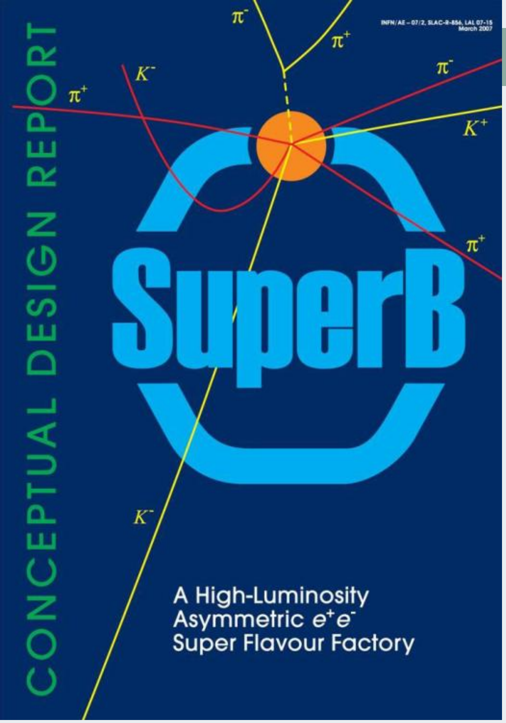
Ministero dell'Istruzione, dell'Università e della Ricerca

Prot. 4447

Al Presidente del Senato della Repubblica
Palazzo Madama
00186 ROMA

Ministerial act sent to parliament on DEC 3 , 20

- The SuperB is an **international project** (~80 Institutions)
- It will be **realized in Italy,** (TorVergata area)
- The **Technical-Design-Report** will be ready in **2012**

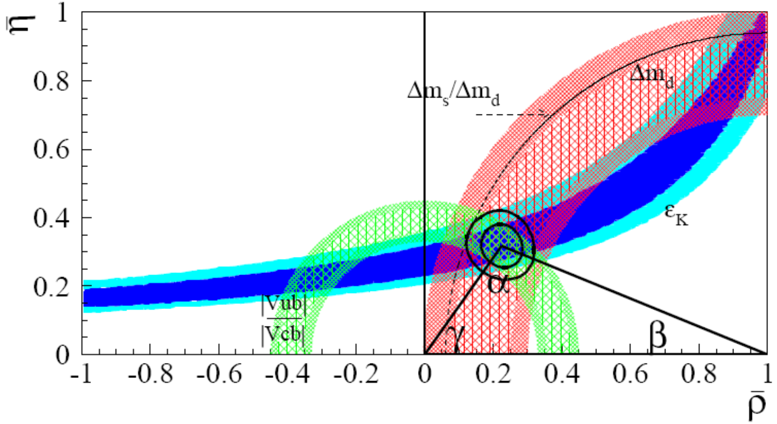


SuperB

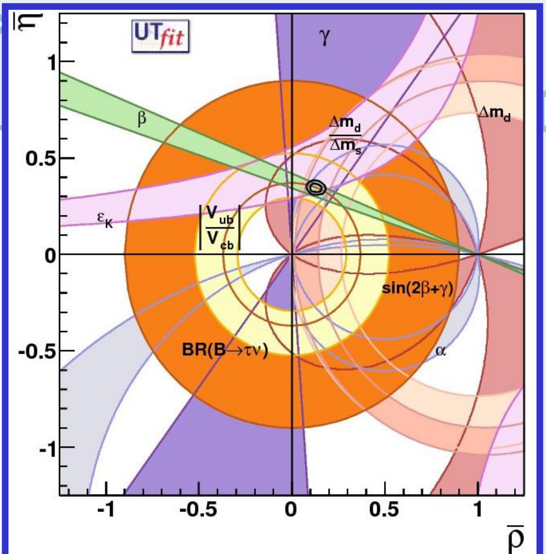
- e^+-e^- collider with the appropriate energy to **produce couples of B and anti-B mesons, in a clean environment** (like BaBar and Belle,but with ~100 times higher luminosity)
- it aims at **improving** the **accuracy** of the **B-factories** by a factor **5-10**
- It will **test the CKM** matrix at **1%** level
- It will **increase the sensitivity** for several channels sensitive to **NP** by one order of magnitude

Role of B-factories in constraining the UT

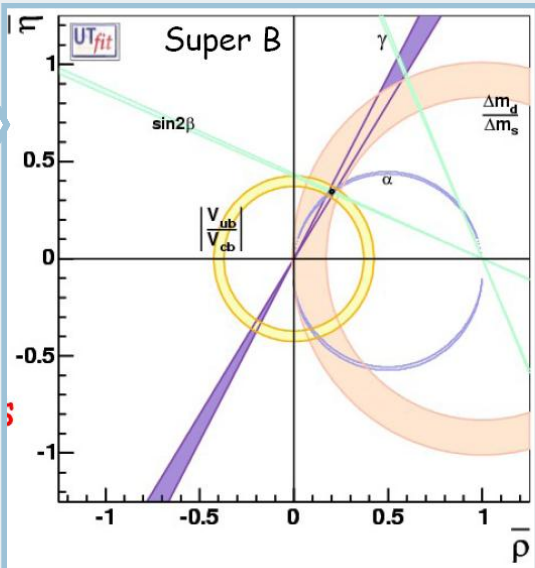
Before B-factories



After B-factories

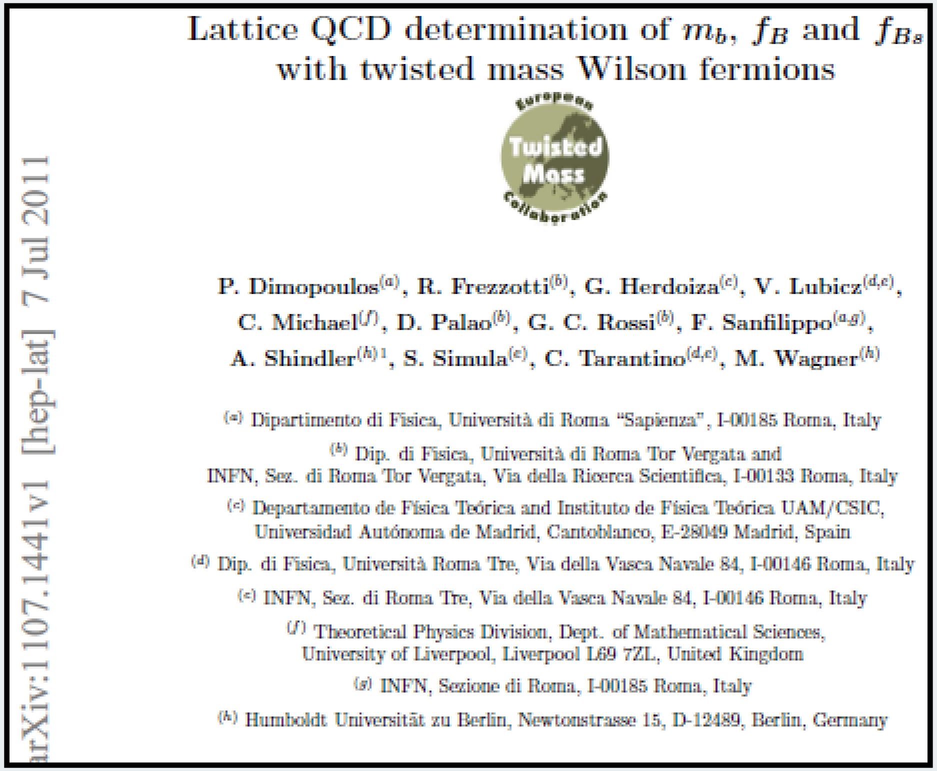


After SuperB-factories?



It is crucial to have theoretical accuracy at the same level, in particular those of the hadronic parameters computed on the Lattice

I am going to present our recent results for m_b, f_B, f_{Bs}



Lattice QCD determination of m_b, f_B and f_{Bs} with twisted mass Wilson fermions

European Twisted Mass Collaboration

P. Dimopoulos[(a)], R. Frezzotti[(b)], G. Herdoiza[(c)], V. Lubicz[(d,e)],
C. Michael[(f)], D. Palao[(b)], G. C. Rossi[(b)], F. Sanfilippo[(a,g)],
A. Shindler[(h)1], S. Simula[(e)], C. Tarantino[(d,e)], M. Wagner[(h)]

[(a)] Dipartimento di Fisica, Università di Roma "Sapienza", I-00185 Roma, Italy
[(b)] Dip. di Fisica, Università di Roma Tor Vergata and INFN, Sez. di Roma Tor Vergata, Via della Ricerca Scientifica, I-00133 Roma, Italy
[(c)] Departamento de Física Teórica and Instituto de Física Teórica UAM/CSIC, Universidad Autónoma de Madrid, Cantoblanco, E-28049 Madrid, Spain
[(d)] Dip. di Fisica, Università Roma Tre, Via della Vasca Navale 84, I-00146 Roma, Italy
[(e)] INFN, Sez. di Roma Tre, Via della Vasca Navale 84, I-00146 Roma, Italy
[(f)] Theoretical Physics Division, Dept. of Mathematical Sciences, University of Liverpool, Liverpool L69 7ZL, United Kingdom
[(g)] INFN, Sezione di Roma, I-00185 Roma, Italy
[(h)] Humboldt Universität zu Berlin, Newtonstrasse 15, D-12489, Berlin, Germany

arXiv:1107.1441v1 [hep-lat] 7 Jul 2011

Our Collaboration

Members from all over Europe:
Cyprus, France, Germany, Great Britain,
Italy, Netherlands, Poland, Spain, Switzerland

European Twisted Mass Collaboration

Our choice for the Lattice action

Gauge Action: tree-level improved Symanzik
(N_f = 2 dynamical fermions, degenerate in mass)

Fermionic Action: twisted mass (tm) at maximal twist

[R.Frezzotti, G.Rossi, hep-lat/0306014]

Important advantage of tm at maximal twist
($\omega=\pi/2 \leftrightarrow m_{PCAC}=0$)

- **Physical observables are automatically O(a) improved**

Simulation details

- **Four values of the lattice spacing**

$$\beta = \{3.80, 3.90, 4.05, 4.20\}$$

$$\downarrow$$

$$a = \{0.098(3), 0.085(2), 0.067(2), 0.054(1)\}\ \text{fm}$$

- **Large volumes**

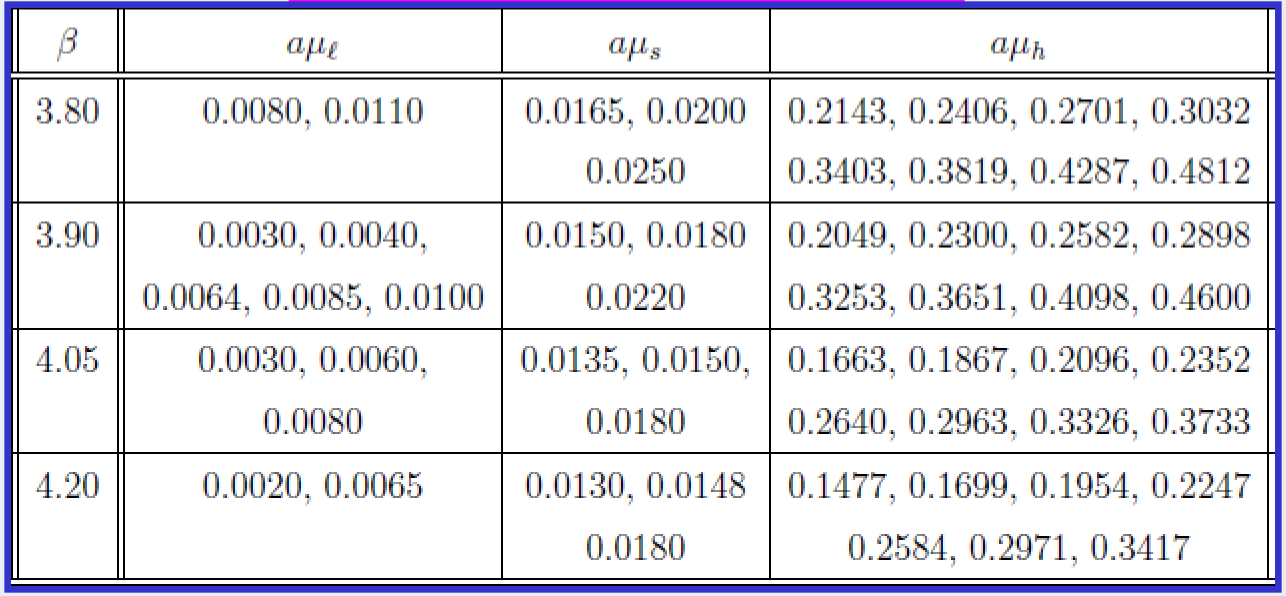
24^3x48, 32^3x64, 48^3x96

- **Simulated sea and valence quark masses:**

$$0.15 \cdot m_s^{phys} \leq \mu_l \leq 0.5 \cdot m_s^{phys}$$

$$0.9 \cdot m_s^{phys} \leq \mu_s \leq 1.2 \cdot m_s^{phys}$$

$$0.9 \cdot m_c^{phys} \leq \mu_h \leq 2.4 \cdot m_c^{phys}$$



β	$a\mu_\ell$	$a\mu_s$	$a\mu_h$
3.80	0.0080, 0.0110	0.0165, 0.0200 0.0250	0.2143, 0.2406, 0.2701, 0.3032 0.3403, 0.3819, 0.4287, 0.4812
3.90	0.0030, 0.0040, 0.0064, 0.0085, 0.0100	0.0150, 0.0180 0.0220	0.2049, 0.2300, 0.2582, 0.2898 0.3253, 0.3651, 0.4098, 0.4600
4.05	0.0030, 0.0060, 0.0080	0.0135, 0.0150, 0.0180	0.1663, 0.1867, 0.2096, 0.2352 0.2640, 0.2963, 0.3326, 0.3733
4.20	0.0020, 0.0065	0.0130, 0.0148 0.0180	0.1477, 0.1699, 0.1954, 0.2247 0.2584, 0.2971, 0.3417

Two methods for studying the heavy mass dependence

- **B-physics on the lattice has the difficulty of large discretization effects of O(a*mb)**

- **The physical b-quark mass (≈4 GeV) cannot be directly simulated on present ($a^{-1} \leq$4 GeV) lattices**

- **Several approaches have been investigated and used so far (HQET, NRQCD, step-scaling,…)**

We have followed two methods

Ratio Method: based on suitable ratios having an exactly known static limit

Interpolation Method: interpolating relativistic data in the charm region and HQET data

The Ratio Method

- **Basic idea: known static limit**

$$\lim_{\mu_h^{\rm pole}\to\infty}\left(\frac{M_{h\ell}}{\mu_h^{\rm pole}}\right)=\text{constant}$$

- **Consider several heavy quark masses:** $\bar\mu_h^{(1)},\bar\mu_h^{(2)},\dots,\bar\mu_h^{(N)}$, **with** $\frac{\bar\mu_h^{(n)}}{\bar\mu_h^{(n-1)}}=\lambda$

- **Build the ratios**

$$\begin{aligned} y(\bar\mu_h^{(n)},\lambda;\bar\mu_\ell,a) &\equiv \frac{M_{h\ell}(\bar\mu_h^{(n)};\bar\mu_\ell,a)}{M_{h\ell}(\bar\mu_h^{(n-1)};\bar\mu_\ell,a)}\cdot\frac{\bar\mu_h^{(n-1)}}{\bar\mu_h^{(n)}}\cdot\frac{\rho(\bar\mu_h^{(n-1)},\mu^*)}{\rho(\bar\mu_h^{(n)},\mu^*)}= \\ &= \lambda^{-1}\frac{M_{h\ell}(\bar\mu_h^{(n)};\bar\mu_\ell,a)}{M_{h\ell}(\bar\mu_h^{(n)}/\lambda;\bar\mu_\ell,a)}\cdot\frac{\rho(\bar\mu_h^{(n)}/\lambda,\mu^*)}{\rho(\bar\mu_h^{(n)},\mu^*)}, \qquad n=2,\cdots,N \end{aligned}$$

where $\mu_h^{\rm pole}=\rho(\bar\mu_h,\mu^*)\,\bar\mu_h(\mu^*)$

$$\boxed{\lim_{\bar\mu_h\to\infty} y(\bar\mu_h,\lambda;\bar\mu_\ell,a=0)=1}$$

- **Perform chiral and continuum extrapolation (smoother in ratios)**

- **Study the dependence on μ_h**

$$y(\bar\mu_h)=1+\frac{\eta_1}{\bar\mu_h}+\frac{\eta_2}{\bar\mu_h^2}$$

and build the product of ratios:

$$y(\bar\mu_h^{(2)})\,y(\bar\mu_h^{(3)})\,\dots\,y(\bar\mu_h^{(K+1)})=\lambda^{-K}\frac{M_{hu/d}(\bar\mu_h^{(K+1)})}{M_{hu/d}(\bar\mu_h^{(1)})}\cdot\left[\frac{\rho(\bar\mu_h^{(1)},\mu^*)}{\rho(\bar\mu_h^{(K+1)},\mu^*)}\right]$$

- **Determine the physical b-quark mass, using the experimental B-meson mass in input:**

$$\boxed{\bar\mu_b=\lambda^{K_b}\bar\mu_h^{(1)}=4.91(15)\ \text{GeV}}$$

Smooth chiral and continuum limit

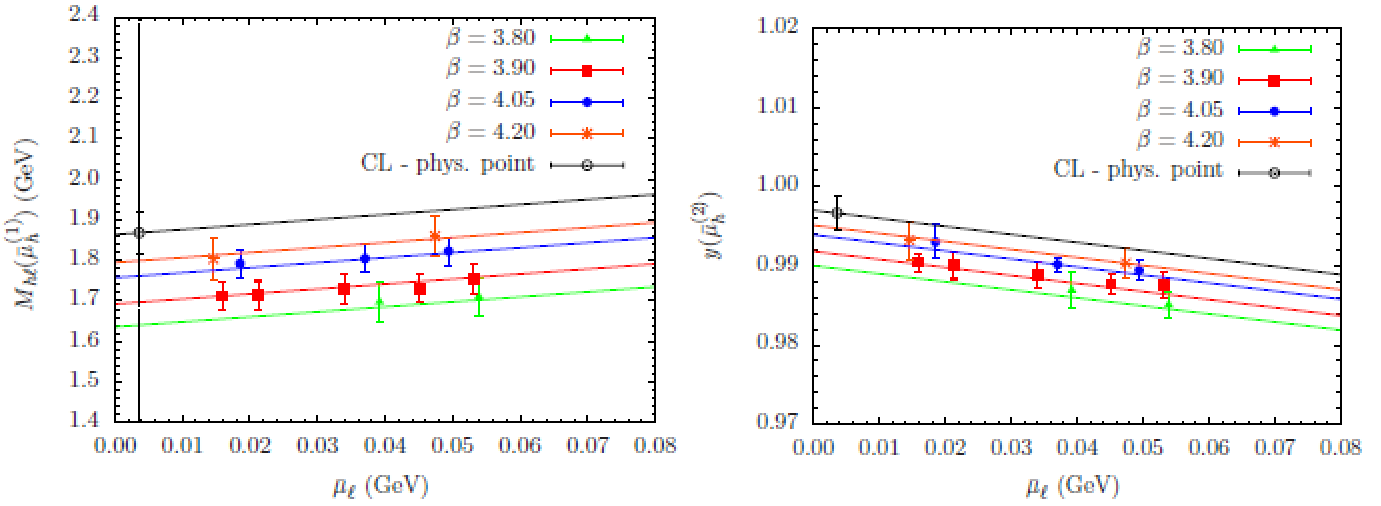


Figure 1: *Light quark mass dependence of the meson mass $M_{h\ell}(\bar\mu_h^{(1)})$ (left) and of the ratio $y(\bar\mu_h^{(2)})$ (right) at the four values of the lattice spacing.*

Dependence on the heavy quark mass (static limit=1)

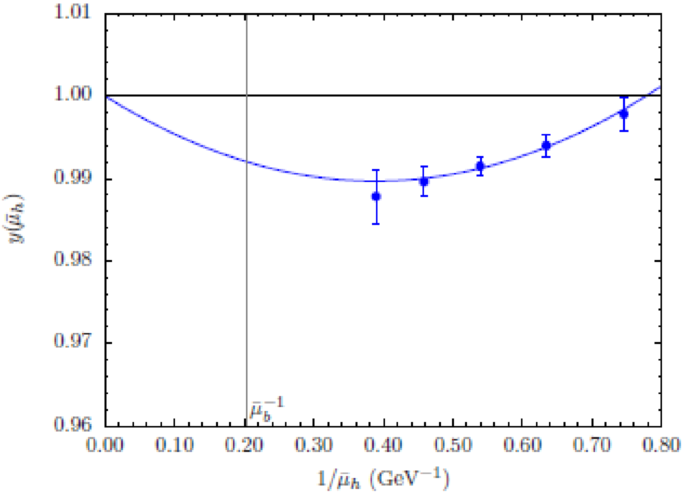


Figure 2: *Heavy quark mass dependence of the ratio $y(\bar\mu_h)$ extrapolated to the physical value of the light quark mass and to the continuum limit. The vertical line represents the value of the physical b quark mass.*

Similarly for the decay constants

•**Known static limit**

$$\lim_{\mu_h^{\rm pole}\to\infty} f_{h\ell}\sqrt{\mu_h^{\rm pole}} = \text{constant}$$

•**Build the ratios**

$$z(\bar\mu_h, \lambda; \bar\mu_\ell, a) \equiv \lambda^{1/2}\frac{f_{h\ell}(\bar\mu_h, \bar\mu_\ell, a)}{f_{h\ell}(\bar\mu_h/\lambda, \bar\mu_\ell, a)} \cdot \frac{C_A^{stat}(\mu_b^*, \bar\mu_h/\lambda)}{C_A^{stat}(\mu_b^*, \bar\mu_h)} \frac{[\rho(\bar\mu_h, \mu^*)]^{1/2}}{[\rho(\bar\mu_h/\lambda, \mu^*)]^{1/2}}$$

$$z_s(\bar\mu_h, \lambda; \bar\mu_\ell, \bar\mu_s, a) \equiv \lambda^{1/2}\frac{f_{hs}(\bar\mu_h, \bar\mu_\ell, \bar\mu_s, a)}{f_{hs}(\bar\mu_h/\lambda, \bar\mu_\ell, \bar\mu_s, a)} \cdot \frac{C_A^{stat}(\mu_b^*, \bar\mu_h/\lambda)}{C_A^{stat}(\mu_b^*, \bar\mu_h)} \frac{[\rho(\bar\mu_h, \mu^*)]^{1/2}}{[\rho(\bar\mu_h/\lambda, \mu^*)]^{1/2}}$$

where

$$\Phi_{hs}(\mu_b^*) = [C_A^{stat}(\mu_b^*, \bar\mu_h)]^{-1} \cdot \Phi_{hs}^{\rm QCD}(\bar\mu_h)$$

•**Perform chiral (HMChPT or polynomial) and continuum extrapolation (of z_s ad z_s/z)**

•**Study the dependence on μ_h (exploiting the known static limit)**

•**Determine f_B and f_{Bs} by inserting the previously determined m_b value**

Smooth chiral and continuum limit

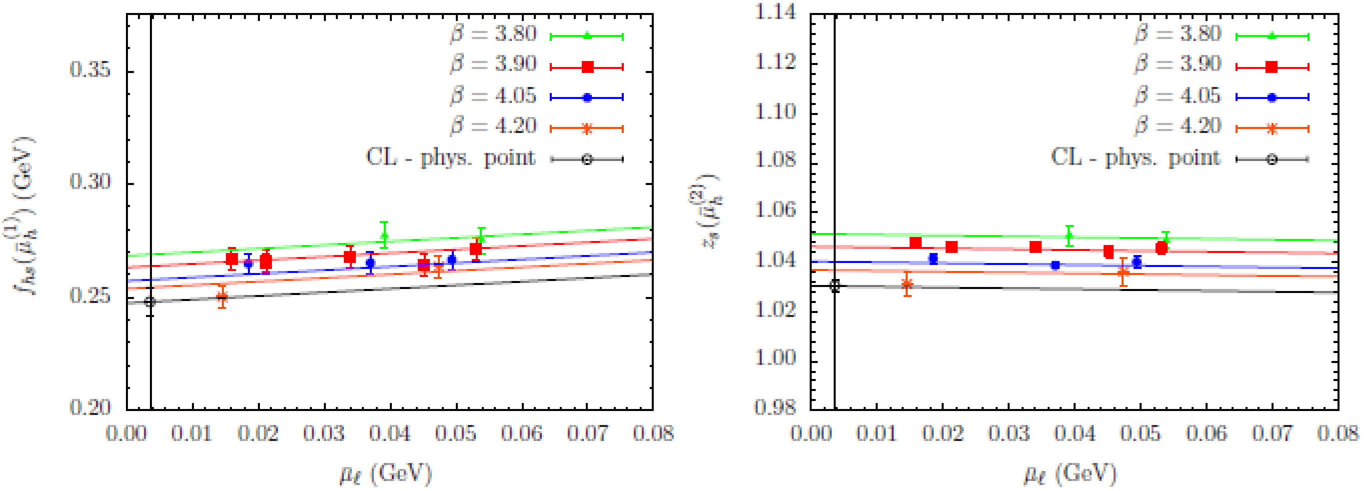
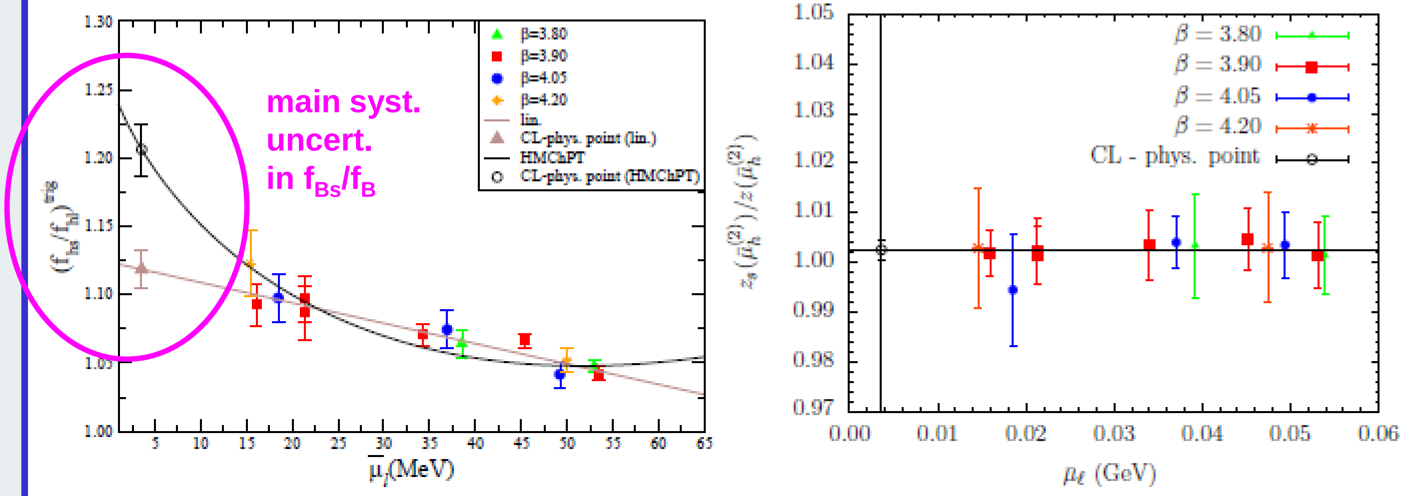


Figure 3: *Light quark mass dependence of the decay constant* $f_{hs}(\bar{\mu}_h^{(1)})$ *(left) and of the ratio* $z_s(\bar{\mu}_h^{(2)})$ *(right) at the four values of the lattice spacing.*



main syst. uncert. in f_{Bs}/f_B

Figure 4: *Light quark mass dependence of the ratio of decay constants* $f_{hs}(\bar{\mu}_h^{(1)})/f_{hl}(\bar{\mu}_h^{(1)})$ *(left) and of the double ratio* $z_s(\bar{\mu}_h^{(2)})/z(\bar{\mu}_h^{(2)})$ *(right) at the four values of the lattice spacing.*

Dependence on the heavy quark mass (static limit=1)

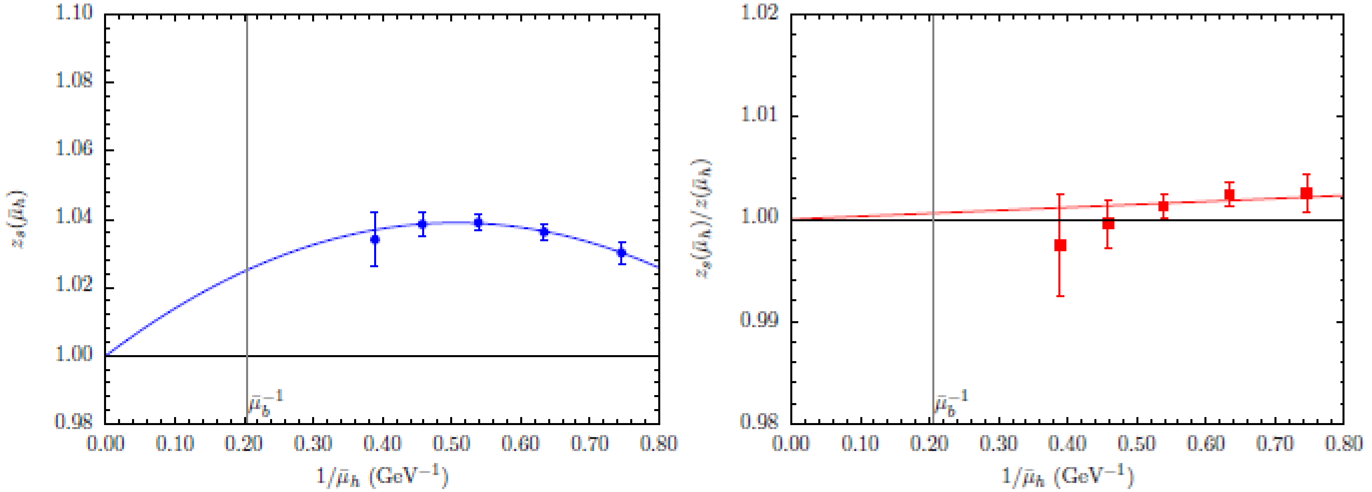


Figure 5: *Heavy quark mass dependence of the ratio* $z_s(\bar{\mu}_h)$ *(left) and of the double ratio* $z_s(\bar{\mu}_h)/z(\bar{\mu}_h)$ *(right) extrapolated to the physical value of the light and strange quark masses and to the continuum limit. The vertical line represents the value of the physical* b *quark mass.*

The Interpolation Method:
Interpolation between relativistic data in the charm region and HQET data

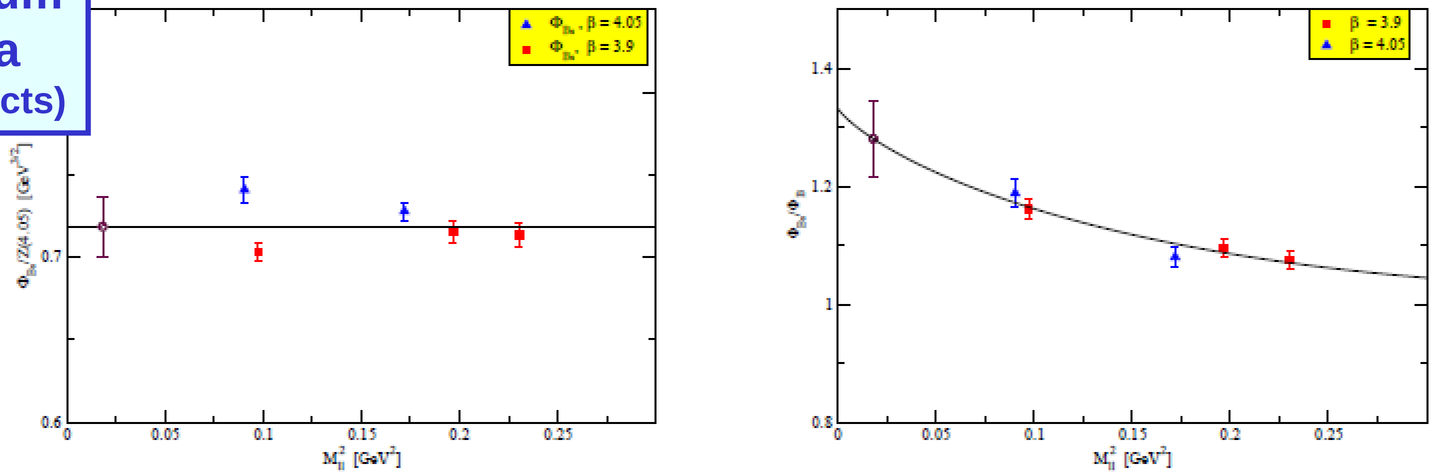
Basic quantities for determining f_{Bs} and f_{Bs}/f_B :

$$\Phi_{hs} = f_{hs}\sqrt{M_{hs}} \qquad \text{and} \qquad \frac{\Phi_{hs}}{\Phi_{h\ell}} = \frac{f_{hs}}{f_{h\ell}}\sqrt{\frac{M_{hs}}{M_{h\ell}}}$$

Static data have been obtained with:

- **HYP2 static action**
- **A subset of the configuration ensembles (β=3.9, 4.05)**
- **Perturbative estimate of the RCs (Z_P^{stat} and Z_S^{stat})**

Chiral and continuum limit of static data
(small discretization effects)



Chiral and continuum limit of relativistic data
is based on the same lattice data and uses the same predictions as in the ratio method

Dependence on the heavy quark mass:

Interpolation between the charm region and the static point, with relativistic data matched to HQET according to

$$\Phi_{hs}(\mu_b^*) = \left[C_A^{stat}(\mu_b^*, \bar{\mu}_h)\right]^{-1} \cdot \Phi_{hs}^{\rm QCD}(\bar{\mu}_h)$$

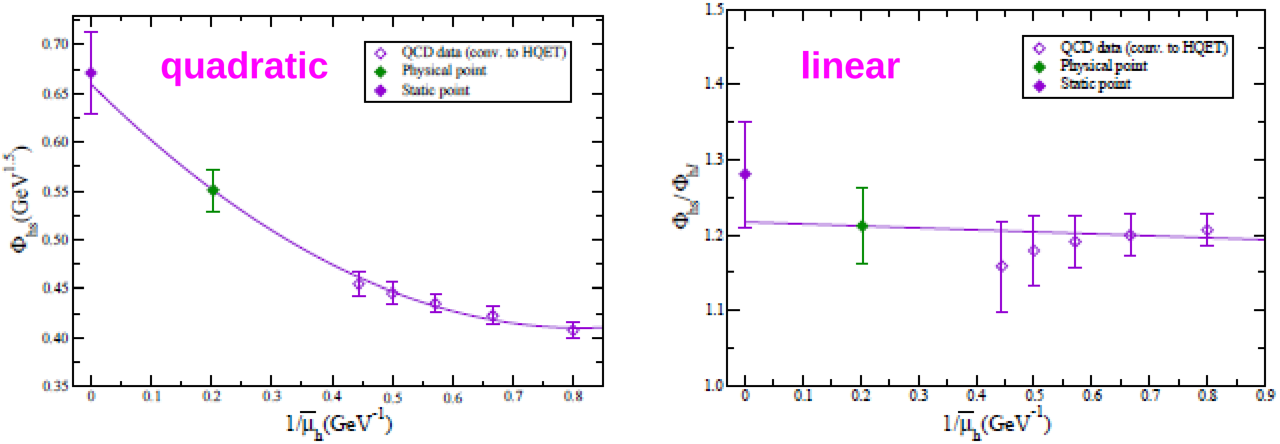
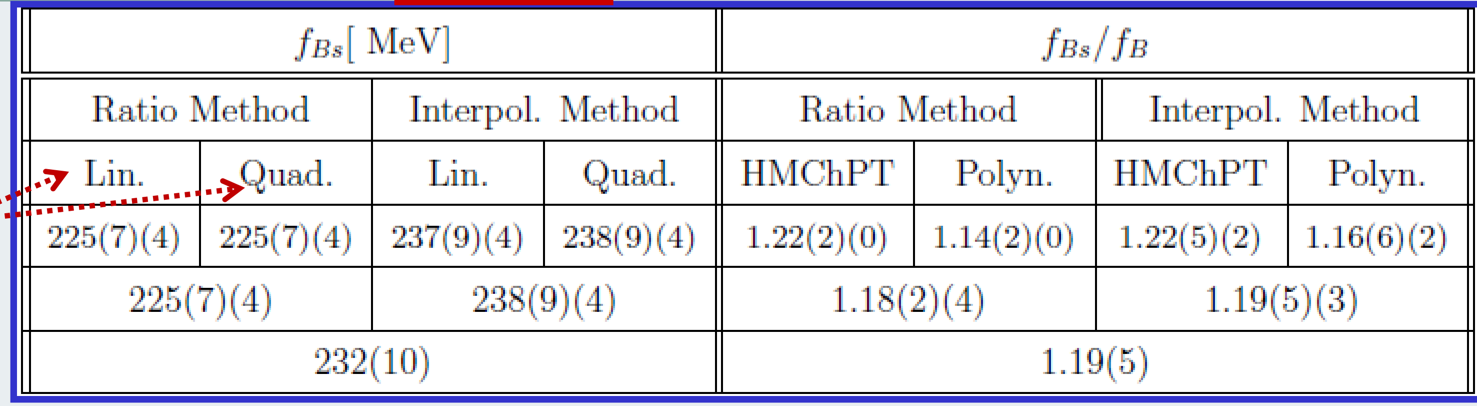


Figure 8: *Dependence of Φ_{hs} (left) and $\Phi_{hs}/\Phi_{h\ell}$ (right), in the chiral and continuum limit, on the inverse of the heavy quark mass.*

Results

The results of two chiral fits are averaged



f_{Bs}[MeV]				f_{Bs}/f_B			
Ratio Method		Interpol. Method		Ratio Method		Interpol. Method	
Lin.	Quad.	Lin.	Quad.	HMChPT	Polyn.	HMChPT	Polyn.
225(7)(4)	225(7)(4)	237(9)(4)	238(9)(4)	1.22(2)(0)	1.14(2)(0)	1.22(5)(2)	1.16(6)(2)
225(7)(4)		238(9)(4)		1.18(2)(4)		1.19(5)(3)	
232(10)				1.19(5)			

The **systematic uncertainty** includes the errors due to:

- **Chiral extrapolation** (comparing two different fits)
- **Continuum limit** (excluding data at β=3.8)
- **Heavy mass dependence** (including two larger masses, varying the fit ansatz)
- **Pole mass definition** (using the LO definition instead of NLO)

$$\overline{m}_b(\overline{m}_b) = 4.29(14) \ \text{GeV} \,,$$

$$f_B = 195(12) \ \text{MeV} \,, \quad f_{Bs} = 232(10) \ \text{MeV} \,, \quad \frac{f_{Bs}}{f_B} = 1.19(5)$$

Comparison with recent (N_f=2, 2+1) results (Lattice 2011)

Our N_f=2 results

$$\overline{m}_b(\overline{m}_b) = 4.29(14)\ \mathrm{GeV}\,,$$

$$f_B = 195(12)\ \mathrm{MeV}\,, \quad f_{Bs} = 232(10)\ \mathrm{MeV}\,, \quad \frac{f_{Bs}}{f_B} = 1.19(5)$$

are well compatible with recent N_f=2, 2+1 results

	$\overline{m}_b(\overline{m}_b)[GeV]$	$f_B[MeV]$	$f_{Bs}[MeV]$	f_{Bs}/f_B
N_f=2+1	4.16(2) HPQCD10	191(9) HPQCD11	226(10) HPQCD11	1.18(2) HPQCD11
		197(8) FNAL/MILC11	242(9) FNAL/MILC11	1.23(3) FNAL/MILC11
N_f=2	4.23(10) ALPHA11	172(12) ALPHA11		

Outlook

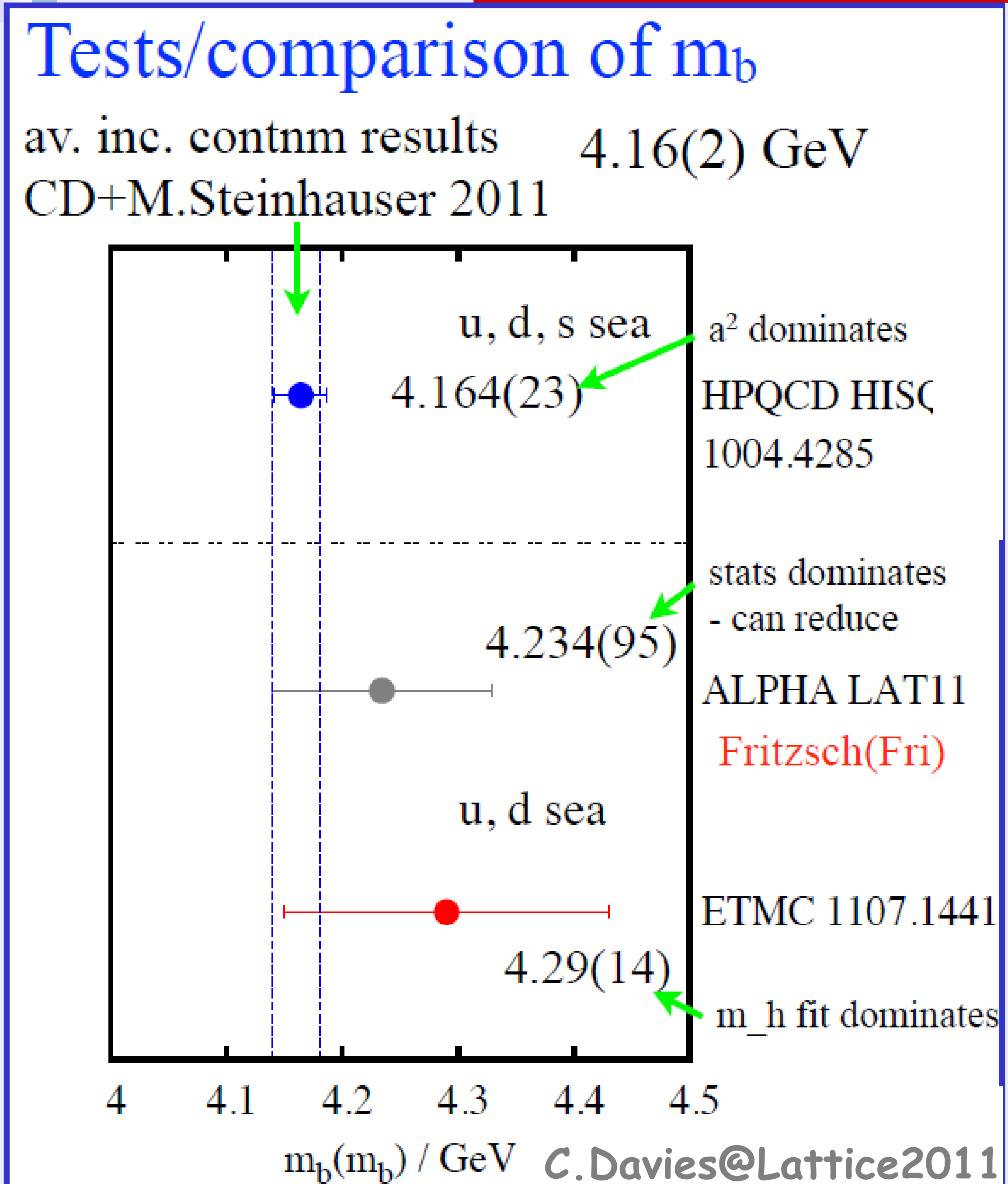
Simulations with N_f=2+1+1 dynamical flavors are being performed by ETMC

In the next future we will perform N_f=2+1+1 analyses, in order to improve the determination of flavor observables, in particular:

- m_b, f_B, f_{Bs}
- B-parameters entering B-$\bar{B}$ mixing
- Semileptonic form factors required for V_{ub} and V_{cb}
- …

BACKUP

Comparison with recent results



Tests/comparison of m_b

av. inc. contnm results
CD+M.Steinhauser 2011

4.16(2) GeV

u, d, s sea

4.164(23)

a^2 dominates

HPQCD HIS

1004.4285

stats dominates
- can reduce

4.234(95)

ALPHA LAT11

Fritzsch(Fri)

u, d sea

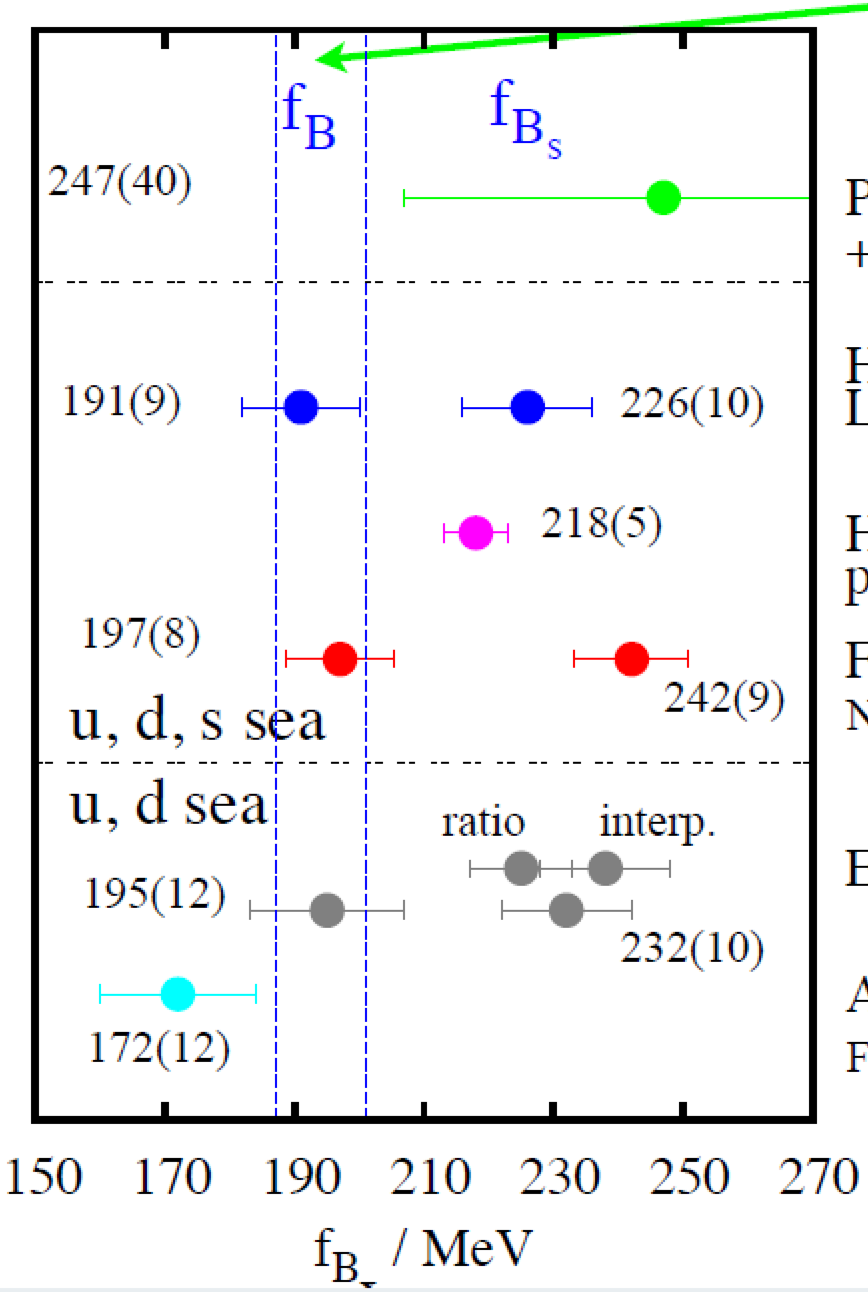
ETMC 1107.1441

4.29(14)

m_h fit dominates

C.Davies@Lattice2011

f_{B_s}, f_B comparison



f_B average : 194(7) MeV (inc. corrs)

down from LAT10

PDG av BR(B->τν) + PDG av Vub

f_B expt

HPQCD NRQCD LAT11 Shigemitsu (Mon)

HPQCD HISQ prelim.

2.4σ apart for f_{B_s}

FNAL/MILC LAT11 Neil (poster)

ETMC 1107.1441

ALPHA LAT11 Fritzsch (Fri)

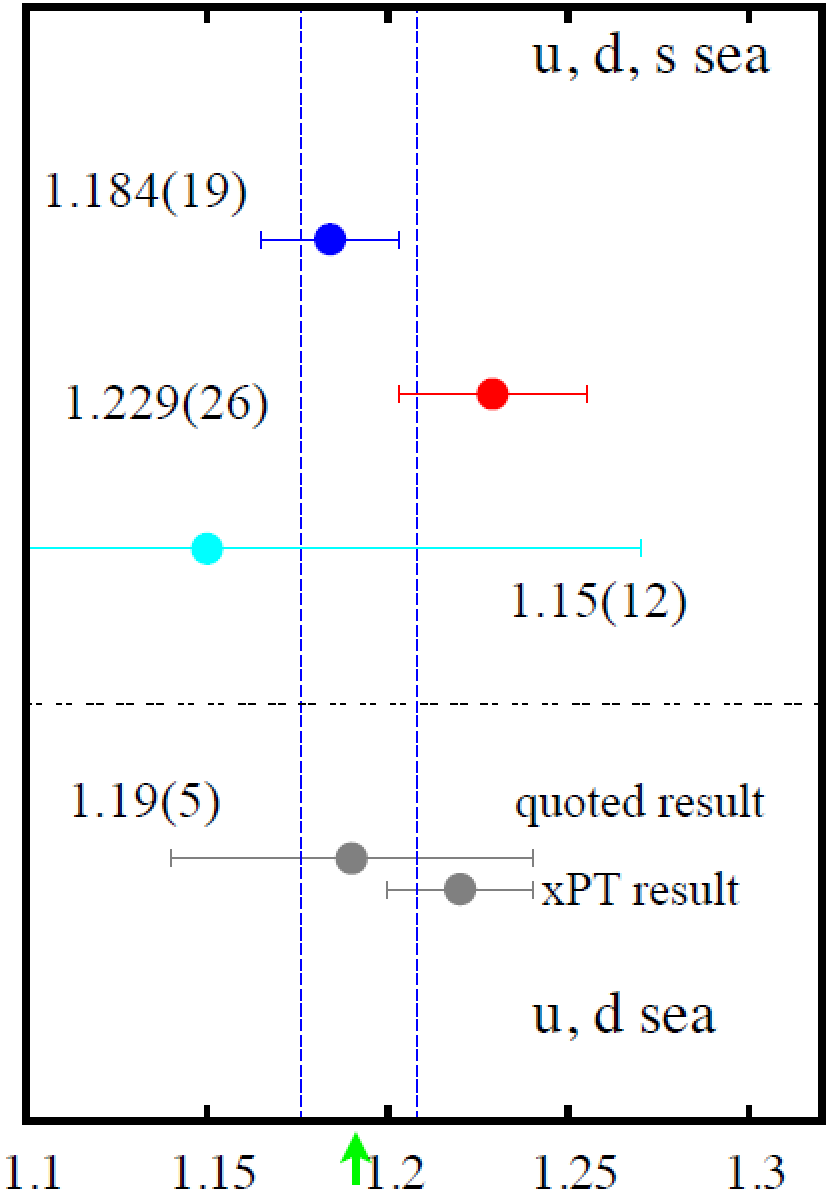
static +1/M
cont. + chiral extrap
a:0.075,0.065,0.048 fm

NOTE:

$f_{B_s} < f_{D_s}$ now quite clear

f_{B_s}/f_B comparison

expect 2% higher than f_{D_s}/f_D for matching $f\sqrt{M}$ ratios



cf $f_K/f_\pi = 1.193(5)$

HPQCD NRQCD LAT11
Shigemitsu (Mon)

FNAL/MILC LAT11
Neil (poster)

correlated average= 1.192(16)

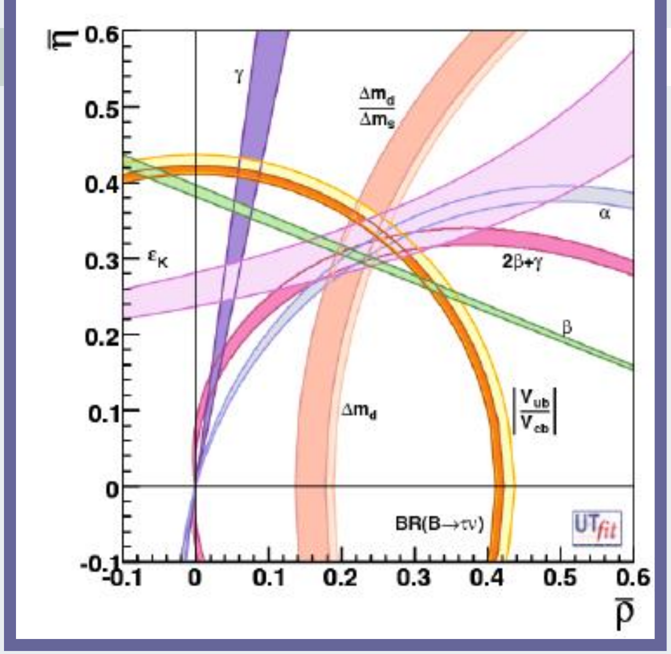
RBC/UKQCD 1001.2023
static h; domain-wall l;
a=0.11fm

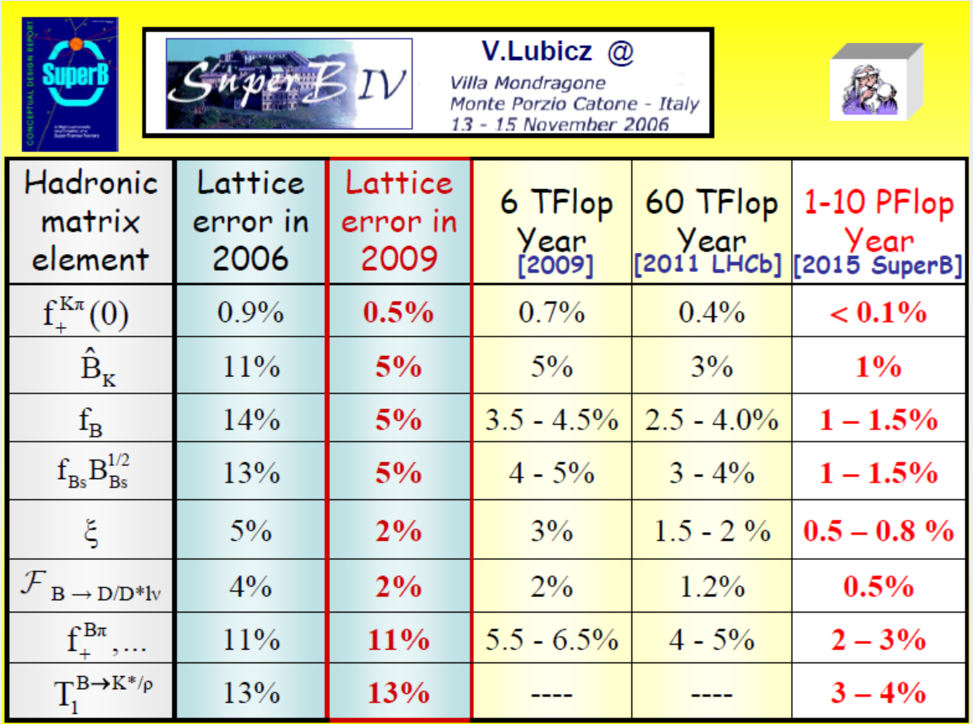
ETMC 1107.1441

improved results soon from 2+1+1 configs at physical m_l?

A look at the future

by Vittorio Lubicz



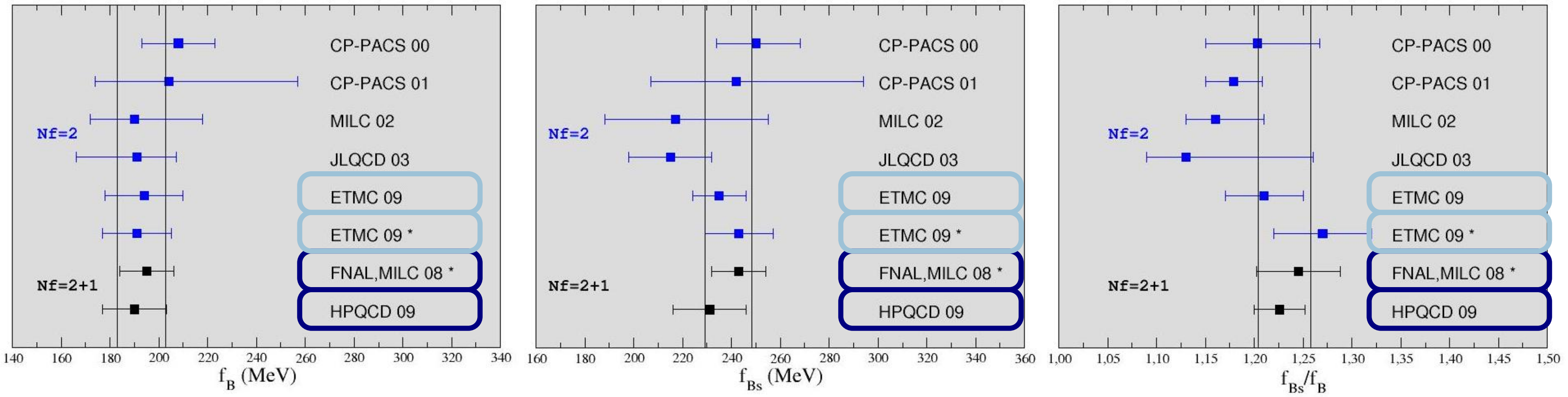


SuperB IV

V.Lubicz @
Villa Mondragone
Monte Porzio Catone - Italy
13 - 15 November 2006

Hadronic matrix element	Lattice error in 2006	Lattice error in 2009	6 TFlop Year [2009]	60 TFlop Year [2011 LHCb]	1-10 PFlop Year [2015 SuperB]
$f_+^{K\pi}(0)$	0.9%	**0.5%**	0.7%	0.4%	**< 0.1%**
$\hat{B}_K$	11%	**5%**	5%	3%	**1%**
f_B	14%	**5%**	3.5 - 4.5%	2.5 - 4.0%	**1 – 1.5%**
$f_{Bs}B_{Bs}^{1/2}$	13%	**5%**	4 - 5%	3 - 4%	**1 – 1.5%**
ξ	5%	**2%**	3%	1.5 - 2 %	**0.5 – 0.8 %**
$\mathcal{F}_{B\to D/D^*l\nu}$	4%	**2%**	2%	1.2%	**0.5%**
$f_+^{B\pi},\ldots$	11%	**11%**	5.5 - 6.5%	4 - 5%	**2 – 3%**
$T_1^{B\to K^*/\rho}$	13%	**13%**	----	----	**3 – 4%**

B-mesons decay constants f_B,f_{Bs} and B-$\bar{B}$ mixing, $B_{Bd/s}$



f_{Bs}= 238.8   9.5 MeV

f_B = 192.8   9.9 MeV

4-5%

f_{Bs}/f_B = 1.231   0.027

2%

Combining with the only modern calculation **HPQCD [0902.1815]:**

$\hat{B}_{Bd}$ = 1.26 ± 0.11, $\hat{B}_{Bs}$ = 1.33 ± 0.06

$f_{Bs}\sqrt{\hat{B}_{Bs}}$= 275   13 MeV

5%

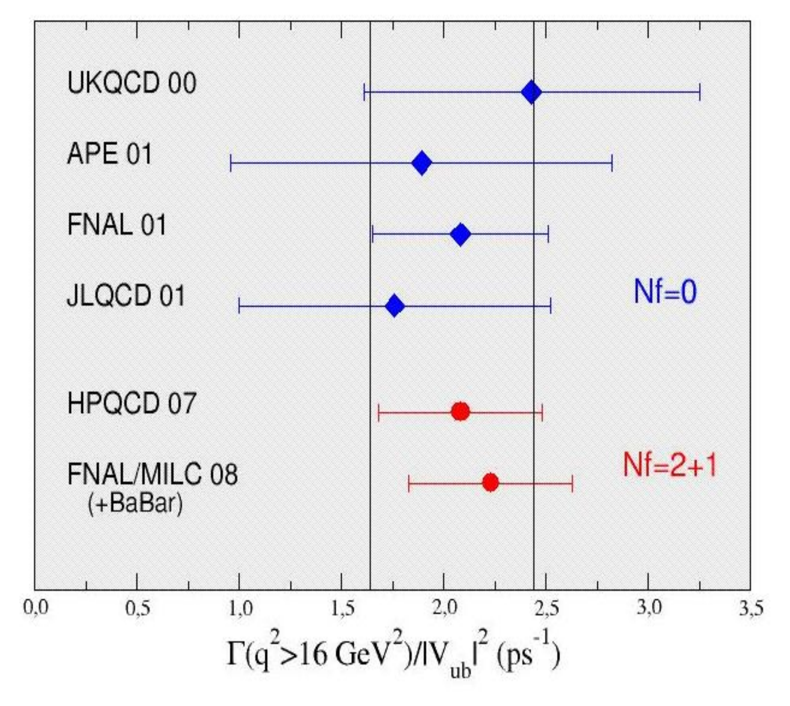
ξ = 1.243 ± 0.028

2%

Exclusive vs Inclusive V_{ub}

THEORETICALLY CLEAN

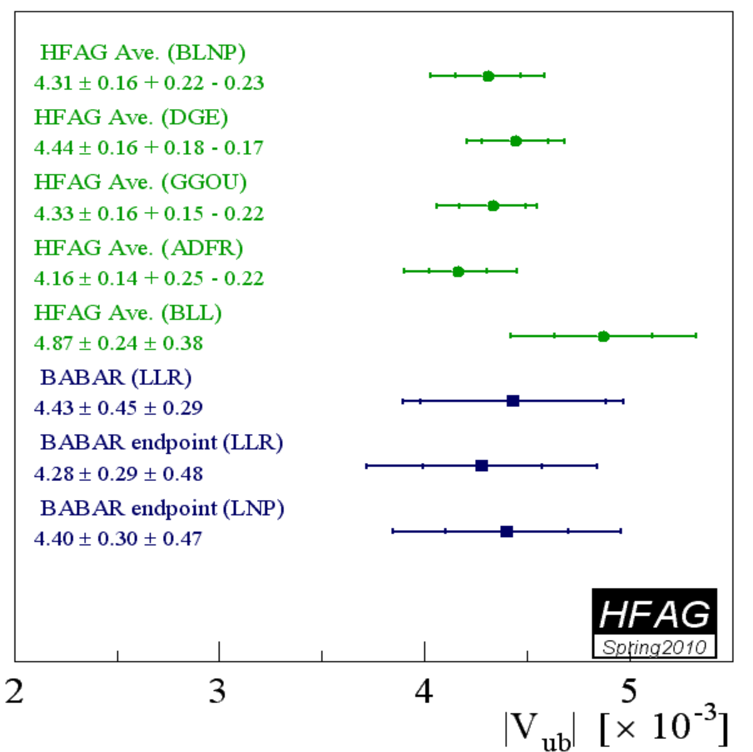
but more lattice calculations are certainly desired



$|V_{ub}|_{excl.} = (35.0 \pm 4.0)\ 10^{-4}$

IMPORTANT LONG DISTANCE CONTRIBUTIONS.

The results have some model dependence



$|V_{ub}|_{incl.} = (42.0 \pm 1.5 \pm 5.0)\ 10^{-4}$

UTfit $|V_{ub}|_{SM\text{-}Fit} = (35.5 \pm 1.4)\ 10^{-4}$

$$\boxed{S_F = \int d^4x\, \overline{\psi}\left[D + m_q + i\mu\gamma_5\tau_3\right]\psi}$$

- Dirac operator
- Twisted mass parameter
- Third Pauli matrix in flavour space (2 flavours)

$$\rho(\bar{\mu}_h, \mu^*) = \left[1 + \frac{16}{3} \cdot \frac{\alpha^{\overline{\mathrm{MS}}}(\bar{\mu}_h)}{4\pi}\right] \cdot \left(\frac{\alpha^{\overline{\mathrm{MS}}}(\bar{\mu}_h)}{\alpha^{\overline{\mathrm{MS}}}(\mu^*)}\right)^{12/(33-2\,N_f)} \cdot \left[1 + \left(\frac{2(4491 - 252\,N_f + 20\,N_f^2)}{3(33-2\,N_f)^2}\right) \frac{\alpha^{\overline{\mathrm{MS}}}(\bar{\mu}_h) - \alpha^{\overline{\mathrm{MS}}}(\mu^*)}{4\pi}\right],$$

$$C_A^{stat}(\mu_b^*, \bar{\mu}_h) = \left(\frac{\alpha^{\overline{\mathrm{MS}}}(\bar{\mu}_h)}{\alpha^{\overline{\mathrm{MS}}}(\mu_b^*)}\right)^{-\frac{6}{33-2\,N_f}} \cdot \left[1 - \left(\frac{-3951 + 300\,N_f + 60\,N_f^2 + (924 - 56\,N_f)\pi^2}{9(33-2\,N_f)^2}\right) \cdot \frac{\alpha^{\overline{\mathrm{MS}}}(\bar{\mu}_h) - \alpha^{\overline{\mathrm{MS}}}(\mu_b^*)}{4\pi}\right] \cdot \left[1 - \frac{8}{3}\frac{\alpha^{\overline{\mathrm{MS}}}(\bar{\mu}_h)}{4\pi}\right], \tag{17}$$