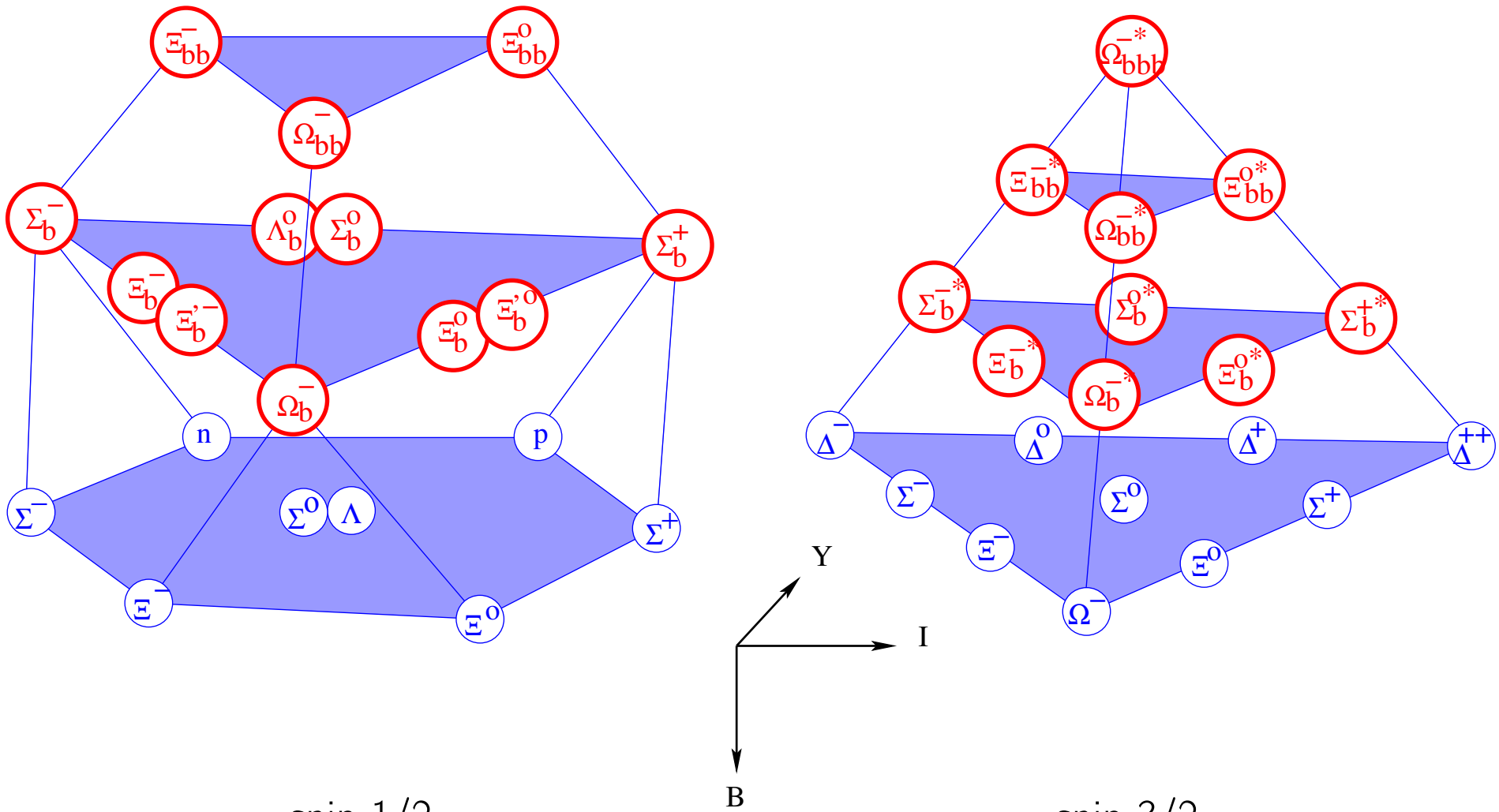
bottom and charm hadron spectroscopy from lattice QCD

$$m_u \approx m_d \quad < \quad m_s \sim \Lambda_{\mathrm{QCD}} \quad < \quad m_c \quad < \quad \frac{1}{a} \quad < \quad m_b$$

randy.lewis@yorku.ca

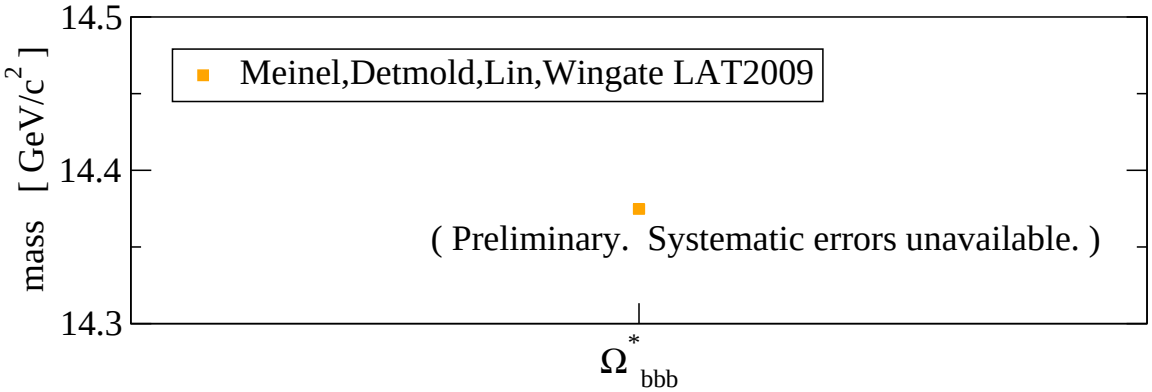
bottom baryons in context

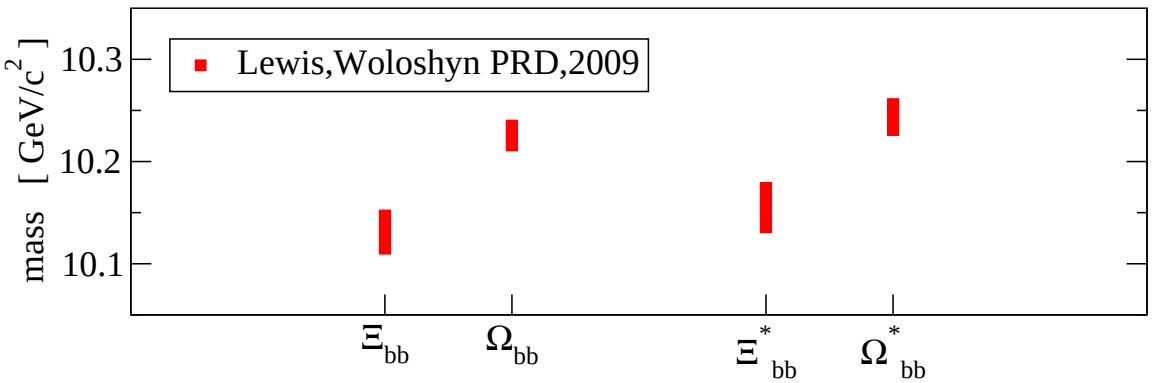


spin 1/2

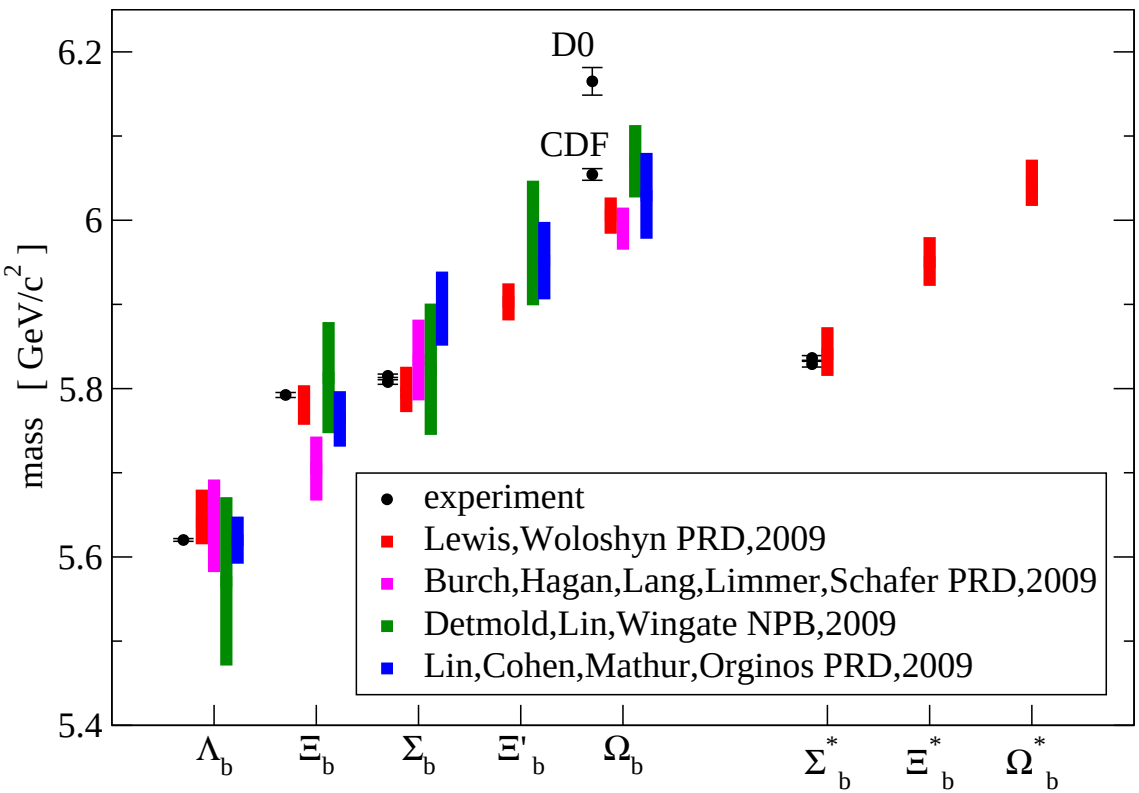
spin 3/2

Mass differences between these multiplets, eg. $m(\Sigma^*) - m(\Sigma)$, vanish as $m_b \to \infty$.





MDLW also have preliminary results for bb and b baryons (see LAT2009 proceedings).

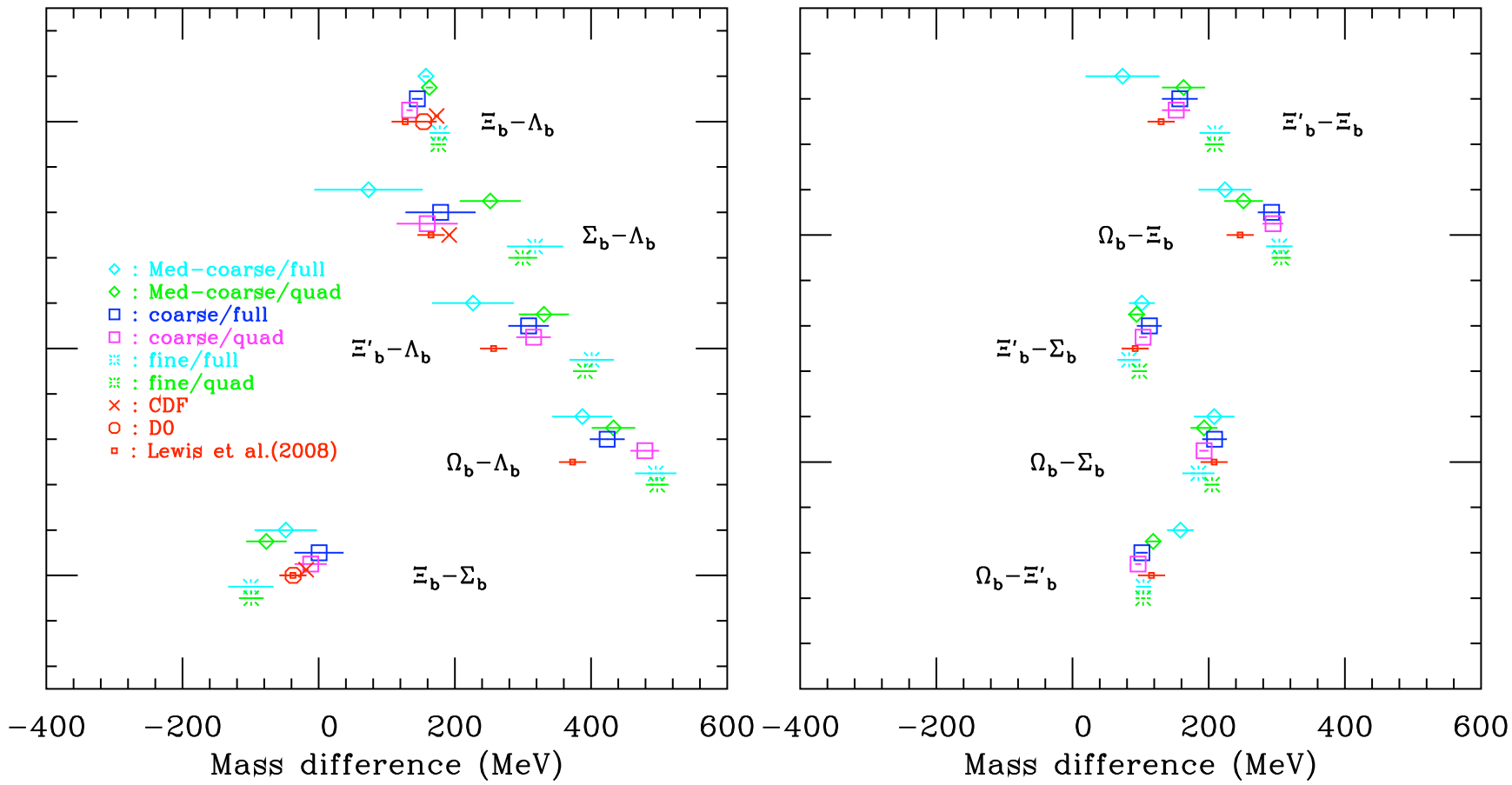


ALSO:

Na (and Gottlieb) PhD thesis, 2008

contains valuable data for mass differences of b and bb baryons.

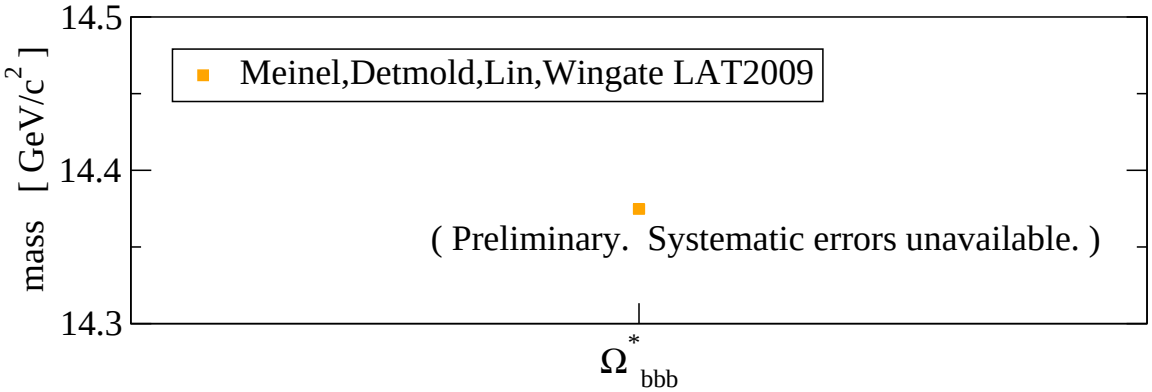
They see a curious systematic dependence: $\mathcal{O}_5$ for Λ_b, Ξ_b versus $\mathcal{O}_\mu$ for $\Sigma_b, \Xi'_b, \Omega_b$.

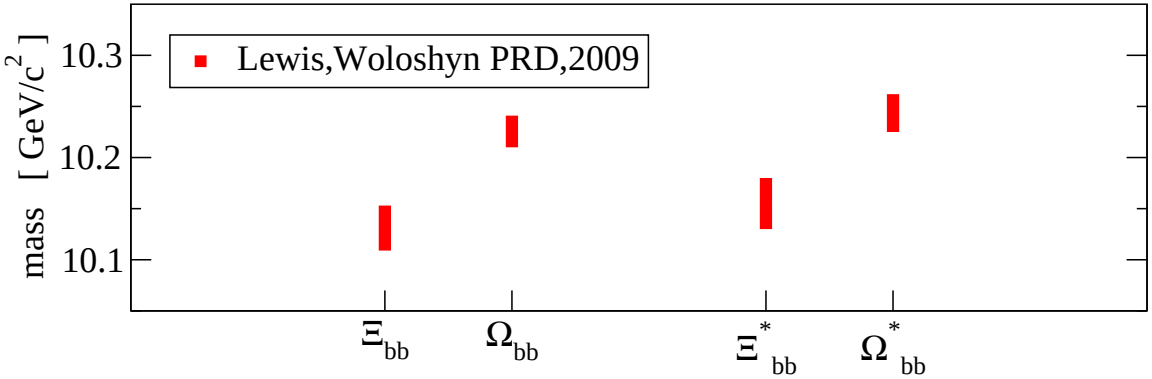


This is figure 4.6 of Heechang Na's thesis (2008).

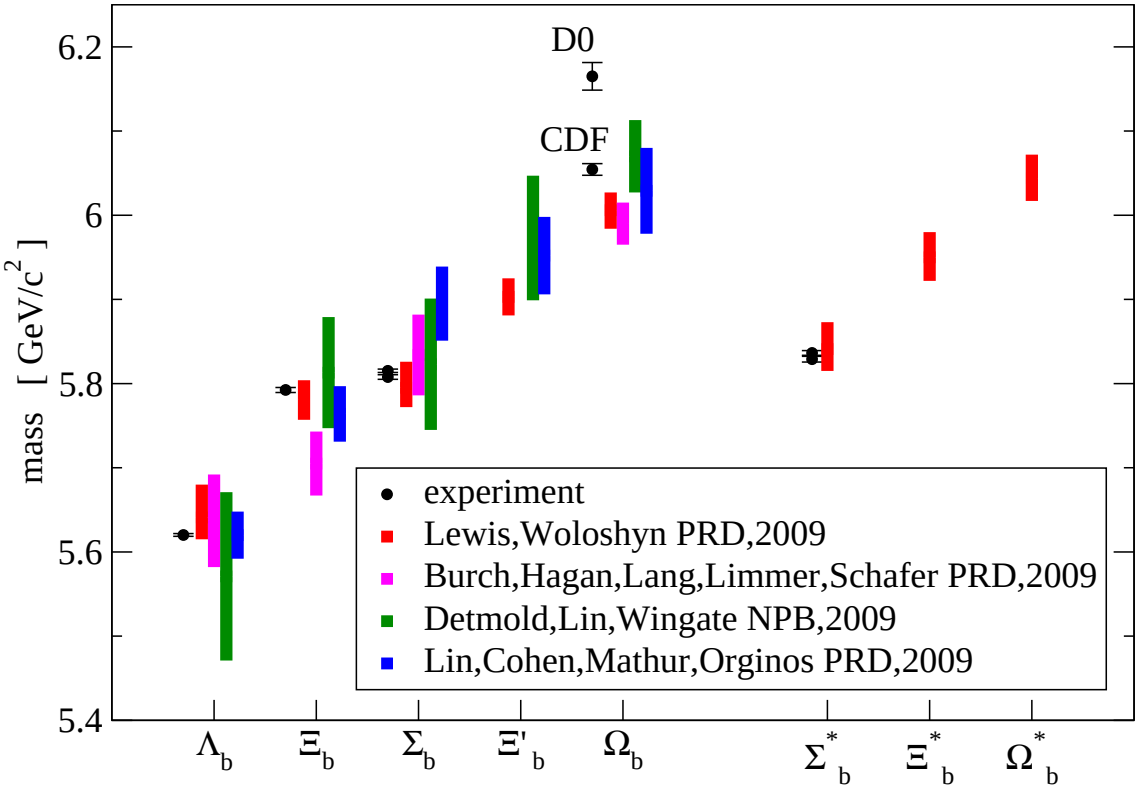
Fine lattice results produce systematically large splittings of (Λ_b, Ξ_b) versus $(\Sigma_b, \Xi'_b, \Omega_b)$ relative to other lattice results and experiment.

The thesis suggests a possible cause: "we cannot separate $J^p = \frac{1}{2}^+$ and $\frac{3}{2}^+$ states using the spin projection operators" for $\mathcal{O}_\mu$. See the thesis for a thorough discussion.





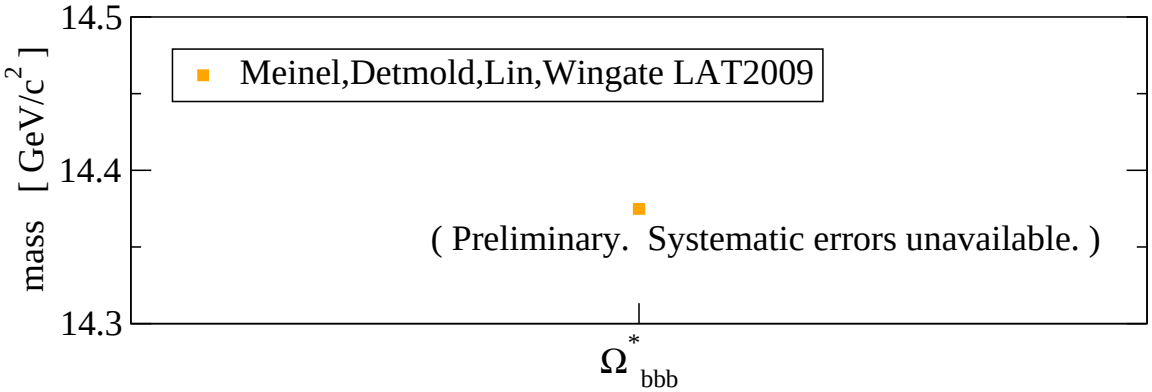
AUTHORS	:	GAUGE ACTION
LW	:	Iwasaki
NG	:	one-loop Symanzik
BHLLS	:	one-loop Lüscher-Weisz
DLW	:	Iwasaki
LCMO	:	Symanzik
MDLW	:	Iwasaki

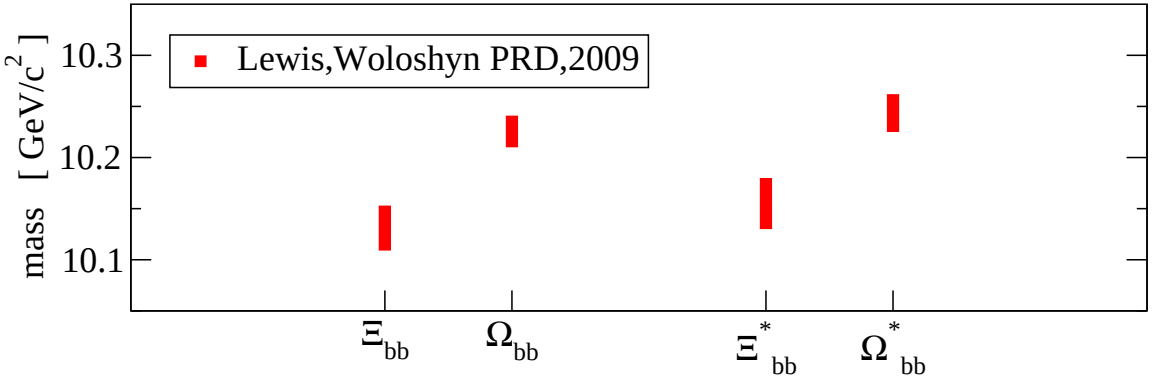


ALSO:

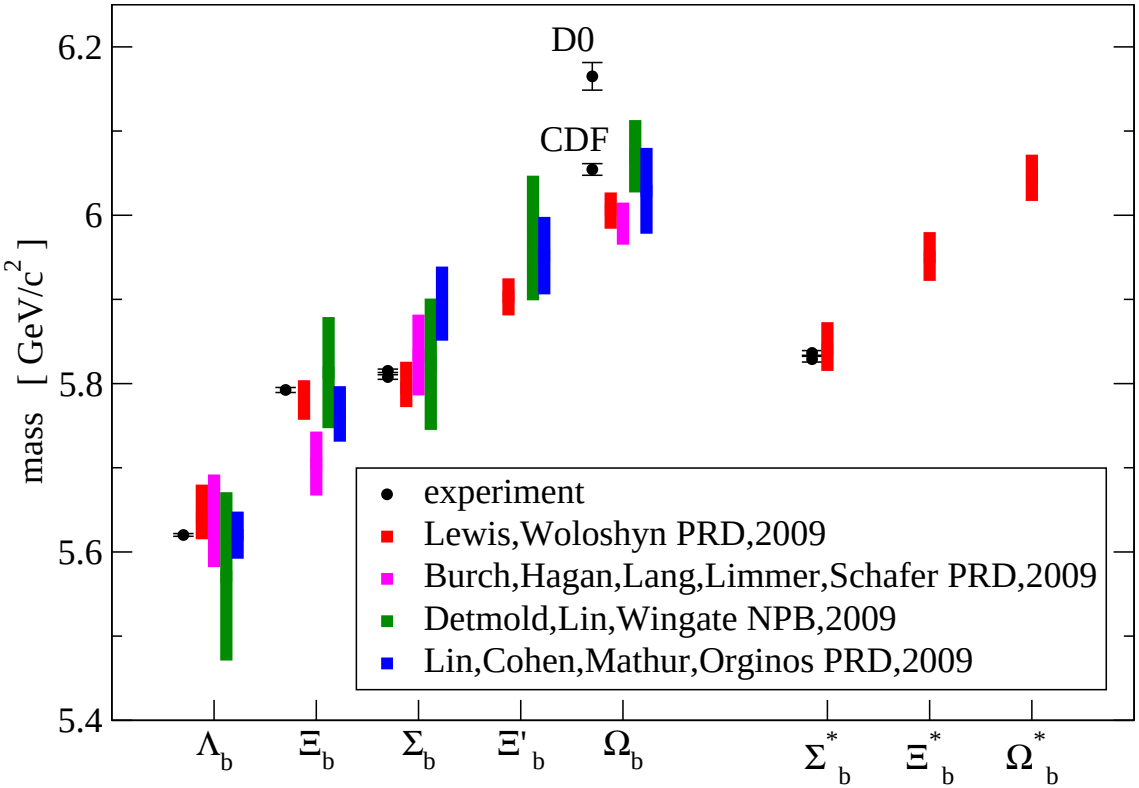
Na (and Gottlieb) PhD thesis, 2008

contains valuable data for mass differences of b and bb baryons.





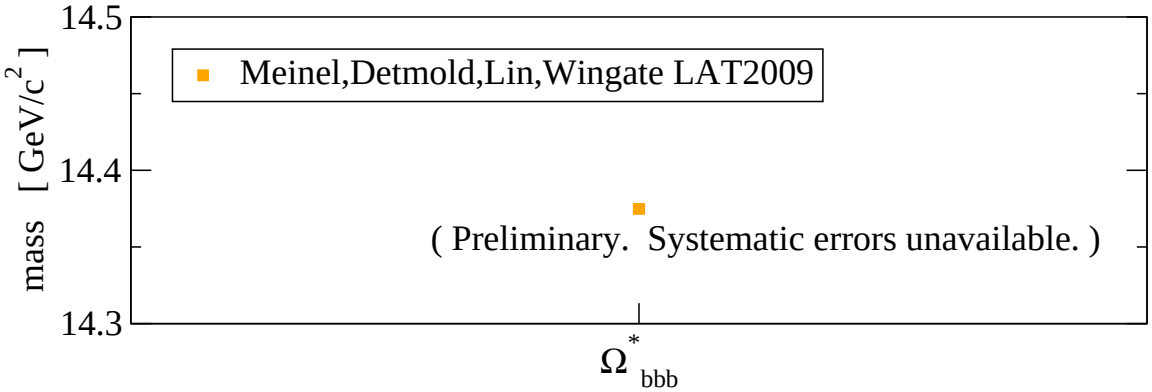
AUTHORS	:	u,d,s ACTION
LW	:	nonpert-tuned clover
NG	:	improved staggered
BHLLS	:	chirally improved
DLW	:	domain wall
LCMO	:	sea = impr. staggered
	:	valence = domain wall
MDLW	:	domain wall

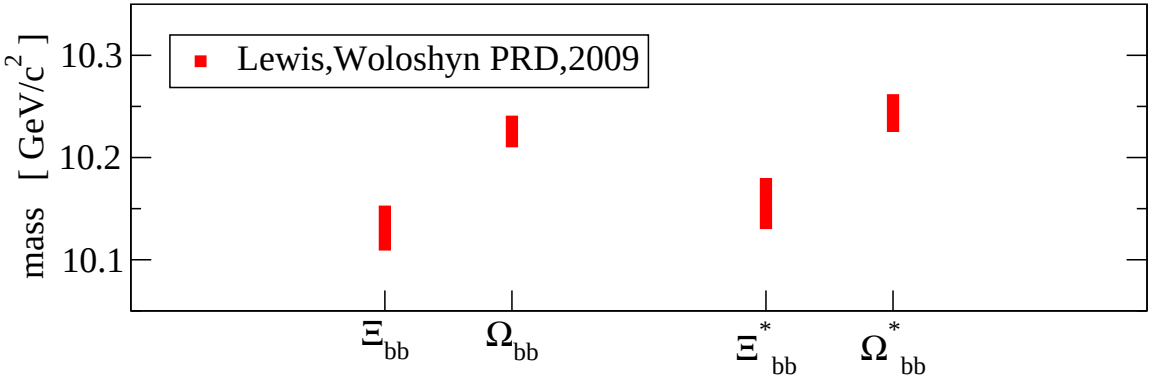


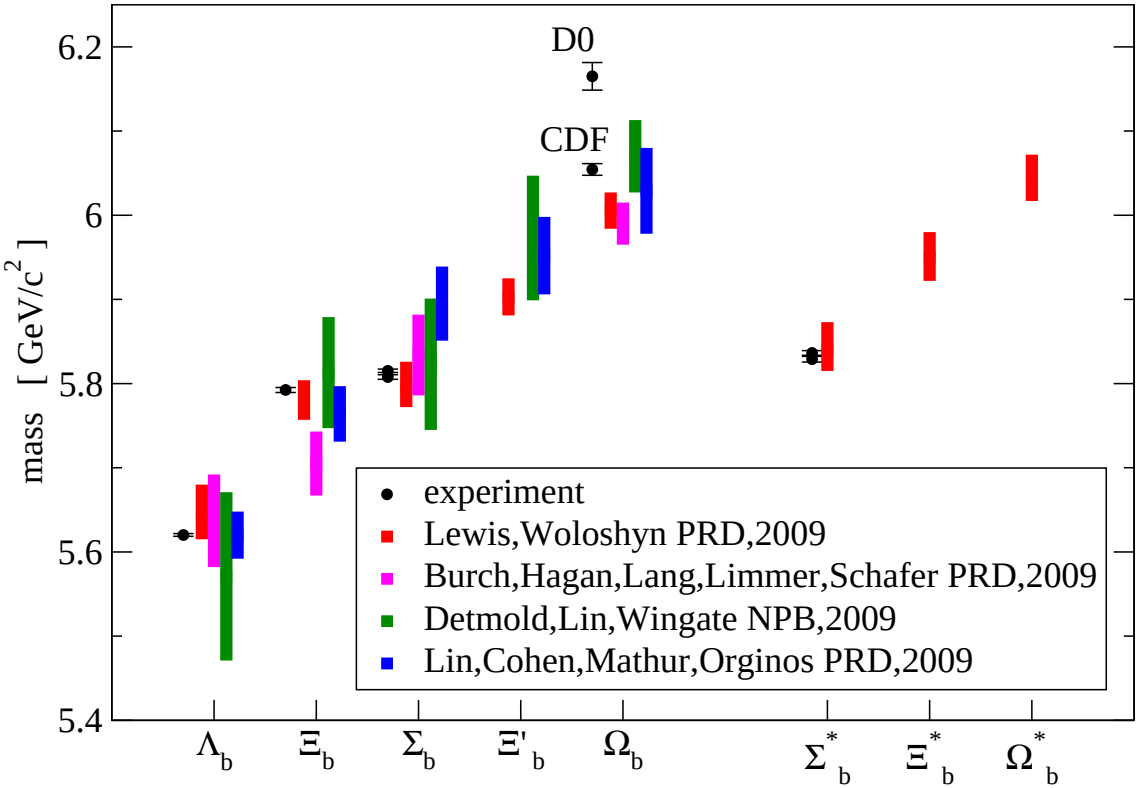
ALSO:

Na (and Gottlieb) PhD thesis, 2008

contains valuable data for mass differences of b and bb baryons.





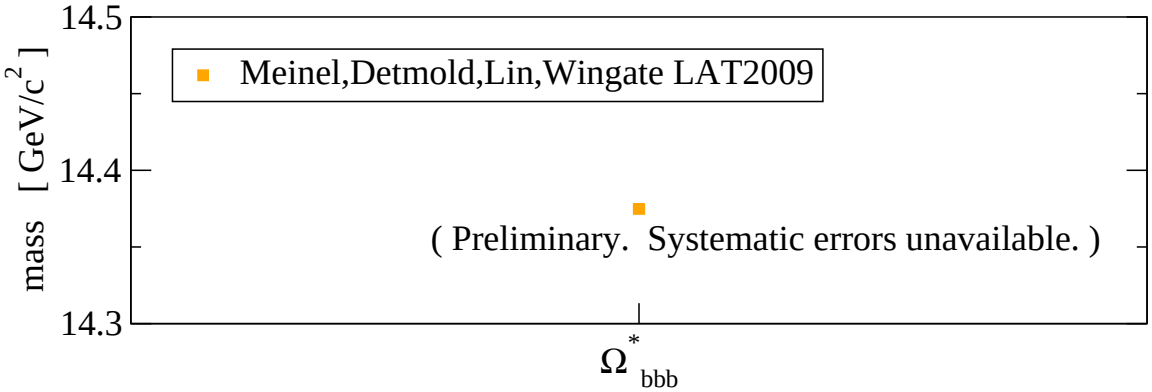


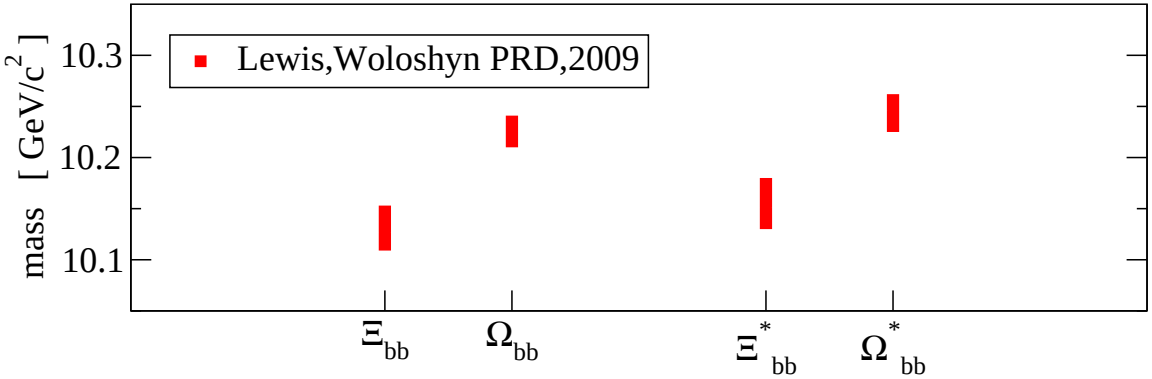
AUTHORS	: b ACTION
LW	: NRQCD incl $O(1/M^3)$
NG	: Fermilab
BHLLS	: static
DLW	: static
LCMO	: static
MDLW	: NRQCD

ALSO:

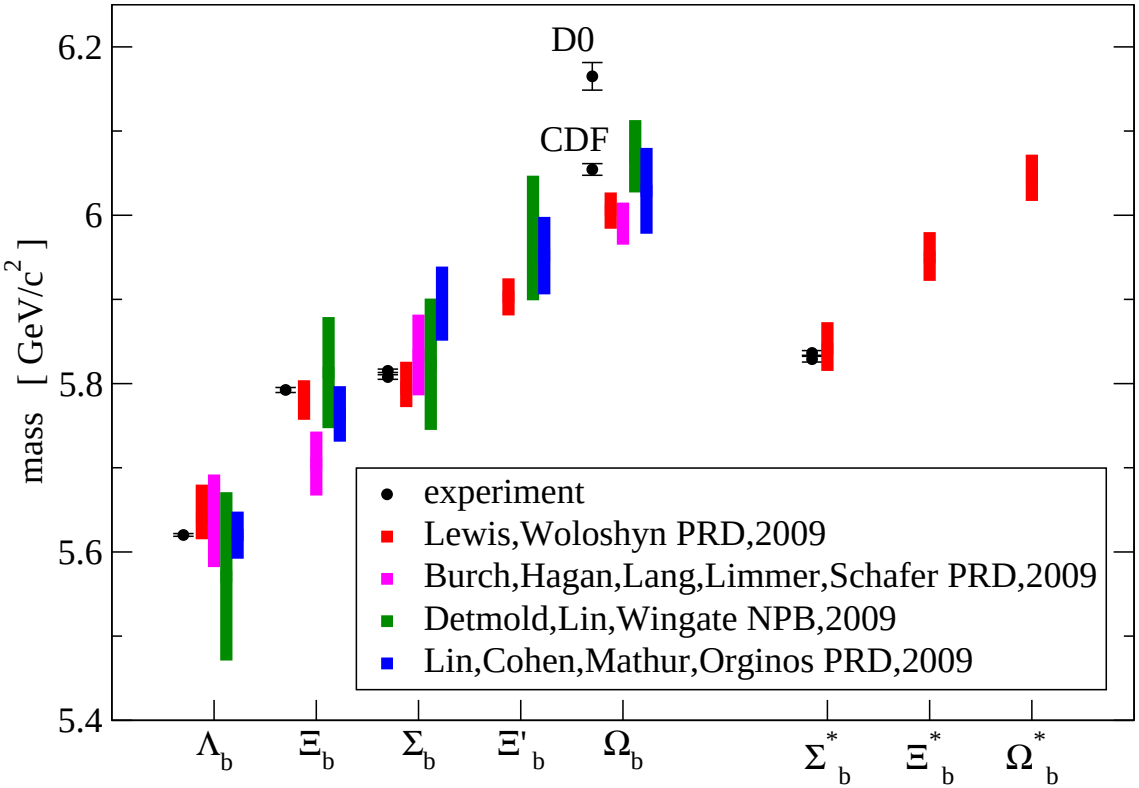
Na (and Gottlieb) PhD thesis, 2008

contains valuable data for mass differences of b and bb baryons.





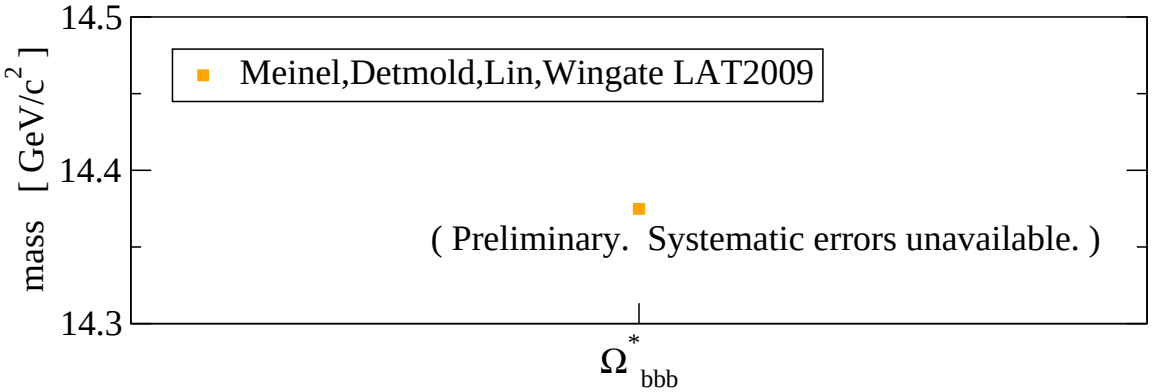
AUTHORS	LATTICE SPACING
LW	0.104 fm
NG	0.15, 0.12, 0.09 fm
BHLLS	0.11, 0.16 fm
DLW	0.114 fm
LCMO	0.124 fm
MDLW	0.11 fm

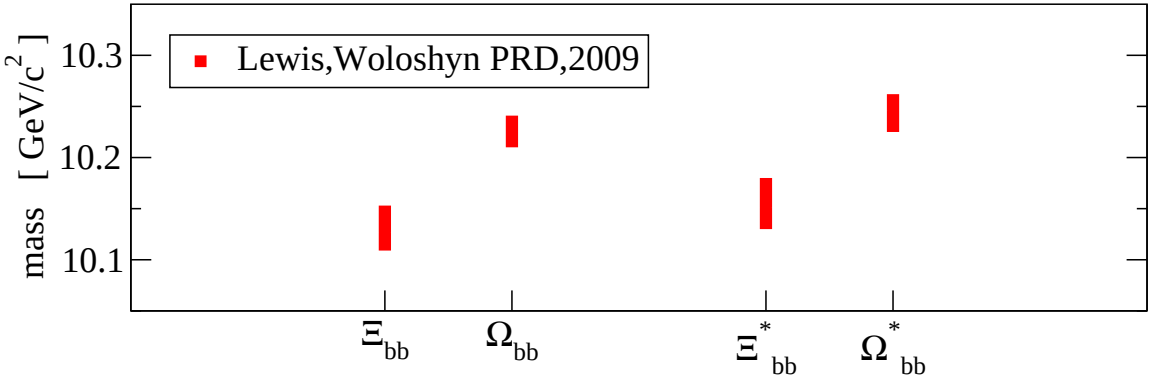


ALSO:

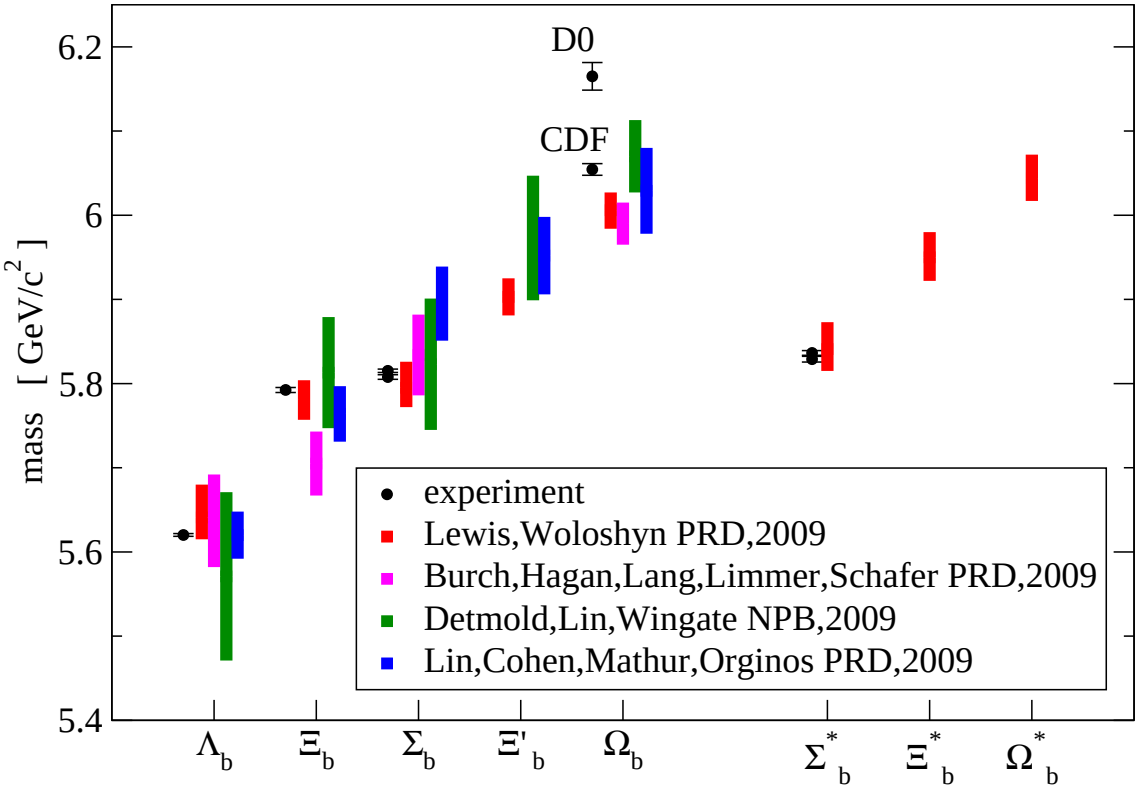
Na (and Gottlieb) PhD thesis, 2008

contains valuable data for mass differences of b and bb baryons.





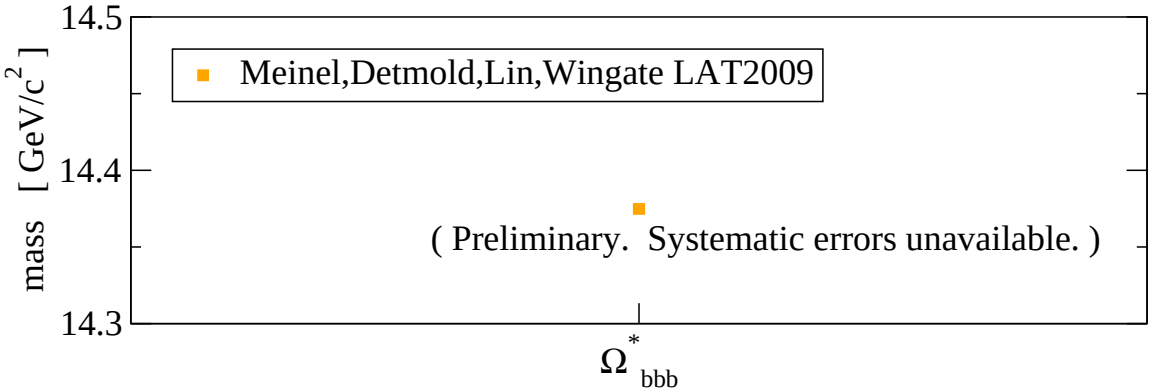
AUTHORS	:	LATTICE VOLUME
LW	:	$(2.1\ \mathrm{fm})^3$
NG	:	$(2.4\ \mathrm{fm})^3$
BHLLS	:	$(1.35\ \mathrm{fm})^3$, $(2.5\ \mathrm{fm})^3$
DLW	:	$(2.7\ \mathrm{fm})^3$
LCMO	:	$(2.5\ \mathrm{fm})^3$
MDLW	:	$(2.7\ \mathrm{fm})^3$

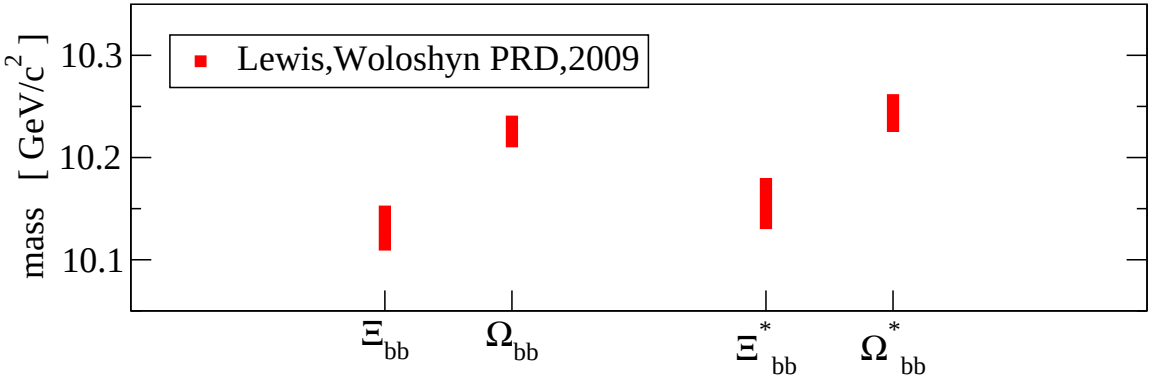


ALSO:

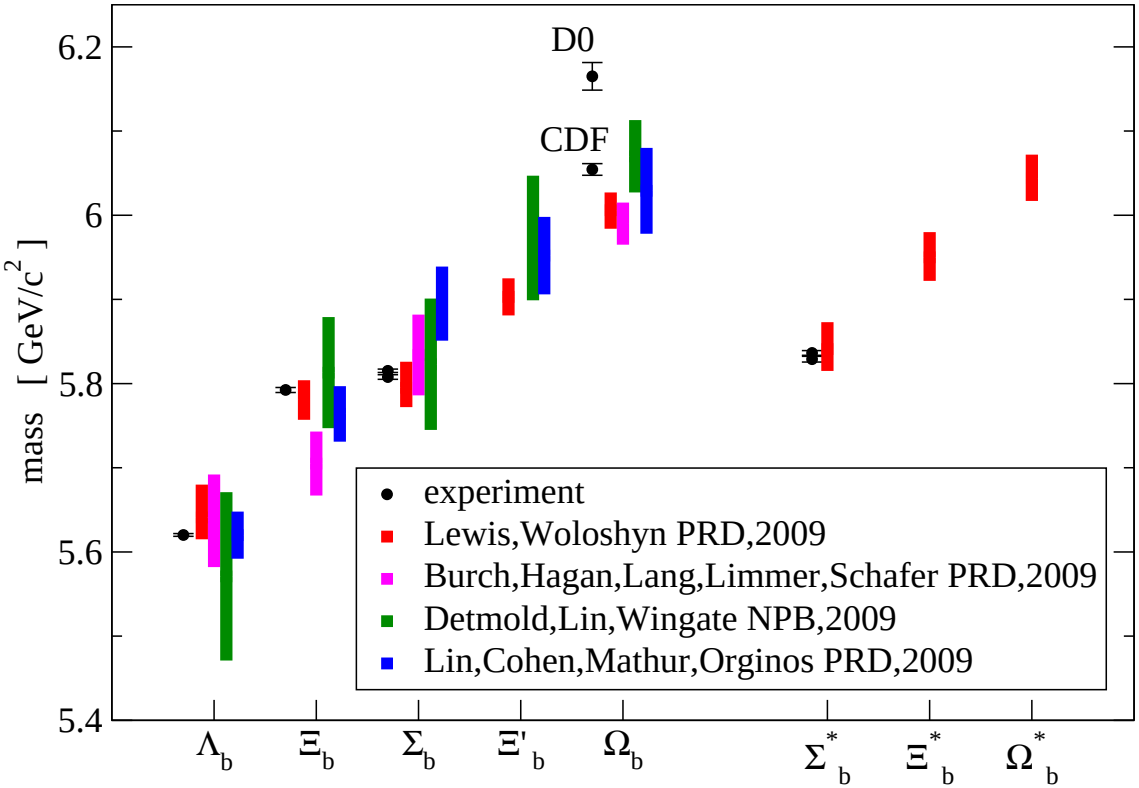
Na (and Gottlieb) PhD thesis, 2008

contains valuable data for mass differences of b and bb baryons.





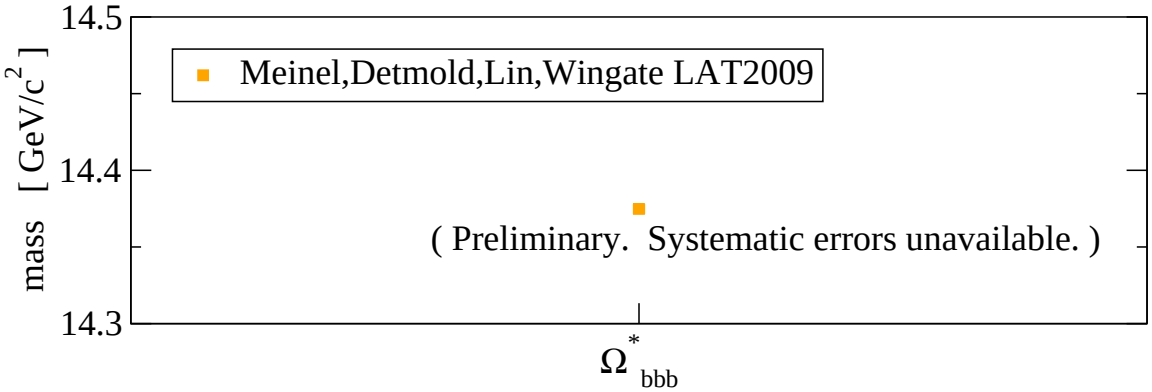
AUTHORS	PION MASS
LW	4; minimum∼600 MeV
NG	2 or 3; min∼290 MeV
BHLLS	461 MeV and 525 MeV
DLW	3 sea + 6 valence;
	minimum∼275 MeV
LCMO	4; minimum∼290 MeV
MDLW	331 MeV

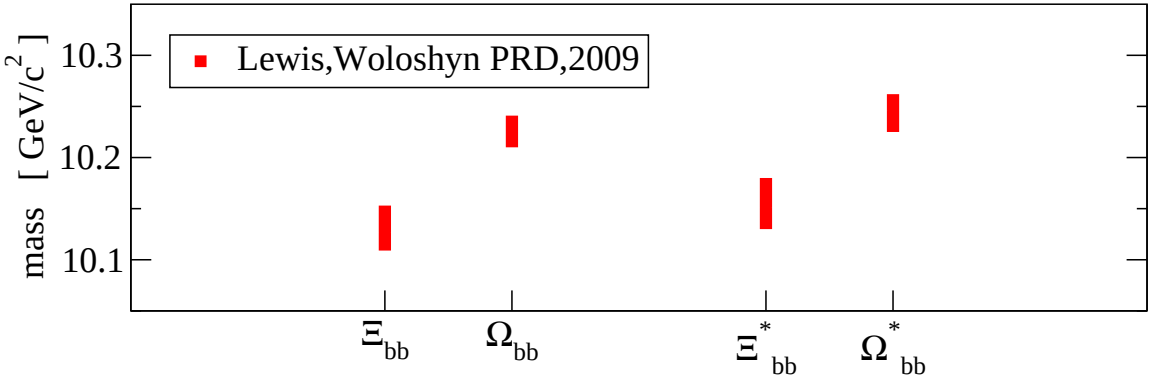


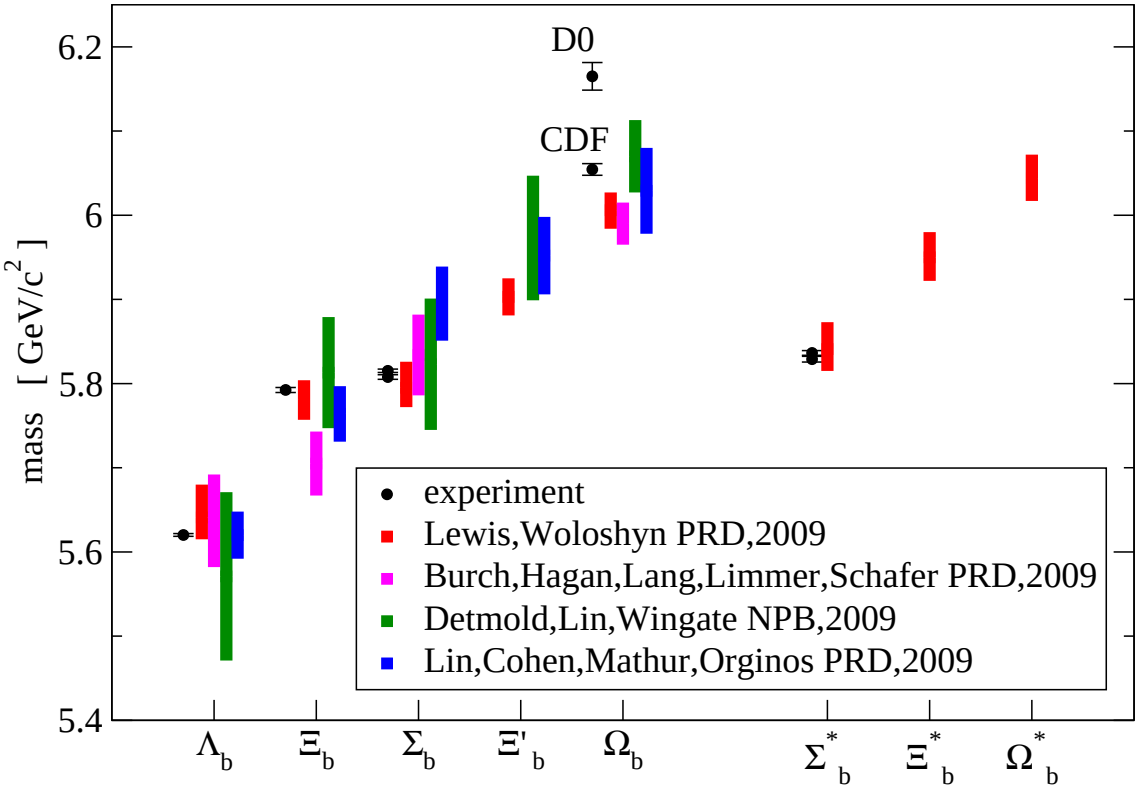
ALSO:

Na (and Gottlieb) PhD thesis, 2008

contains valuable data for mass differences of b and bb baryons.





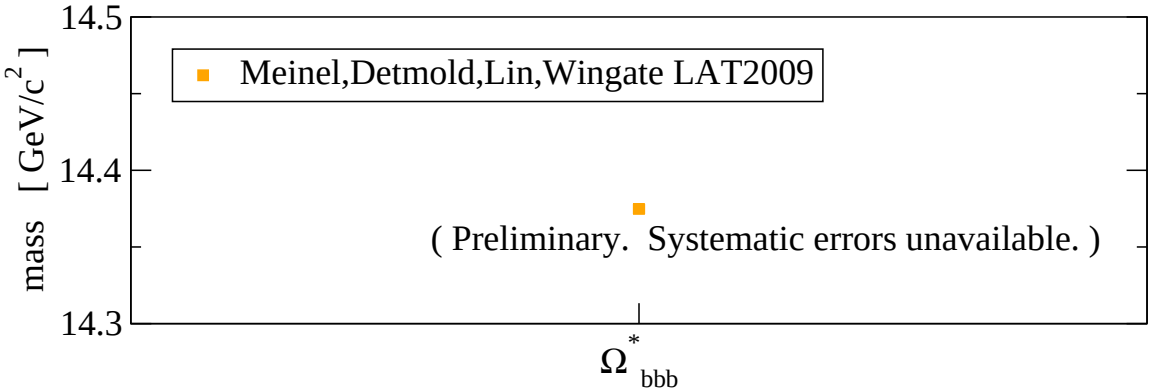


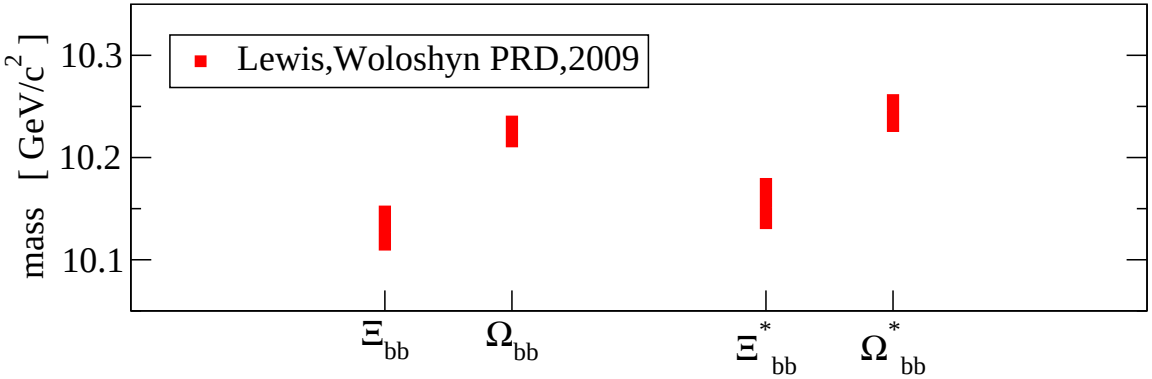
AUTHORS	: s MASS
LW	: 2; interpolate to physical
NG	: ∼physical
BHLLS	: s quark is absent
DLW	: $O(10\%)$ > physical
LCMO	: ∼physical
MDLW	: $O(10\%)$ > physical

ALSO:

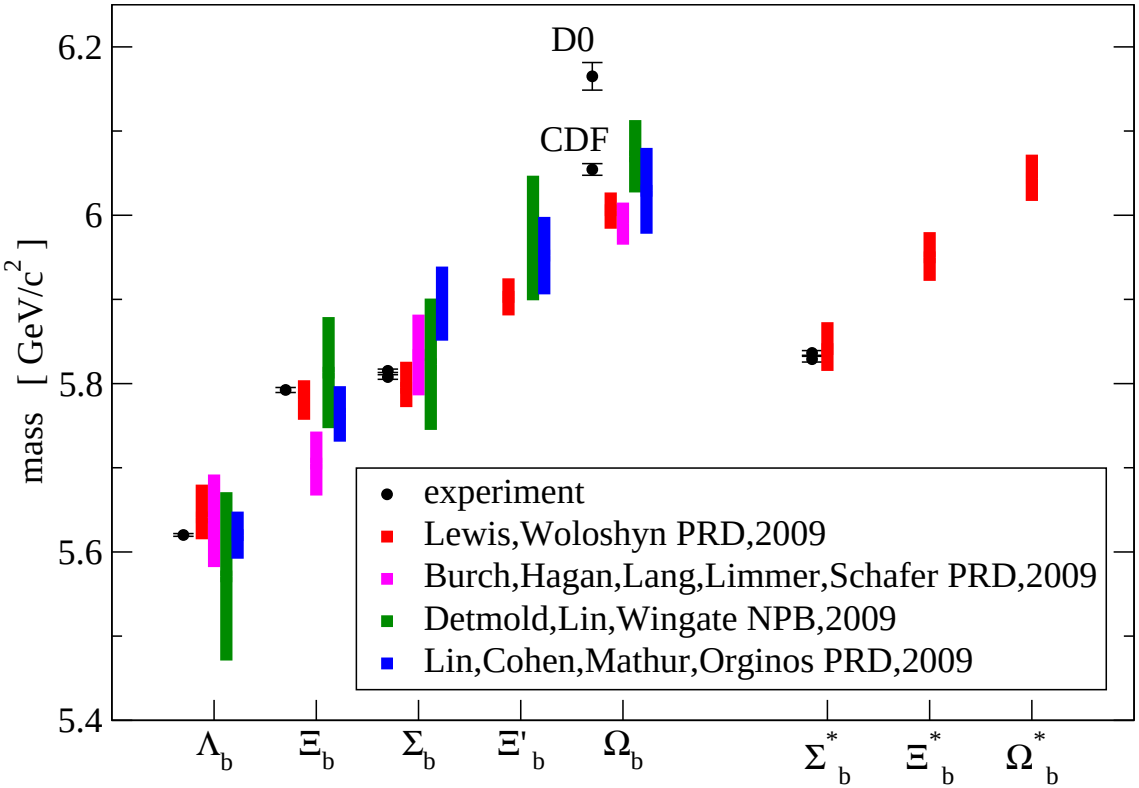
Na (and Gottlieb) PhD thesis, 2008

contains valuable data for mass differences of b and bb baryons.





AUTHORS	b MASS
LW	3; interpolate to physical
NG	1; ∼physical
BHLLS	∞
DLW	∞
LCMO	∞
MDLW	1; physical

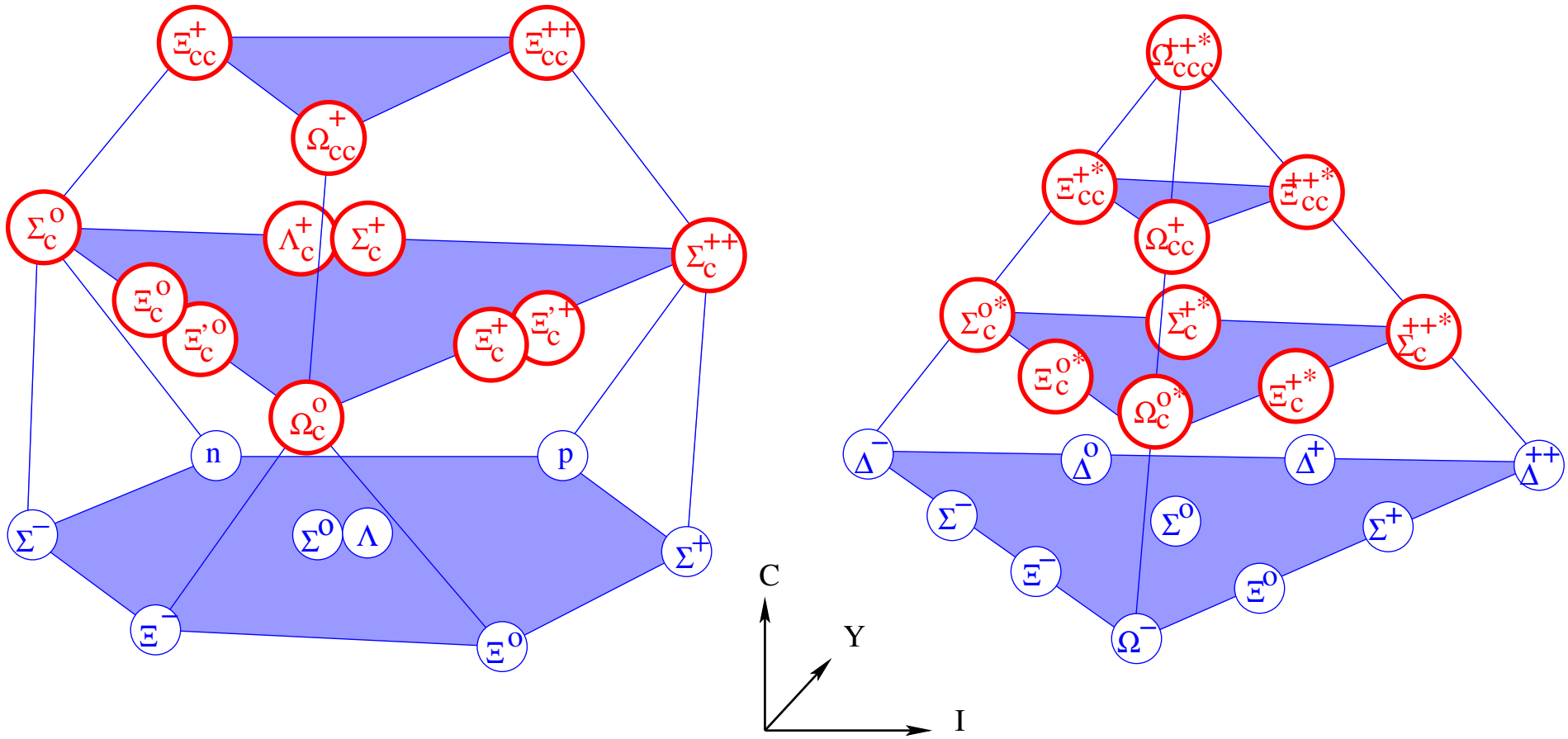


ALSO:

Na (and Gottlieb) PhD thesis, 2008

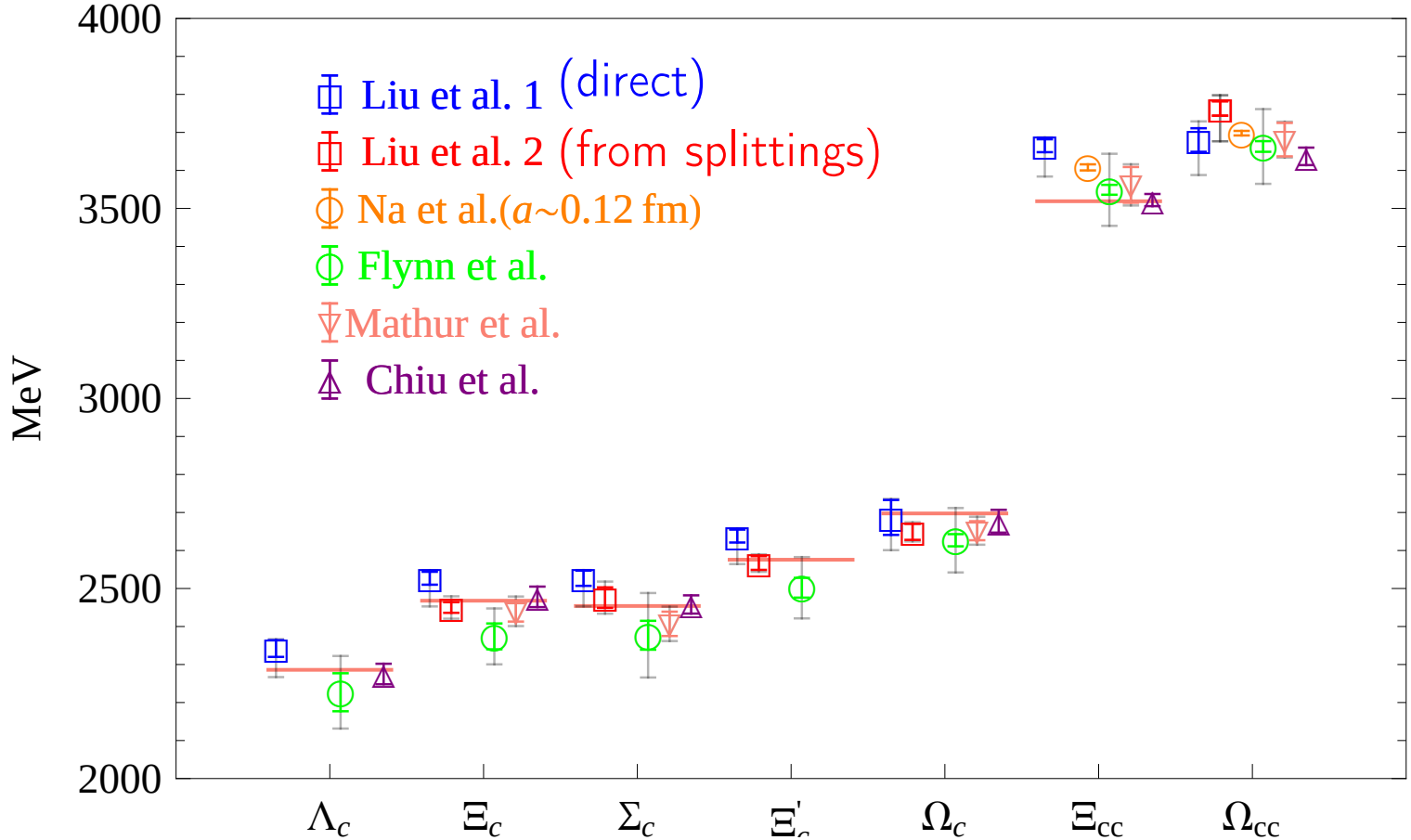
contains valuable data for mass differences of b and bb baryons.

charmed baryons in context



spin 1/2

spin 3/2



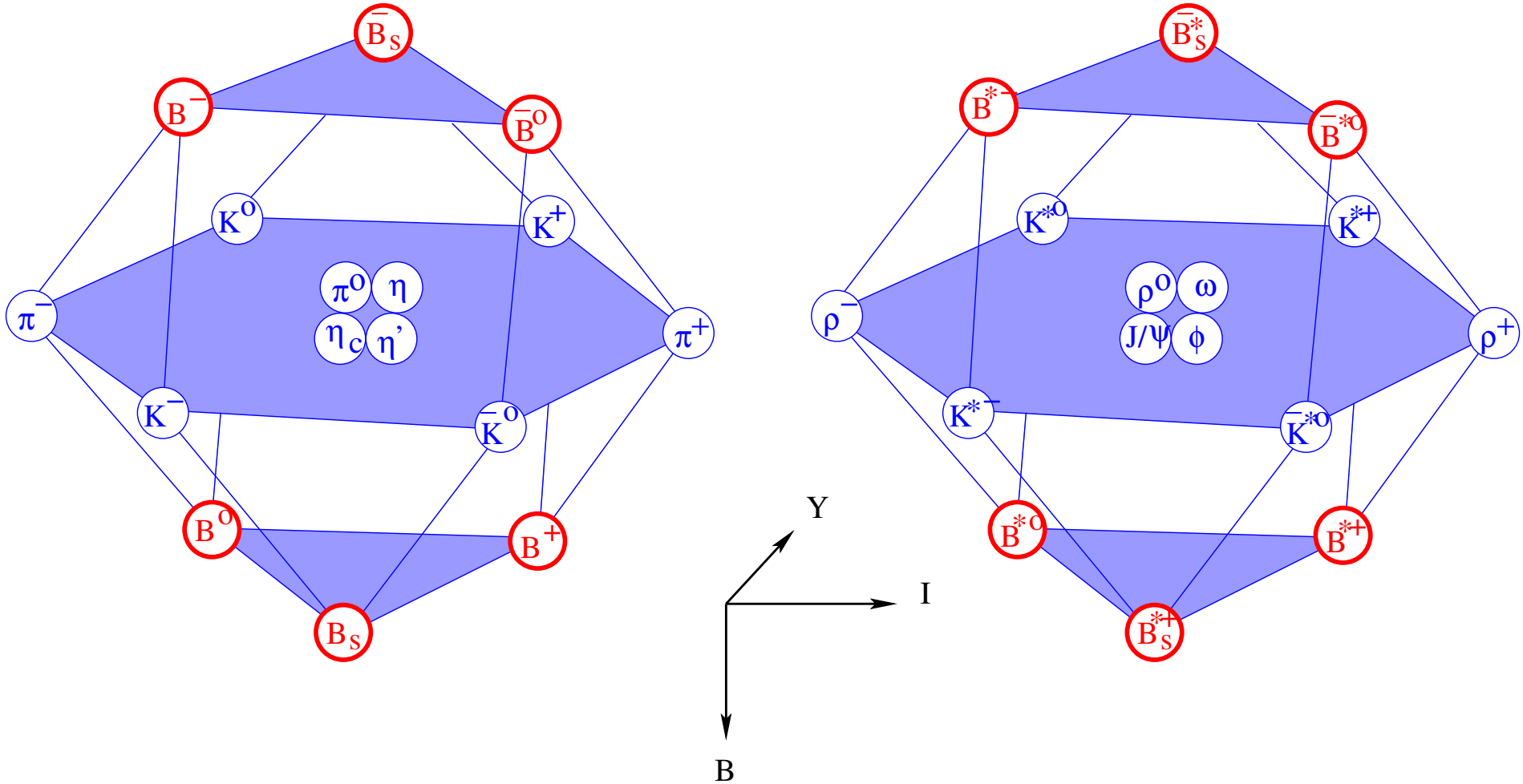
This is figure 14 of Liu,Lin,Orginos,Walker-Loud arxiv:0909.3294.

LLOW use Symanzik gauge, staggered sea, domain wall valence, Fermilab charm, $a = 0.125$ fm, volume = (2.4 fm)^3, $m_\pi \geq 290$ MeV.

NG study many mass differences, including Ξ^*_{cc} and Ω^*_{cc}.

Flynn+, Mathur+, and Chiu+ are quenched results, including spin 3/2.

bottom mesons in context

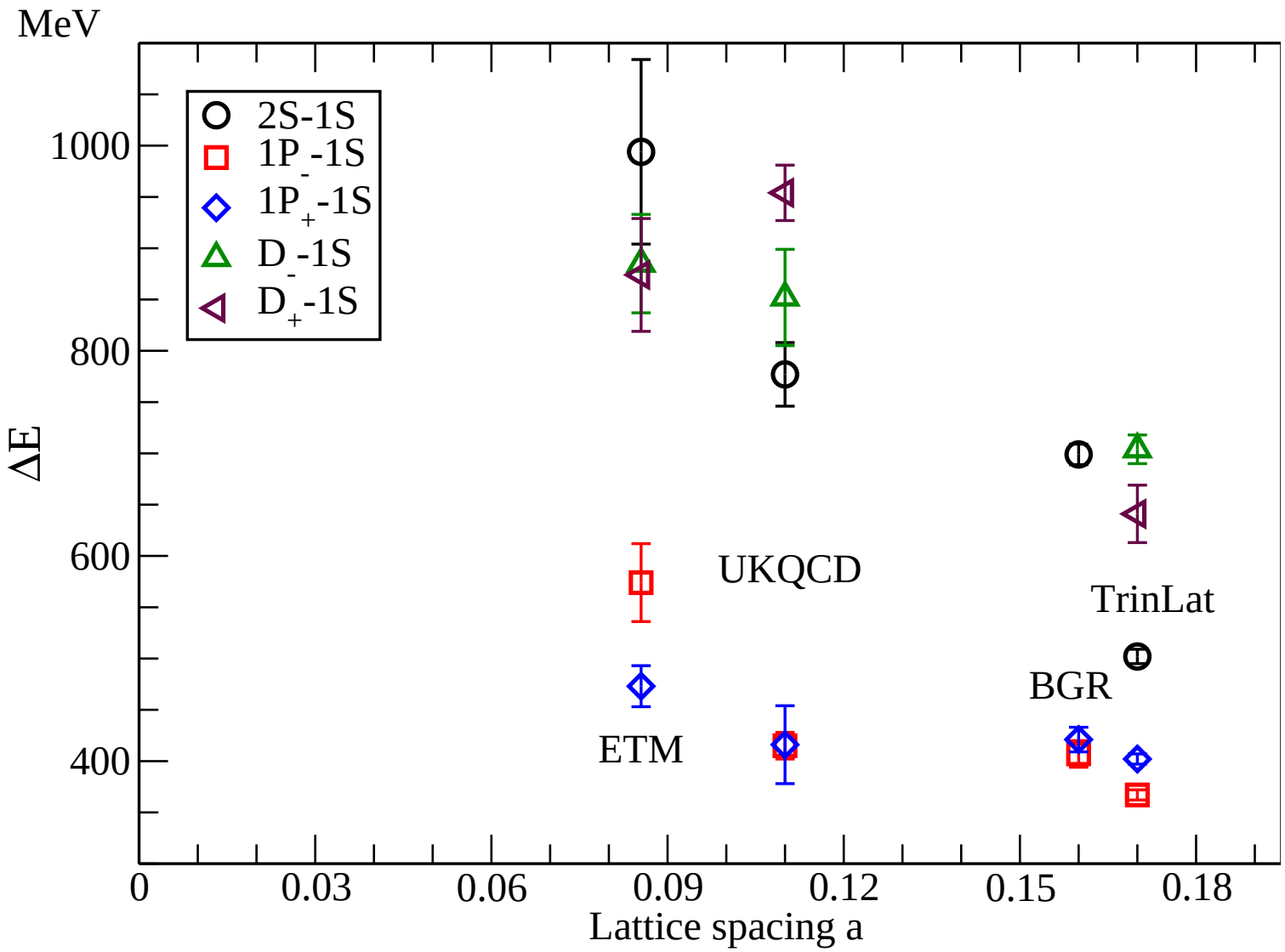


pseudoscalars vectors

As $m_b \to \infty$, heavy quark symmetry $\Rightarrow m(B^-) = m(B^{*-})$, $\quad m(B^0) = m(B^{*0})$, $\quad m(B_s) = m(B_s^*)$.

These doublets are named 1S. Excited doublets are named 1P$_-$, 1P$_+$, 1D$_-$,1D$_+$,. . . 2S,. . . .

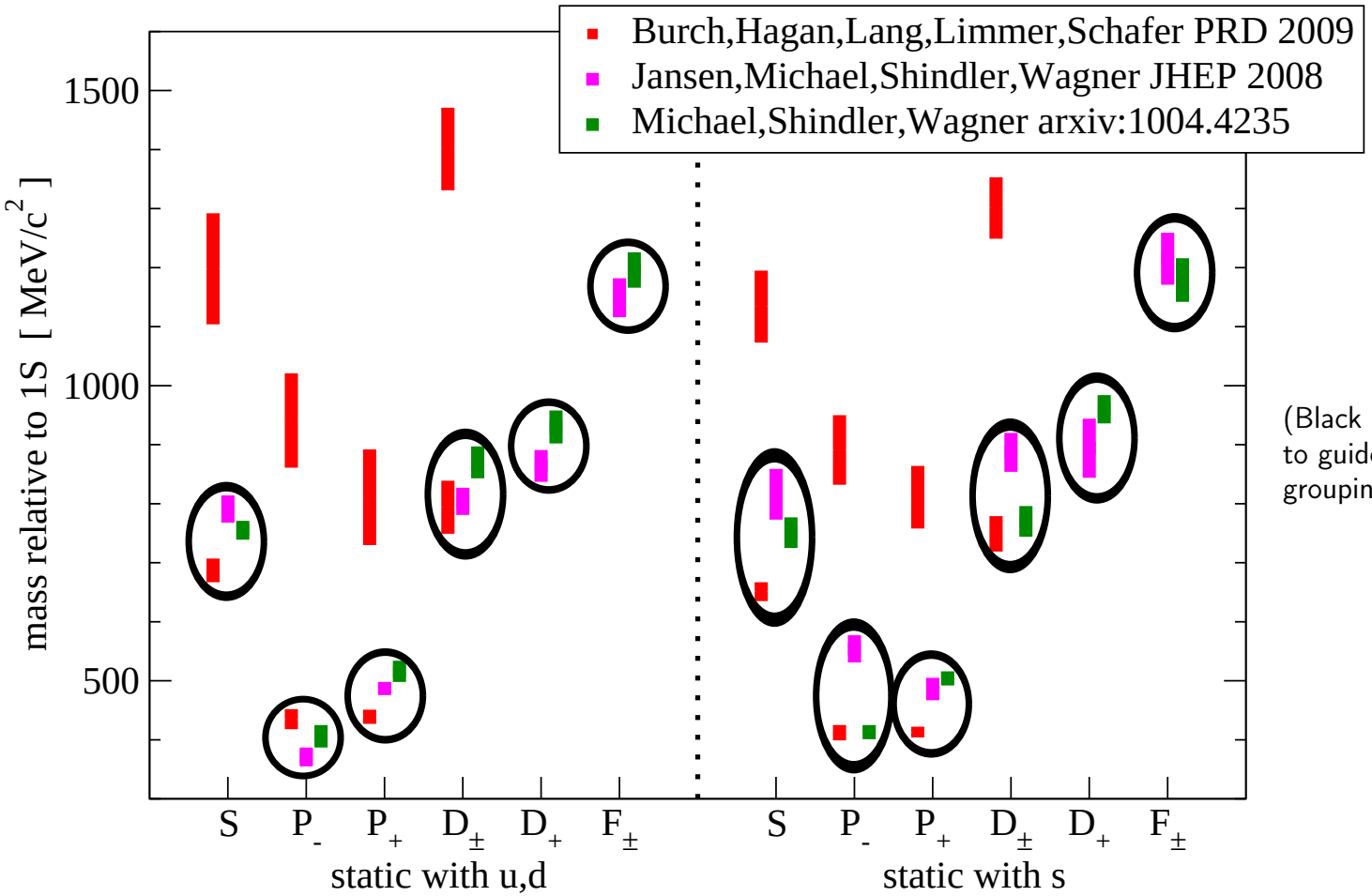
Status of the static-strange ($\sim B_s$) spectrum for $N_f = 2$ in 2007



This is figure 21 of Koponen Phys.Rev.D78:074509,2008.

Warning: Do not attempt continuum extrapolations with different actions.

spectrum of static-light mesons with $N_f = 2$

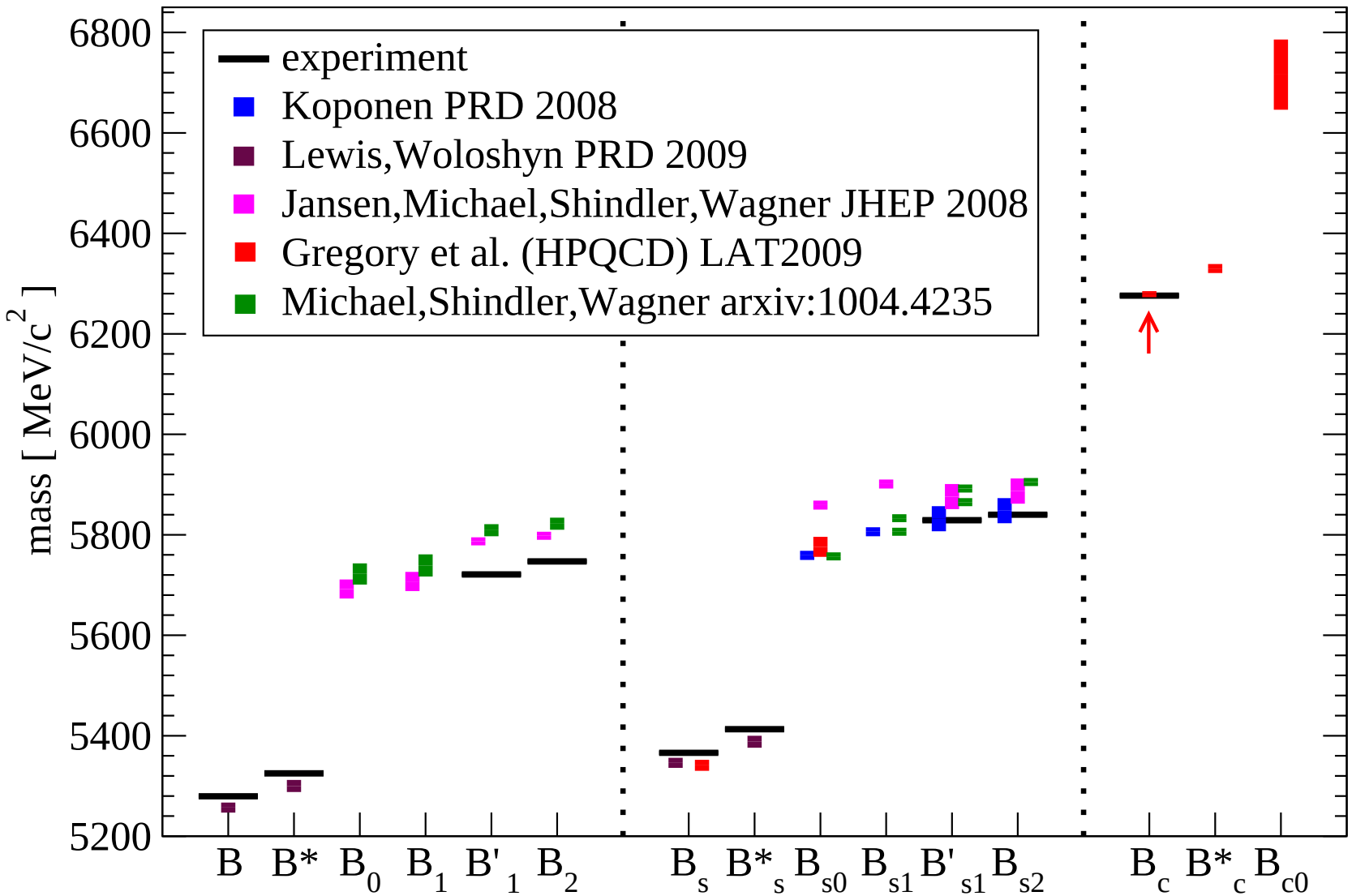


(Black ovals are only to guide the eye in grouping relevant data.)

JMSW use tree-level Symanzik gauge, two twisted mass light quarks, static "b", $a = 0.0855$ fm, volume = (2.05 fm)^3, $m_\pi \geq 300$ MeV.

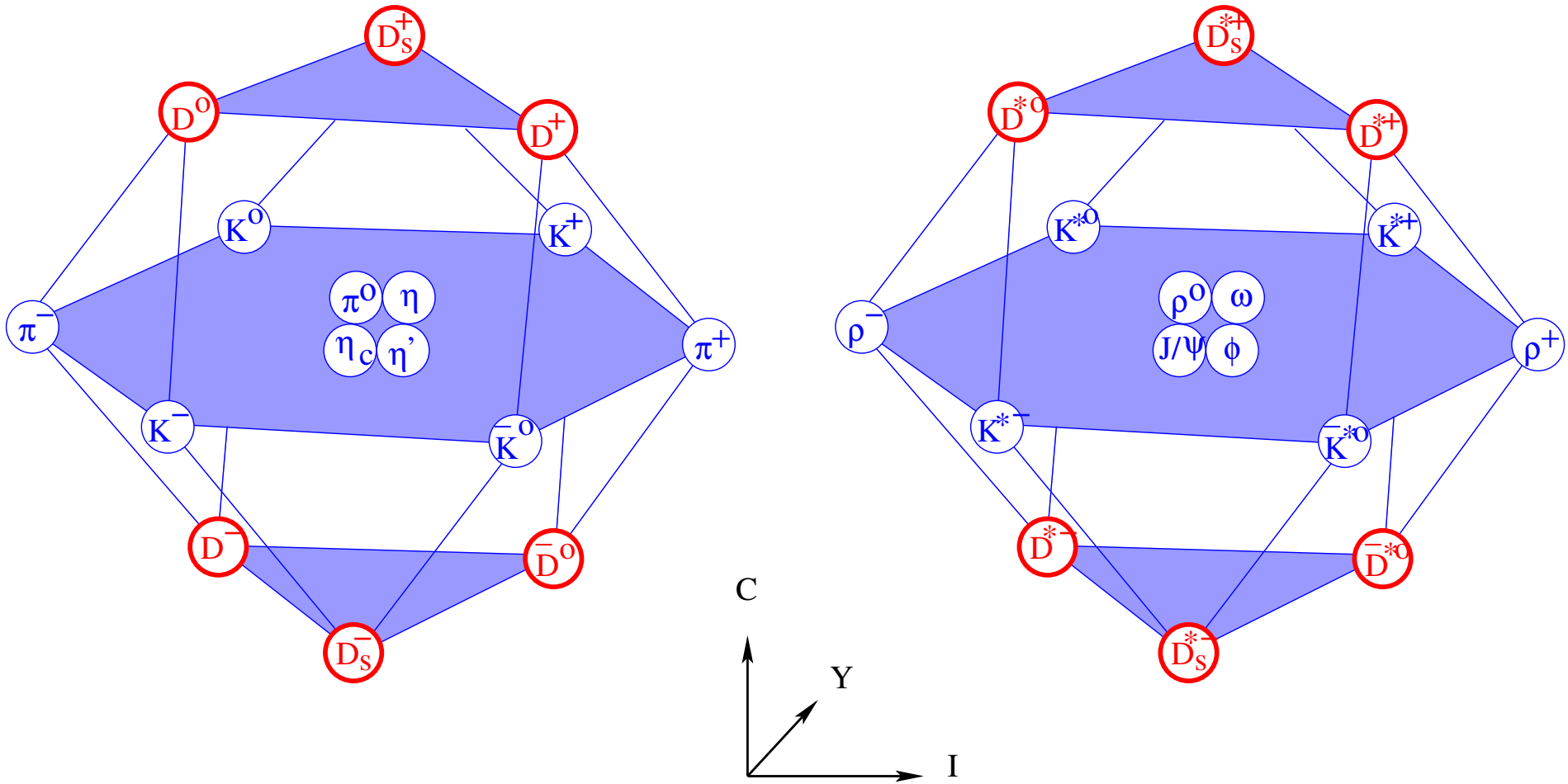
MSW is similar but $a = 0.051$, 0.064, 0.080 fm and a partially-quenched s quark.

spectrum of bottom mesons



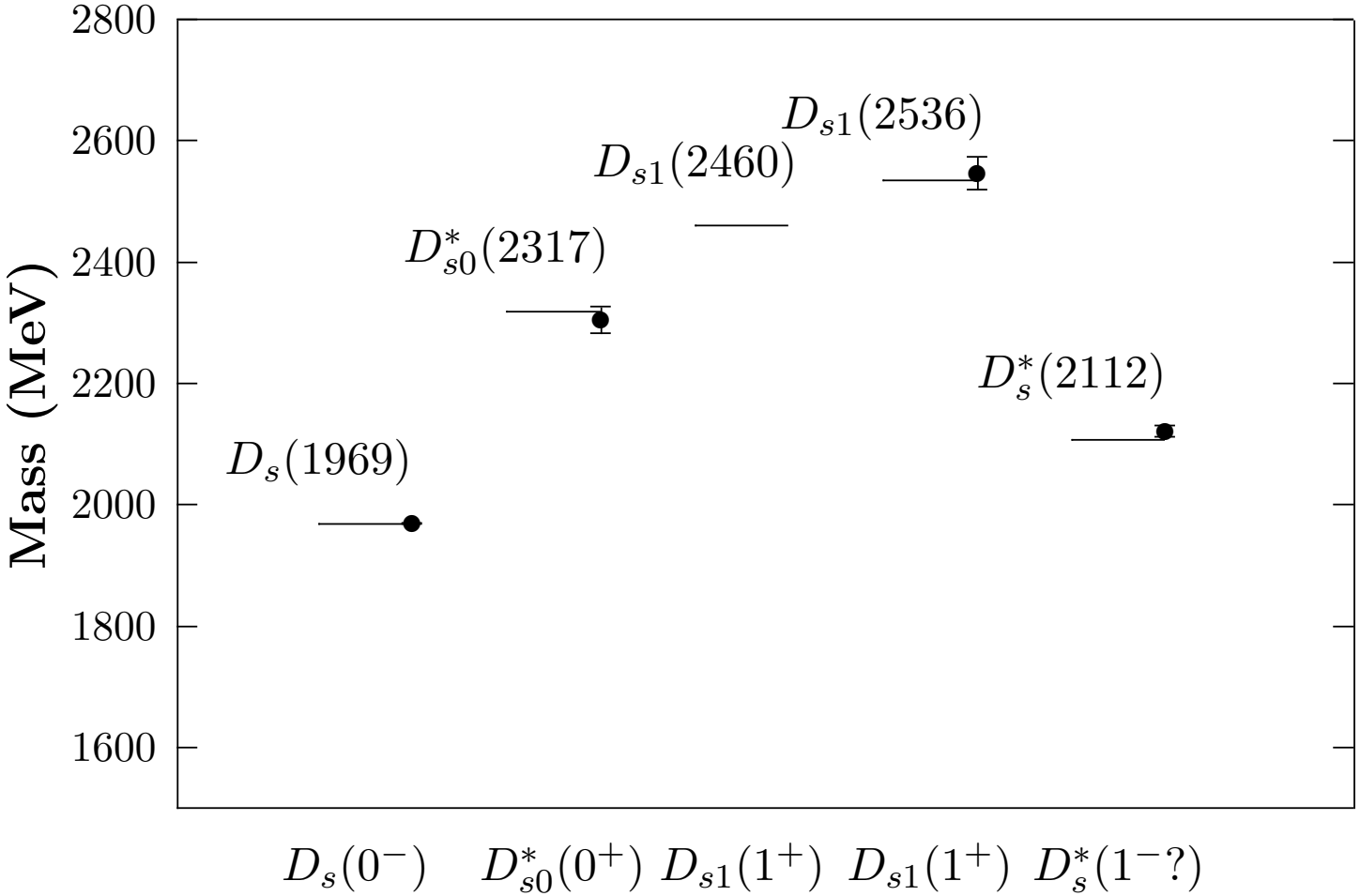
HPQCD: tune parameters to Υ, η_c, pion and kaon.

charmed mesons in context



pseudoscalars

vectors



This is figure 5 of Dong,Alexandru,Draper,Liu,Li,Streuer,Zhang LAT2009.

Iwasaki gauge, domain wall sea, overlap valence,
$a = 0.08$ fm, volume = $(2.7 \text{ fm})^3$, $m_\pi = 331$ MeV.

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Gregory,Davies,Follana,Gamiz,Kendall,Lepage,Na,Shigemitsu,Wong LAT2009 arxiv:0911.2133

Michael,Shindler,Wagner arxiv:1004.4235